Trudy
Not to belabour, but the whole direction is just plain wrong.
If anything we need to limit the height in wood to below three, not go for six. I know, someone is paying your wages and this is your terms of reference, this has no impact on you, it has to be political.

We have been fighting to get the cities to go to mid rise but not to do so in frame. No matter what you do, it is still wood. It burns.
There are many more ways of building mid rise without doing so in wood.
And it is not just the first instance of fire but what happens when the quake hits, the gas lines and water lines rupture, the fires start and the sprinklers of course do not work.
The greatest losses in just the smaller quakes in LA have not been from the quakes but loss by fire after.

As an example of pushing in the RIGHT direction, here is a note sent to Surrey after they lost the last big wood project before it was finished; sure sprinklers might have saved it but maybe not.
We are also doing mid rise in Ladysmith for assisted living; with ARXX, NOT wood.
Rick
There will be an article on this soon.

The following information was submitted from the City of Surrey website:

To: Mayor and Council
Subject: Downtown Surrey and Sustainable Forms
Message: Given yet another fire in not even completed wood frame apartments, this would be an ideal time to now bonus the project if it moves to 6 storeys in NON-combustible form. Even if this means lowering the parking ratio, for the core it would be a compatible move. There are more options in assembly and more safe and livable configurations in high density mid rise forms if the upper floors are terraced. This whole approach can be seen in the Missing Housing Of Metro Vancouver presentation by MVPC/VCPC/SFU on www.plancanada.com web site.
This is recommended for all your towncentres, a move to mid rise high density but not in wood frame as some are now advocating, which would be the worst of all conditions.
Richard Balfour maibc
Dir. NCI/MVPC/VPOE

s.22

Trudy
I see you are the contact person on the issue.
This whole code consideration of 6 floors in frame is INSANE.
We can fault the poor landscape architects for this in the last planning exercise, they were advocating all kinds of things that make no sense from a safety point of view. And of course the wood industry who just want to push wood. And the politicians who have no idea what the impact is from their cavalier considerations.
Many of us have been fightiing for high density and mid rise for many reasons but one was to push

people OUT of wood frame into a bonused 6 floor NONCOMBUSTIBLE ASSEMBLY which has many more built options in technology at good pricing and without the risk to life.
This is a disaster. More to follow
Go to www.plancanada.com to the Missing Housing presentation put on for Planning Commission and SFU.

s.22

o follow, might have to use satire given the mindset in this province.
This is only a form of population control. Notice the big fire in Surrey; and they want to rebuild in wood, who in their right mind would buy into the new woodpile?
'reference ministry site, aibc letter (who put these people in response situation?)

Non-Responsive

From: Khash Vorell (GHL) [mailto:kv@ghl.ca]
Sent: Friday, July 18, 2008 3:45 PM
To: Rotgans, Trudy FOR:EX
Cc: Teddy Lai (GHL); Michael Ernest; Mitchell, Peter FOR:IN; Geoff Thiele; Lina Bowser; Khash Vorell (GHL)
Subject: APEGBC and AIBC Joint Letter Regarding the 6-Storey Wood-Frame Initiative

Hi Trudy,

Further to our focus meeting of July 9, 2008, and on behalf of both APEGBC and AIBC, attached is a letter providing comments regarding the proposed 6-storey wood-frame initiative to amend the BC Building Code 2006.

Regards,

Khash Vorell, M Eng, P Eng
GHL CONSULTANTS LTD
Building Codes & Fire Science
950 - 409 Granville Street
Vancouver, BC V6C 1T2

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and Geoscientists of BC

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Fax: (604) 683-8568 or toll free in BC 1-800-661-2955
www.aibc.ca

ARCHITECTURAL INSTITUTE OF BRITISH COLUMBIA

July 18, 2008

VIA email: trudy.rotgans@gov.bc.ca
Original Via Mail

Ms. Trudy Rotgans, MAIBC
Manager, Codes Development
Building and Safety Policy Branch
Office of Housing and Construction
Ministry of Housing and Social Development
PO Box 9844 Stn Prov Govt
Victoria BC V8W 9T2

Dear Ms. Rotgans:

Re: Proposed Amendments to the BC Building Code to Allow Six Storey Wood-Frame Construction

We are writing to provide APEGBC's and AIBC's comments and suggestions regarding proposed changes to the BC Building Code (the "Code") that would permit wood-framed structures of up to six storeys.

We have considered the "scoping review" dated June 18, 2008 (revised June 30, 2008) *Multi-Level Wood-Framed Structures: Requirements for Building Beyond Four Storeys"* (the "Scoping Review") and the Building Policy Advisory Committee's notes of its conference call on June 25, 2008 (the "BPAC Notes"). We also sought comments from and had a meeting of members of both professions on July 9, 2008 (at which your attendance was very helpful) to discuss the Scoping Review and BPAC Notes and any additional issues or concerns not identified in those documents.

EXECUTIVE SUMMARY

Based on discussions with our members, we do not see any insurmountable technical issues to six storey above-ground wood-frame construction for residential occupancy. The associations are committed to addressing issues that have been identified or are identified during the review process and developing guidelines, with the assistance and support of the Provincial government, with the objective of protection of personal property and the health, safety and welfare of the public.

It is critical that both the architecture and engineering professions are consulted throughout the review process so that they can provide input to Building and Safety Policy Branch ("BSPB") and its consultants on technical and other issues identified to date and in the future and as any particular proposed Code changes evolve. Equally important is the need for sufficient time before and after any Code changes are enacted to educate industry participants on the changes' implications; and so that technical issues can be addressed and all industry participants can make appropriate arrangements. This includes sufficient lead-in time between publication date and enforcement date to enable timely project-design decisions. Failure to identify the technical issues to our members and other industry participants in advance of the changes could have serious consequences.

We also strongly support the idea of BSPB creating an industry advisory committee that would act as a liaison and information source to BPSB, its consultant(s), APEGBC, AIBC and other stakeholders such as the Union of BC Municipalities (UBCM) and the Fire Commissioners' Office. Both professions welcome the opportunity to participate in industry-wide and specialist advisory committees.

SPECIFIC ISSUES IDENTIFIED

Given the time constraints, our list of issues and concerns has to be considered incomplete. Typically the process for implementing such significant changes to the Code is that good practices are first developed and become accepted as an industry standard, leading to an amendment to the Code to reflect this. The consultation and education process recommended in advance of any Code change will likely identify all the technical and Code related issues. However the compressed time-frame we are operating under increases the risk that some issues or solutions to problems will not be identified prior to the changes to the Code.

In addition to the items identified in the BPAC Notes and the Scoping Review, our comments are as follows:

1) **Fire Safety**

There will be increased opportunity to use a combination of the more traditional wood stick-frame construction and pre-engineered wood products. Such systems will require the availability of properly fire tested and listed assemblies with load limits addressed to make 6-storey wood-frame construction feasible.

When pre-engineered wood products such as cross laminated wood panels are used in the design, care must be taken to address the significant impact the failure of such panels in a fire may have on the overall structural integrity of the building, thus minimizing the ability to fight a fire safely using current fire fighting practices.

There must be consultation and careful coordination of this initiative with regional fire services throughout BC and the Office of the Fire Commissioner to ensure such stakeholders are in agreement so that regional variances are not imposed.

Criteria for height limits should be clear, to avoid misinterpretation or abuse.

2) **Fire Flow and Water Supply**

Some municipalities currently have engineering criteria which trigger much higher fire flow, including the amount of water needed for fire fighting of wood-frame construction, than is otherwise required under the Code. For example, some municipalities still use the Fire Underwriter Survey (FUS) guide to calculate fire flow, even though the FUS guide is no longer referenced in the Code. There is a need for consistent use and application of an appropriate standard to assess the required fire flow for a 6-storey wood-frame construction. It is recommended that BSPB clarify the appropriate standard to be used in determining fire flow for buildings, and consult with the various municipalities through UBCM so that common ground can be found.

3) Fire Safety During Construction

Although the Code's fire safety provisions primarily relate to completed and occupied buildings, fires during construction have proven to be a significant risk to surrounding structures as well the buildings under construction. In the case of 6-storey wood-framed buildings, the level of exposure and fire risk to adjacent properties will be more significant because of the 50% additional fire load.

Due to increasing concerns around security during the construction phase, additional research is necessary to address the fire hazard to the building as well as to the adjacent properties. Various means should be explored to reduce this risk.

4) Occupancy

The issues and concerns identified in this letter are based on the assumption that the Code changes are primarily intended to address residential use. Limitations on appropriateness of this initiative to other residential occupancies such as assisted living must be appropriately explored and addressed.

The proposal must address mixed-use occupancies, at least in the form of ground floor retail, assembly, office, etc. We understand that a consideration in this Code change is to increase density, which will increase the demand for mixed-use buildings. Therefore the initiative should explore the possibility of concrete construction for other occupancies posing higher fire hazard.

5) Code Requirements and Current Construction Practices

Prior to moving towards a 6-storey Code change, it is crucial that the existing problems and interpretations revolving around 4-storey wood-frame buildings are addressed by BSPB. Examples of these issues include:

- Methods of protection for openings in and penetrations of fire rated membranes.
- Continuation of vertical fire separations and means to achieve this in the concealed joist or truss space. (This issue sometimes is mitigated by using the ceiling "membrane" rating approach, which also has issues).
- Continuation of horizontal ceiling membrane rating without interruption.
- Fire resistance and load bearing requirements of fire separations in currently tested and listed assemblies. (This relates to load restriction factors resulting from conversion from working stress design to limit states design.)
- The existing 4-storey residential construction is lacking Code intent and objective statements. To assist designers in assessing and interpreting the Code, it is essential that the new requirements have clear intent and objective statements.

6) Alternative Solutions

A Code change permitting 6-storeys of wood-frame construction should eliminate the general need for alternative solutions.

In case of need for alternative solutions on specific projects, we would support creation of a Provincial body to review alternative solutions. This was also recommended by the Provincial Modernization Strategy Task Force.

7) Structural and Seismic Issues

The structural portions of the current Code and the referenced CSA documents do not require changes to allow the design and construction of 6-storey wood-frame buildings. The seismic design section of the Code has a maximum 20-metre height limit for wood shear walls, which should not pose a significant constraint.

The material design codes are written based on the limitations imposed by the National Building Code of Canada (NBCC) on the specific material. For example CSA O86 contains material specific to 4-storeys in the Wood/Drywall mixed systems. There is no guidance given for higher buildings. The aspect ratios allowed for shear walls may need to be reviewed to assess their appropriateness for the proposed 6-storey buildings. It is recommended that the Province formally notify the Canadian Standards Association (CSA) of their plan to allow 6-storey wood-framed construction in order that the CSA-O86 committee can assess whether this change would trigger the need to issue an addendum covering some items specific to 5- and 6-storey buildings.

It is imperative that guidelines be developed for structural engineers to facilitate the changes in practice required when increasing the building height by 50%. The Structural Engineering Association of BC ("SEABC") has committed to assist in the development of these guidelines through APEGBC. Sufficient time is needed for development of such guidelines. Significant work and resources are necessary to research, develop and adapt a comprehensive guideline for the structural design of engineered systems. This work should be done prior to any amendments to the Code, and the support and assistance of the Province would be of great benefit in meeting this need expeditiously.

8) **Wood Shrinkage**

Designing wood structures requires accommodating how wood changes dimension with moisture content. Some of the effects of shrinkage are cumulative with building height. This could be a matter of concern from design, aesthetic, maintenance and operational perspectives (e.g. air and water infiltration and shrinkage gaps between building components). Such considerations may be addressed through the increased usage of pre-engineered wood products as opposed to traditional wood-frame stick construction. However, in case of wood-framed stick construction additional research is necessary and similarly guidelines should be developed to address this concern.

9) **Building Envelope**

Increased building height will likely result in higher environmental moisture loads due to higher wind forces and increased rain runoff collection areas. Cladding systems must be able to accommodate the higher loads. Additional research, testing and consultation is necessary in this area and similarly guidelines for practitioners should be developed.

10) **Design Coordination**

Due to the level of complexity associated with 6-storey wood-frame residential construction there will be an increased requirement for guidelines and careful coordination of the architecture and engineering design of these structures. This will be especially crucial in areas of BC having high seismic and wind loads.

11) **Peer Review Process**

It is understood that a feasibility study and research project is being sought by the Province and BSPB regarding the 6-storey wood-frame building initiative. It is recommended that the work and findings of the consultant(s) preparing this study be objectively peer-reviewed by at least two members of the National Building Code Standing Committee on Fire Safety and Occupancy who are independent of the material industries.

12) **Industry Preparedness**

The education and training of the construction industry in the application of new technology and building systems is a significant consideration that must be addressed to facilitate the successful implementation of such an initiative.

13) Insurance & Warranty Considerations

The Homeowner Protection Office and the Municipal Insurance Association are considered important stakeholders. They must be engaged as both groups will impact the ability for individual municipalities to be able to issue permits for these types of structures.

14) Implementation Considerations

Initially proceeding with some prototype projects and requiring independent third-party review during the first few years would be an appropriate way in which to proceed.

15) Regulatory Coordination

It is also important that any changes to the Code be carefully drafted to avoid interpretations that would create inappropriate "Code creep": what was intended to be prohibited should not be possible. (As discussed above, it is equally important that any Code changes be drafted so that what was intended to be permitted is clear and not contradicted by another portion of the Code). This can be addressed by providing clear intent and objective statements for the proposed changes to Code articles.

The Code change should also be coordinated with other pertinent regulatory standards and codes such as those relating to fire fighting and water supply.

CONCLUSION

Both AIBC and APEGBC have considered and are supportive of the concept of 6-storey wood-frame construction subject to design, technical and implementation issues being appropriately addressed as outlined above. The associations are prepared to work with the Province in addressing the issues.

We thank you for the opportunity to comment on this initiative. We look forward to further developments, discussion, and being able to contribute to the process of implementing the changes successfully.

Yours truly,

Khash Vorell, P.Eng.
Chair, APEGBC Building Codes Committee

Yours truly,

Teddy Lai, MAIBC
Chair, AIBC Regulatory Coordination Committee

/gat

cc. Peter R. Mitchell, P.Eng., Director, Professional Standards & Development, APEGBC
Michael Ernest, MAIBC, Director of Professional Practice, AIBC

Non-Responsive

From: Jim Mutrie [mailto:jim@jkk.com]
Sent: Wednesday, June 25, 2008 4:38 PM
To: Kuan, Steven Y FOR:EX
Subject: SEABC - 6 Story Wood Frame

Steven

We had a SEABC directors meeting last night and one of the items that came up was the statements in the press attributed to the Premier and Rich Coleman to the effect that the building code would be modified to allow wood framed buildings higher than the current 4 story limit, perhaps up to 6 stories and that the "regulatory change could be in place by September". Do you know where the government is on this and if it intends to proceed is the September time frame at all real? The reason for the question is that if this is coming down the pipeline soon then SEABC should be urgently convening a task force of the Wood Frame Committee to look into the ramifications of the move and preparing guidelines and educational programs for our members to occur in the early fall. The September time line means work over the summer which nobody will like but if it is real then we just have to do it.

Please let me know where you think this is as I have been given the task of organizing something if it is real.

Thanks for your help.

Cheers

Jim Mutrie

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J. G. Mutrie, B.A.Sc., P.Eng.
Consultant

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Canada, V7P 3P7

jim@jkk.com

tel: 1-604-988-1731
fax: 1-604-988-0927

www.jkk.com

NotesPrint Close Window

Text Attachment: Log ID 11452
113908 Incoming Email

From: Hansen, Lucia FOR:EX
Sent: Monday, May 26, 2008 10:50 AM
To: Correspondence Serv. Sectn, Forests FOR:EX
Subject: 113908 - FW: 6 Storey Wood Frame Buildings

draft reply

From: Coleman.MLA, Rich [mailto:Rich.Coleman.MLA@leg.bc.ca]
Sent: Tuesday, May 13, 2008 11:19 AM
To: Hansen, Lucia FOR:EX
Subject: FW: 6 Storey Wood Frame Buildings

From: Diane Delves [mailto:ddelves@quantumproperties.ca]
Sent: Tuesday, May 13, 2008 11:04 AM
To: Coleman.MLA, Rich
Subject: 6 Storey Wood Frame Buildings

Dear Mr. Coleman,

The Vancouver Sun reported in this morning's paper that the Province is considering amending the building code to allow for 6 storey wood frame buildings. Abbotsford is positioned to take advantage of this change immediately as the RML (low rise) zone allows up to 6 storey heights and the City also has a Density Bonus provision which allows higher density in exchange for a cash contribution to an affordable housing fund.

I am currently working on a project s.21 where a 6 storey low rise would make sense. Can you provide me with any further information on this proposal?

Yours truly,

Diane M. Delves, AACI, P.App.

President & CEO

Quantum Properties Inc.

101-2200 West Railway Street

Abbotsford, BC V2S 2E2

Phone: 604.854.1201

Fax: 604.854.1204

Website: www.quantumproperties.ca

NotesPrint Close Window

Text Attachment: Log ID 11453
113917 Incoming Email
-----Original Message-----
From: Hansen, Lucia FOR:EX
Sent: Monday, May 26, 2008 10:50 AM
To: Correspondence Serv. Sectn, Forests FOR:EX
Subject: 113917 - FW: Web site feedback email

draft reply

-----Original Message-----
From: Coleman.MLA, Rich [mailto:Rich.Coleman.MLA@leg.bc.ca]
Sent: Tuesday, May 20, 2008 12:26 PM
To: Hansen, Lucia FOR:EX
Subject: FW: Web site feedback email

-----Original Message-----
From: webmaster@richcolemanmla.bc.ca [mailto:webmaster@richcolemanmla.bc.ca]
Sent: None
To: Coleman.MLA, Rich
Subject: Web site feedback email

Reply-To: webmaster@richcolemanmla.bc.ca

Message-Id: <20080520191146.4516E2028AC6@mla.governmentcaucus.bc.ca>
Date: Tue, 20 May 2008 12:11:46 -0700 (PDT)
Return-Path: nobody@mla.governmentcaucus.bc.ca
X-OriginalArrivalTime: 20 May 2008 19:11:47.0313 (UTC)
FILETIME=[5976DE10:01C8BAAD]

requiredfirst s.22 [redacted]
requiredlastn
requiredemail
requiredposta
comments: Rich : I am planning on building a 100 Unit SENIORS HOUSING PROJECT at
s.21 [redacted] I have read that you are considering allowing 5 storey wod
frame construction.

This is a brilliant idea. It is done in Seattle all the time.

s.21 [redacted] it will increase affordability.

Please let me know of any developments with respect to this.

s.22 [redacted]

CITY OF CHILLIWACK
OFFICE OF THE MAYOR

MINISTER OF FORESTS AND RANGE
RECEIVED
MRL #: 113495
JUN 02 2008
DUE DATE:
☑ DRAFT REPLY ☐ DIRECT REPLY
☐ PNA ☐ FYI ☐ FILE

CSS
JUN 05 2008
MINISTRY OF FORESTS AND RANGE AND MINISTRY RESPONSIBLE FOR HOUSING

May 28, 2008

The Honourable Rich Coleman
Minister Responsible for Housing
PO Box 9049
Stn Prov Gov't
Victoria, BC
V8W 9E2

Dear Minister Coleman;

In May, Premier Gordon Campbell announced his government's support of British Columbia's forest industry by allowing the construction of wood-frame condominiums higher than the current four-storey limit. In addition, as reported in the Vancouver Sun on Tuesday, May 13th, your Ministry advised the Canadian Homebuilders' Association of your support of this initiative.

The City of Chilliwack Council at the their May 20th regular meeting unanimously endorsed a resolution in support of the government's initiative encouraging changes to the BC Building Code that would allow for wood-frame construction up to six (or more) storeys for residential uses.

While continuing to maintain the objectives of the code with respect to structural, safety and fire protection, the City of Chilliwack believes allowing for more than four-storey wood-frame construction, will have a profound and positive effect on our community. It is our belief the more cost-effective use of one of British Columbia's sustainable resources will allow developers the opportunity to be more creative in their building design, as well as receiving the benefits of additional density.

More importantly this initiative could have a profound effect in the supply of much-needed safe, affordable housing for the community by way of a variety of "density bonus" zoning options.

Sincerely,

Clint Hames
Mayor

8550 Young Road, Chilliwack, British Columbia V2P 8A4
Phone: (604) 792-9311 Fax: (604) 792-2561

Bill, Karen F FOR:EX

From: Leslie Whittaker [lwhittaker@udi.org]
Sent: Thursday, June 19, 2008 3:15 PM
To: Minister, FOR FOR:EX
Cc: Vasey, Jeff FOR:EX
Subject: UDI LETTER - INCREASING THE HEIGHTS OF WOOD FRAME BUILDINGS
Attachments: Ltr R. Coleman June 17 2008 IncrsngHeightsWooodFrameBldgs.pdf

Good Afternoon Minister Coleman

At the request of Maureen Enser, Executive Director of the Urban Development Institute Pacific Region, attached please find a letter regarding "Increasing the Heights of Wood Frame Buildings".

Leslie

History Checked ☑
91769.

RECEIVED
94407
JUL 17 2008
CORP OPS - CORRESPONDENCE UNIT
MINISTRY OF HOUSING AND SOCIAL DEVELOPMENT

MINISTER OF FORESTS AND RANGE
RECEIVED
MRL #:
JUN 20 2008
DUE DATE:
☑ DRAFT REPLY ☐ DIRECT REPLY
☐ FNA ☐ FYI ☐ FILE

2008-06-19

URBAN DEVELOPMENT INSTITUTE – PACIFIC REGION
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Vancouver BC V6B 1P2 Canada
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info@udi.org
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June 17, 2008

The Hon. Rich Coleman
Minister of Forests and Range and
Minister Responsible for Housing
PO Box 9049, STN PROV GOVT
Victoria BC V8W 9E2

Dear Minister:

Re: Increasing the Heights of Wood Frame Buildings

In recent media reports, you have indicated that the Province would like to increase the density and heights of wood frame buildings from four to six floors. The Urban Development Institute (UDI) is very pleased that your Ministry is moving forward with this initiative and fully supports your efforts.

For 35 years, UDI has recognized the need to grow sustainability and affordably. We have been promoting wise and efficient urban growth, good planning and progressive development practices. We believe your initiative to increase the height of wood frame buildings will support the sustainability and affordability objectives of our communities.

Wood frame construction is economical. Increasing the densities of wood frame construction will assist our industry in delivering a more affordable product to British Columbia families. The construction costs of a wood frame building are approximately 60% of the costs of building a concrete one.

Increasing densities through allowing more floors using wood frame adds environmental benefits, especially when these densities are combined with easy access to public transit.

As the Minister of Forests, we know you appreciate the economic benefits this initiative will have on British Columbia's troubled Forestry Sector. There is a real opportunity to use more of their product in the province's new buildings.

UDI and its members are very encouraged by this initiative. Our members have had considerable experience with six plus storey wood frame buildings in several jurisdictions. We are willing and able to assist your Ministry with its work program.

Thank you, Minister, for your progressive leadership in this area. Please let us know how we can best assist you.

Best regards,

Maureen Enser

Maureen Enser
Executive Director

Union of
British
Columbia
Municipalities

Suite 60
10551 Shellbridge Way
Richmond
British Columbia
Canada V6X 2W9
604.270.8226
Fax 604.270.9116
Email: ubcm@civicnet.bc.ca

President
Susan Gimse

Executive director
Gary MacIsaac

History Checked

92794

DEPUTY MINISTER'S OFFICE
MINISTRY OF HOUSING
AND SOCIAL DEVELOPMENT
AUG 08 2008
131372
VICTORIA, BRITISH COLUMBIA

MINISTER OF HOUSING AND SOCIAL DEVELOPMENT
REFERRAL NUMBER:
REFER TO: MIN ☐ DM ☐ MA ☐ AC ☐
RECEIVED: JUL 29 2008
DRAFT REPLY ☑ INFO☐ FILE ☐
REMARK:

July 23, 2008

Honourable Rich Coleman
Minister of Housing and Social Development
Parliament Buildings
Victoria, B.C.
V8V 1X4

Dear Minister Coleman:

Re: Six Storey Wood-Framed Construction

The UBCM Executive met on July 18. 2008 and discussed a recent proposal by the province to change the BC Building Code to allow for the construction of six storey wood-framed buildings.

The UBCM Executive after reviewing the matter would indicate cautious support for the proposed six-storey-wood framed construction based on the following measures:

- phased implementation – from four storey, to five storeys on top of one story non-combustible construction;
- informed evidence based decision making – need to consider construction techniques (use of engineered lumber etc.), fire protection issues, enforcement/regulation issues, and potential liability concerns;
- education/training and best practice guidelines for building industry, building officials and fire fighters;
- public review of proposed Building Code changes.

The Executive understands that there are potential concerns related to wood shrinkage when constructing six storey wood-framed buildings, particularly when set against a concrete structure such as an elevator shaft. In addition, there are a number of different fire fighting issues that need to be considered, such as the need for ladder trucks, additional firefighters when responding to a fire, and additional firefighting training when dealing with six storey wood-framed buildings.

We would request that all of these issues be addressed when looking at changes to the BC Building Code to permit the construction of six storey wood-framed buildings.

Sincerely,

Susan Gimse

Susan Gimse
President

RECEIVED
DEC 1 6 2008
146292
CORP OPS - CORRESPONDENCE UNIT
MINISTRY OF HOUSING AND SOCIAL DEVELOPMENT

94407 +

Bowen, Chelsea HSD:EX

From:	HSD Minister HSD:EX
Sent:	Tuesday, December 16, 2008 3:39 PM
To:	HSD MHSD Correspondence, HSD:EX
Subject:	NEW MAIL: MID-RISE WOOD-FRAME RESIDENTIAL CONSTRUCTION CONSULTATION: Letter from UDI
Attachments:	Decembder 15Ministry of houisng six story .doc

Draft reply

From: Leslie Whittaker [mailto:lwhittaker@udi.org]
Sent: Monday, December 15, 2008 3:50 PM
To: HSD Minister HSD:EX
Subject: MID-RISE WOOD-FRAME RESIDENTIAL CONSTRUCTION CONSULTATION: Letter from UDI

Minister Coleman

Attached, please find a letter from the Urban Development Institute – Pacific Region regarding Mid-Rise Wood-Frame Residential Construction Consultation.

Leslie

Leslie Whittaker
Administrator
Urban Development Institute
200 - 602 West Hastings Street
Vancouver, B.C V6P 1P2
Tel.: 604-669-9585
Fax: 604-689-8691
E-mail: lwhittaker@udi.org

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info@udi.org
www.udi.bc.ca

December 15, 2008

The Hon. Rich Coleman
Minister of Housing and Social Development
PO Box 9049, STN PROV GOVT
Victoria BC V8W 9E2

Dear Minister:

Re: Mid-Rise Wood-Frame Residential Construction Consultation

As we noted in our June 17, 2008 letter to you, the Urban Development Institute (UDI) is very supportive of the government's progressive initiative to increase the density and heights of wood-frame buildings from four to six floors. We would also like to thank your staff for meeting with UDI members on November 25, 2008, so the industry's perspective on the proposed *Code* changes could be discussed.

Increasing the densities of wood-frame construction will assist our industry in delivering a more sustainable and affordable product to British Columbia families. If more wood product is used, it will also have the economic benefit of assisting B.C.'s troubled forestry sector and the communities that depend on it.

We note that historically, wood-frame buildings have played a significant role in the recovery of a housing market. These projects are generally smaller, easier to finance and require fewer pre-sales. During slow markets there are still many buyers who are drawn to wood-frame residential buildings because they are less costly and offer occupancy in a much shorter time frame.

We look forward to working with your Ministry and offer the following suggestions to maximize the full benefit of the six-storey construction initiative.

First, we caution that the enhanced standards from five and six storey construction should not migrate to apply to one to four storey wood-frame construction. Because of past increases in *Code* requirements for wood-frame construction, the gap in cost between this type of construction and concrete is declining. Adding further regulations onto the one to four-storey format is not necessary and may create the unintended consequence of reducing the amount of wood used in construction as concrete may be perceived as a viable cost-effective alternative, thus negating some of the benefits to the forest sector.

Second, there is a question as to how hybrid buildings will be treated – that is, a combination concrete and wood-frame. Many six-storey wood-frame buildings will have one or more concrete floors for parking, retail or office space – especially along commercial streets like Broadway in Vancouver. The proposed *Code* changes are written assuming all six-storey projects will be entirely wood-frame.

In addition to this, the proposed *Code* changes may be used by some municipalities to designate "challenging" buildings on sloped sites as five floor buildings, when in the past they were considered four-storey buildings. There may be an unintended consequence where the enhanced standards for five-storey projects will increase the costs to develop these projects.

We suggest that there be provisions in each section in the new *Code* requirements that recognizes that in the case where four or less floors of the five or six floor building are wood-frame, the current *Building Code* requirements apply.

In terms of the specific proposals identified on the Ministry's consultation website, UDI offers the following comments.

Proposed Code Change 1

"This proposed code change for building height requires that buildings built under 3.2.2.45 are less than 18 metres to the uppermost level of the top storey."

The regulation will have to be clear regarding how grade will be measured – especially for sloped sites or those with berms.

Concern has also been raised that some hybrid buildings with high ceiling main floors that are concrete (non-combustible) will be limited to five stories because of the height limit. One solution could be limiting the height of the wood-frame portion only of the building.

Proposed Code Change 2

"This proposed code change for building area defines the total permissible building area for each floor of a five and six-storey wood-frame building."

This change could have a negative impact on some projects – especially hybrid buildings and developments on sloped sites. Along many arterial commercial streets, developers will not be able to take advantage of the mid-rise wood-frame initiative. As noted these projects usually have at least one concrete (non-combustible) floor of retail space at street level. Under this proposed *Code* change, fire walls would have to be built in the middle of this retail space – making it unusable for large retailers.

Some local governments have been flexible with regard to "challenging" four-storey wood-frame projects on sloped sites where there is an additional partial floor. Many four-storey mixed use buildings that include a concrete ground floor will be pushed into the five-storey *Code* classification because of grade considerations or the height of the ground floor ceiling. This limits the floor areas and as a result will add additional costs to the construction of these buildings that would not have occurred if the new *Code* considerations are not put in place.

We recommend that the Province apply the space limits noted in this proposed *Code* change to the wood-frame portion of the building – not the entire building – especially in cases where the non-combustible portions are sealed from the rest of the building. In the long-term, the Ministry should review the need for the limits in floor area. Is the 7,200 m^2 limit still required with sprinklers and increased building standards?

Proposed Code Changes 3 and 4

"Noncombustible exterior cladding can protect a building from exterior fire spread. This proposed code change for exterior cladding materials requires exterior cladding to be noncombustible except in limited circumstances."

"Limiting the combustibility of exterior cladding provides an added measure of protection against exterior fire ignition and spread, and exposure of adjacent structures. This proposed code change for exterior cladding, notwithstanding proposed code change #3, requires that noncombustible material be used where it is required by the spatial separation provisions of the code."

Wood-frame exterior walls are inherently more energy efficient that non-combustible exterior walls. This proposed change will make it more difficult to achieve the ASHRAE insulation requirements that are part of the province's recently approved *Green Building Code* standards. For example, steel studs are generally used in concrete construction to provide structure for insulated cavities. Unfortunately these studs act as thermal bridges and negate much of the value of the insulation between them. Wood studs on the other hand perform far better. With the Ministry's *Green Building Code* initiative to reduce building energy use and greenhouse gas emissions, developers should be encouraged to use wood studs wherever possible in exterior walls.

The vinyl siding exemption will likely not work since flammable building paper and pressure treated wood strapping would be on top of the gypsum board. Some types of exterior foam insulation and vinyl windows may not be allowed on these projects as well.

Again, these clauses should have an exemption for five-storey buildings that have one or more of the floors with non-combustible construction. For example, they should not apply to projects that are considered "challenged" four floor wood-frame buildings (please see above), that will be considered as five floor construction, only because the new *Code* now has a five-storey designation. If in the past these types of projects were considered four-storey projects, they should continue to be considered as four-storey buildings.

The exterior cladding requirements should also be written in performance based objective-code language. Design improvements such as sprinklered balconies could be incorporated into projects to allow more flexibility in the cladding used.

Proposed Code Change 5

"Shear walls provide resistance to lateral earthquake loads. This proposed code change for shear walls provides direction to the structural engineer on designing and locating shear walls."

As noted in our meeting with provincial staff on November 25, 2008, municipal planning departments and design panels prefer buildings to be stepped back at higher floors. This will prove difficult to do with the shear wall requirement because having a very small fifth and sixth floor will not be viable.

This proposed *Code* change may also have the unintended consequence of increasing shrinkage problems as it may increase the use of non-wood components for shear walls.

We also ask that the Province consider including objective based codes for this proposed *Code* change. Structural engineers should be allowed to design shear structures with off-sets as long as they meet provincial structural design objectives.

Proposed Code Change 6

"This proposed code change permits building diaphragms to yield. This issue is also being considered during a public review at the national level. Please refer to: https://www.nationalcodes.ca/publicreview/2008/index_e.shtml."

UDI fully supports this proposed *Code* change.

Proposed Code Change 7

"The proposed code change allows hold-open devices on fire doors within a public corridor. This issue is also being considered during a public review at the national level. Please refer to: https://www.nationalcodes.ca/publicreview/2008/index_e.shtml."

UDI fully supports this proposed *Code* change.

Proposed Code Change 8

"This appendix note focuses on the matter of shrinkage, particularly in taller wood-frame buildings."

The practical implications of this are not fully understood. The Province should ensure that this does not result in significant amounts of greenhouse gas emissions being released during the drying of buildings after the roof has been constructed. Again, separate requirements should be allowed for hybrid projects where there are four or fewer floors of wood-frame construction.

Future Issues

Horizontal Exiting: UDI fully supports this proposal. As noted at our November 25th meeting with staff, "It will be difficult to achieve fire access to the door of each 'building' when there are multiple fire walls separating 'buildings'." In fact, we advocate that this proposal should be incorporated in the *Code* immediately for hybrid buildings where there are four or fewer floors of wood-frame construction.

Independent 3rd Party Review of Building Design & Field Review or Site Inspections: UDI would have concerns with regard to these proposals being implemented – especially for hybrid buildings. Certainly, much more consultation would be needed with industry. It will be difficult in many areas of the Province to have professionals available to do this work. We also note that fees for third party reviews may not cover the insurance costs for this work.

Education and Training: As an organization that conducts dozens of educational events for the development industry, we strongly support the need for more educational programs for mid-rise wood-frame construction. In fact, UDI is working with Ministry staff to organize an education seminar for our members in the New Year regarding the future regulations for mid-rise wood-frame construction.

In conclusion, the industry is very supportive of your Ministry's mid-rise wood-frame initiative. Given the current downturn in both the construction and forestry sectors, the timing of your proposal could not be better. We hope the Ministry will consider UDI's suggestions to maximize the benefits of the initiative.

It is also important to understand that changing the *Building Code* to allow mid-rise wood-frame construction is only the first step. Municipal Zoning By-laws will have to be amended to allow this type of affordable and sustainable development in key areas. These projects are especially needed along transit routes to increase ridership and assist the Province in meeting its greenhouse gas emission reduction targets. We hope the government will work with local governments to take advantage of these important changes. UDI looks forward to working with you and your Ministry as this work continues.

Best regards,

Maureen Enser
Executive Director

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and Geoscientists of BC

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April 1, 2009

Mr. Jeff Vasey, Executive Director
Ministry of Housing and Social Development
Building and Safety Policy Branch
PO Box 9844, Stn Prov Govt
Victoria BC V8W 9T2

Dear Mr. Vasey:

At a meeting on Tuesday, March 31, 2009, the structural engineering members of the APEGBC Mid-Rise Bulletin Task Force and representatives from Forintek met to discuss concerns raised in their analysis of five and six storey wood frame residential building projects (mid-rise buildings). The structural engineers present from the APEGBC Task Force included:

- Jim Mutrie, P.Eng.(CSA-A23.3 Committee Member)
- Rob Simpson, P.Eng., Struct.Eng.
- Thomas Leung, P.Eng., Struct.Eng. (CSA-086 Committee Member)
- Grant Newfield, P.Eng. Struct.Eng. (CSA-086 Committee Member)
- Robert Malczyk, P.Eng. Struct.Eng. (CSA-086 Committee Member)
- Bill Marsh, P.Eng.
- Rob Smith, P.Eng.
- Don Anderson, Ph.D., P.Eng. (SCED Committee Member)

The representatives present from Forintek included:

- Erol Karacabeyli, P.Eng. (SCED Committee Member)
- Marjan Popovski, Ph.D., P.Eng. (CSA O86 Committee Member)

Steven Kuan, Ph.D., P.Eng. from the Building and Safety Policy Branch also attended the meeting.

The APEGBC Task Force determined that the use of conventional design techniques currently applied to four storey residential wood frame structures resulted in designs of mid-rise buildings that were too conservative due to high seismic design forces, were labour intensive and required custom hardware, all of which would negatively impact the economic viability of mid-rise wood frame buildings.

The Code permits the use of design techniques traditionally used in steel and concrete mid-rise/high-rise construction but these are not currently being used in wood frame building projects. The use of these design techniques on mid-rise buildings allows for lower design forces, resulting in a more economical and efficient design not significantly more complicated than currently followed in four storey practice.

Sophisticated research, including computer modeling, done separately by Forintek and members of the APEGBC Mid-Rise Task Force was carried out. On the basis of this research it is the considered opinion of both groups that following these design techniques to their limit, as currently allowed under the BCBC, could lead to designs that may result in the collapse of a storey under the design earthquake.

APEGBC and Forintek are recommending the following provisions, or others having the same effect, be added to the BCBC change amendments enabling the construction of mid-rise buildings:

> *"When determining design force levels for mid-rise buildings using mechanics based building periods multiply* V *(minimum lateral earthquake force) x 1.2*
> *When dynamic analysis procedures are used multiply* V *x 1.2 and consider the building irregular."*

The design loads recommended above are lower than those used in current industry practice, but greater than the current minimum loads allowed by the BCBC. This will provide mid-rise wood frame residential buildings that are economical and life safe.

Please feel free to contact us regarding any further assistance we can provide in addressing this matter.

Yours truly,

Peter R. Mitchell, P.Eng.
Director, Professional Standards and Development

PRM/lb

cc: Steven Kuan, Ph.D., P.Eng.
Senior Seismic Engineer
Building & Safety Policy Branch

Jensen, Jun'ichi MEM:EX

From: Rodney McPhee [RMcPhee@cwc.ca]
Sent: Thursday, March 19, 2009 8:03 PM
To: Andrew Harmsworth (GHL)
Cc: Khash Vorell (GHL); Lam, Roger SG:EX; Helen Griffin; Etienne Lalonde; Mary Tracey
Subject: RE: Justification for proposed Code Change

See my responses below.

Rodney A. McPhee, CET, CIP, ASFPE
Director, Codes and Standards
Canadian Wood Council
email: rmcphee@cwc.ca
Ph: 613-747-1801

From: Andrew Harmsworth (GHL) [mailto:ah@ghl.ca]
Sent: Thursday, March 19, 2009 10:42 PM
To: Rodney McPhee
Cc: Khash Vorell (GHL); Lam, Roger HSD:EX; Helen Griffin; Etienne Lalonde; Mary Tracey
Subject: RE: Justification for proposed Code Change

Sorry, I meant F-15. thanks for your explanation. Okay

In terms of your Code proposal - I think this is what is missing. We need to see each design with an extra column in the table stating 'based on test F-XX' or 'extrapolated from Test F-ZZ' so that in reviewing the code change proposal, each design can be reviewed for supporting documentation. Similarly, prior to acceptance in the code, this gives us, as consultants, the ability to refer to the tests, or develop an AS based on the tests. This can be done, but I can't do it tonight. When do you need such information?

I am confused by your 1.5 hour ratings, when the highest test rating on wood studs I see is 79 minutes with GFI and resiliant channel. Generally speaking, the 1.5 h ratings were assigned to assemblies with 15.9 mm GWB based in the first part on the results of Test Assembly No. F16. This was an assembly that had a single layer of 15.9 mm on the fire side and with the 1 h result, it re-affirmed the historic generic listing of 1 h for 1 layer of 15.9 mm Type X GWB. With that, using the Component Additive Approach, the layer of 15.9 mm contributed 40 minutes to the FRR, assuming we only got 20 minutes contribution from the framing, as per the CAM.

When looking at Test Assembly F18, where the 2x2 12.7 mm result gave 79 minutes, and comparing it with Test Assembly F08, where the 1x2 12.7 mm result gave 51 minutes, this suggested that the additional layer of 12.7 mm in F18 contributed an additional 28 minutes. With that, it was agreed that the second layer of 15.9 on both sides would likely also contribute 30 minutes to the result from F16. (Which is conservative compared to the approach some have taken using the historic CAM values where they would add 40 minutes for each layer of 15.9 mm gwb.

Another question. Each test has different loading? Why and how does that relate to the design? I presume that each assembly was loaded to full capacity, based on the stud spacing, +/- 10%. The superimposed load takes into consideration the self-weight (dead load) of the materials used. So when the type of gwb or number of layers of gwb differ, the superimposed load differs, while the stud framing remains the same. Obviously, when the staggered stud walls or double stud walls are tested, with twice as many studs in the wall, in order to maintain a consistent maximum load per stud, the total superimposed loads are doubled.

How do we apply this loading to our designs - simply design per 086, or are there load reductions required?
These loads were full design loads based on design using O86. There are not considered 'restricted load cases' and the loads were calculated based on the current calculation examples in ULC S-101.

Thanks

Andrew

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Andrew:

Yes, the 1h FRR value assigned to the **Part 3 Table Entry W8c** is an 'extrapolation'. (Note other **W8** entries includes staggered wall assemblies assigned 1.5 h ratings when 15.9 mm GWB is used)

In the following, I am referring to **Test Assembly No.'s** from Table 1 contained in **IRC report IRC-833.**

I would first point out that in your email you incorrectly refer to/describe **Test Assembly No. F18** as a 1x2 gwb configuration with a 51 minute fire resistance period. That description and test result is actually applicable to **Test Assemblies F08** (single row of studs) and **F15** (2 staggered rows of studs), and both assemblies achieved the 51 minute test result. **Test Assembly F18** was a 2x2 gwb configuration on a single row of studs and achieved a test result of 79 minutes.

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In the second part, the 1 h value assigned to **Table Entry Assembly W8** having the 2x2 layers of 12.7 mm GWB on the 2 rows of staggered studs on a single sill plate with GFI was then extrapolated based on the test results of **Test Assembly No. F18**, which was a single row of studs with the 2x2 layers of 12.7 mm GWB, with GFI, and also with an RC under the two layers of GWB on the fire exposed side. **Test Assembly No. F18** exhibited a fire resistance period of 79 minutes (Thus both **Part 3 Table Entry W2c** and **W8c** are assigned a fire resistance rating of 60 minutes).

Let me know if you need any more information.

Rodney A. McPhee, CET, CIP, ASFPE
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As you may know I have been discussing your proposed Code Change to add Fire Resistance Ratings to the Appendix with BC BSPB, as well as working on the first 6 storey residential building in BC. We will be using the CWC designs as part of the first 6 storey wood frame, and therefore this becomes an interesting exercise in looking at your proposed designs and understanding how they are demonstrated as compliant per the fire test reports issued by NRC (IRC-IR-764, 806 and 833 and RR No 184, also NRCC-47737 - are there others I do not have?)

Looking at your fire ratings table, a question has arisen for which I could not find the answer (maybe I missed it). Did NRC test 2 layers of 1/2 in gwb on either side of staggered wood stud (including glass fibre insulation in our case).

I see your wall design W8 - but can find no justification in the fire test reports, except for test F18 which was 51 minutes for a 1x2 gwb configuration. Is W8 simply an extrapolation of this design?

Thanks

Andrew

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Jensen, Jun'ichi MEM:EX

From: Peter Reese [PReese@rwa.ca]
Sent: Monday, March 16, 2009 5:35 PM
To: Rotgans, Trudy SG:EX
Subject: FW: Wood Solutions Fair - Midrise Wood Frame Panel
Attachments: Panel Discussion notes for review.pdf

Hi Trudy -

Khash suggested I send this to you also, for your input

Look forward to meeting you Wednesday

Peter Reese, MAIBC, CP

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From: Peter Reese
Sent: Monday, March 16, 2009 5:20 PM
To: kv@ghl.ca
Subject: Wood Solutions Fair - Midrise Wood Frame Panel

Hi Khash -

I understand we will be on the Panel this Wednesday - it was suggested we coordinate what we intend to present, so I enclose some notes for my 15 minutes of fame - let me know if you have comments, or if there are points included you will cover

Thanks - look forward to meeting you

Peter Reese, MAIBC, CP

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PANEL DISCUSSION - MIDRISE WOOD FRAME - WOOD SOLUTIONS FAIR - 18 Mar 09

- Architectural Implications:

    - Code change relates to Group C Residential, up to 6 Stories, Sprinklered
    - Height: Maximum 6 stories and 18 M measured from grade "to uppermost floor level of uppermost storey" - UDI notes that different Municipalities have different definitions of Grade
    - Building Area: Gross Floor Area unchanged, therefore smaller footprint - 7200 M2 GFA therefore 5 stories equals 1440 M2 Building Area - 6 stories equals 1200 M2 Building Area - can have larger footprint by adding firewalls to divide developments into technically separate buildings - it is assumed the total fire load and degree of risk remains the same as currently
    - Existing 3.2.2 multiple occupancy rules would allow 6 storey hybrid building with lower floors as another Major Occupancy - eg. 1 storey Retail considered as 2 hour rated concrete building with 1 hour rated 5 floor wood frame Residential building above, totaling 18 M high
    - Stacked shear walls plus no irregular shapes or massing
    - Mezzanines not allowed to increase height above 6 stories or 18 M
    - Cladding:
        - Non-combustible, tested wall assembly with thermal barrier, or fire retardant treated wood
        - Stucco requires cavity compartment every 2 stories
        - Unclear if vinyl siding over GWB allowed
        - Have heard Vancouver won't allow cementitious board such as Hardiplank - wants to see real wood - question about equivalency using accelerated weathering test
        - Balconies and overhangs: Perforated vinyl soffits not acceptable - there are implications for venting
        - Typical wood frame Balcony wood fascia and posts not acceptable
        - Restrictions on cladding materials, particularly wood trim, may result in new building vernaculars and use a wider range of materials - balcony design may be reconsidered - lining up joints and building elements may require more care and craft than typically seen on 4 storey frame buildings with wood trim
        - As cladding becomes more expensive, clients will want to reduce building jogs
    - Windows: Higher buildings may require higher performance windows - sliding glass doors may be more problematic at higher floors
    - Emergency generator may be required
    - Coordination and Field Review may become more rigorous - fee and insurance issues
    - Architectural Style:
        - Requirements tend towards 4 square, block buildings which could lead to architecturally stolid, boxy, uninteresting buildings and overbearing streetscapes - or could lead back to a future of ordered, neo-renaissance buildings with attention to base, middle, top, and urbane European streetscapes, or to a fresh, innovative approach - opportunity to create a new "Vancouverism" model
        - Facade design and material quality becomes extremely important - requires focusing on the textural, not just Architectural, design - big impact on urban design
        - This building type requires thoughtful restraint and more sophisticated detailing - sometimes our lowrise buildings feel like full scale models of

real buildings - this could be an opportunity to design robust, flexible, metabolic, future proof, future heritage buildings - could explore prefabrication, compartmentalization, panelization, modularity, sophisticated details such as exterior window blinds or shutter panels, integration of venting, shading and solar systems - could also be an opportunity to design more texturally rather than just architecturally, with attention to meaningful façade design

- What do we about overhangs on 6 storey buildings - are there stringcourses and cornice lines
- Ideally top two floors could vary from typical floor plate, but may not be allowed by current shear wall requirements

- Opportunities to improve performance and life safety
  - Require double doors in Corridors to divide floors into 2 smoke refuge areas as per BC Housing Assisted Living projects
  - Design dwelling units to be air tight compartments as per BC Housing Provincial Homelessness Initiative requirements intended to limit bedbug spread – this would limit smoke migration in a fire – if suites had individual heat recovery ventilation, suite entry doors could be weatherstripped
  - Require upgraded insulation in wall and floor assemblies - mineral wool could be required to reduce fire spread - non-combustible foam could be required to control fire and smoke spread
- Opportunities for design innovation:
  - Hybrid systems and hybrid buildings
  - Possibility of frame construction for top floors of multistory concrete buildings

- <u>Implementation issues:</u>

- In practice, change will probably be implemented gradually - stakeholders including AIBC and Insurance and Warranty providers have expressed concerns - zoning does not yet allow many locations for 5 and 6 storey buildings

  - Home Warranty Insurance: HPO Homeowner Protection Office notes main issue is home warranty insurance providers will need to provide coverage - Travelers notes concerns are:
    - Safety
    - Structural
    - Education and Training
    - Wood Shrinkage
    - Building Envelope
    - Industry Awareness
    - Regulator Awareness

    - Significantly they "require significantly more information to better assess this type of housing and the potential risks involved in providing warranty insurance"

  - Fire Departments: Concerns expressed include:
    - Training and equipment challenges
    - Exiting time

- Smoke control measures - my understanding is that smoke and toxic fumes are main life safety dangers
- Fire fighting from interior of buildings
- Request non-combustible exit shafts
- Request emergency generators for emergency lighting

- AIBC Recommendations: AIBC noted a number of technical concerns such as:
  - Fire resistance rating continuity
  - Coordination of fire rated assembly Code tables
  - Extension of midrise wood frame to assisted living and congregate care uses
  - Fire fighters exposure to risk
  - Durability standards
  - Course of construction fire risk
  - Education and training, for design professionals, building officials, contractors and trades
  - Development of best practices guides

- Recommendations:
  - Reconcile Code limitations
  - Complete best practices guides
  - Provide education seminars
  - Create an industry advisory group
  - Start with pilot projects
  - Establish a Provincial Code Interpretations Office

- Nearest Precedent: Washington State allows 5 storey wood frame over 1 storey 2 hr rated concrete, but requires:
  - I hour rating for interior non-load bearing walls on lowest frame storey
  - Smoke proof and pressurized exit stair and elevator shafts
  - Emergency generator for emergency lighting
  - Special structural inspections

- Implementation Option - begin with 6 storey hybrid buildings:
  - 4 stories frame over 1 or 2 stories concrete
  - 5 stories frame over 1 storey concrete
    - could give more comfort to all stakeholders during transition period to 6 storey frame buildings

- <u>Technical Issues:</u>

  - Structural: Seismic design is the main issue, though wind load becomes bigger issue - amount of nails in wood
  - Building Envelope: No significant difference from current best practices between 4 and 6 stories at any particular site, although more attention is warranted - window standards may be affected
  - Wood Shrinkage / Differential settlement :
    - Issues can be managed with careful detailing, use of appropriate materials, and more attention to keeping kiln dried wood dry during construction
    - Coordination issues re: effects on all building systems – eg. flexible plumbing connections
    - Use of TJI or other engineered floor system
    - Detailing, Coordination and Field Review implications
      - At masonry elevator core and fire walls

- Brick veneer supported on ledgers at each floor
- Sill and head members - opportunity for using alternate materials - at least use kiln dried plates
- Option to extend wall framing to underside floor and support joists on hangers
- Opportunity for increased use of engineered wood
- Issues re: increased mix of engineered wood and dimension lumber

- NFPA 13 required - all rooms including Bathrooms, Closets, and Balconies sprinklered
- Requirement to meet ASHRAE 90.1 (2004)
- 1 Hour Floors: Affects 4-6 storey buildings - existing fire and sound ratings are being called into question by new testing - eg. insulation lowers the fire rating - lower structural loading for dimension lumber joists can lead to joists at 12"rather than 16" centres which then lowers sound transmission ratings
- Elevators: Hydraulic elevators may not be suitable, particularly regarding speed
- 15 M fire access to each "building" may require equivalency
- Status of requirement to bring 2 hr fire walls to Grade without offsets
- Status of Horizontal Exit approval - my understanding is additional exit stairs required at fire walls if project divided into more than 2 buildings - issue of cost plus loss of sellable space

- Construction Issues:
  - Protection of kiln dried lumber throughout construction period
  - More attention to all aspects of construction - less wild west, wood butchering, cut and cover attitude
  - Probably increased use of prefabricated components

- Cost Implications - of moving from 4 to 6 storey frame buildings:
  - Additional exterior non-combustible cladding and trim
  - More kiln dried lumber to avoid additional shrinkage
  - More structural lumber to take additional loading
  - Possible need to use 5/8" instead of 1/2" ply for shear walls, and may require ply both sides
  - Cost of additional fire walls
  - Cost of sprinklering Balconies, Bathrooms and Closets
  - Cost of sprinklering Attics or creating fire compartments to underside roof
  - Possible increased costs of elevator
  - Possible costs for staging scaffolding
  - Plus soft costs: consultant fees, insurance, etc
  - Contractors pricing for unknowns
  - Big cost if emergency generators were required

  - What is incremental cost of going from 4 storey to 6 storey wood frame
    - where are the costs - one is parking - below grade parking is concrete at $40,000 per stall - current parking regulations probably require 2 levels underground parking for midrise
    - What is cost of 6 storey wood frame compared to 6 storey concrete
      - is it $150/SF vs $250/SF or is it $220/ SF vs $250/SF
      - if costs are within 15%, and people will pay more to live in a concrete building, where is the incentive to build wood frame

Non-Responsive

From: Khash Vorell (GHL) [mailto:kv@ghl.ca]
Sent: Monday, March 16, 2009 11:50 AM
To: Rotgans, Trudy HSD:EX; Nicol, John HSD:EX
Subject: Two Comments re your March 18 presentation -

Trudy & John,

I noted couple of items on your draft presentation which require your attention.

1) In two places (page 2 and 14, highlighted in red) it is indicated that local government may enact bylaws to define grade or manipulation of grade. My comments on this statement are as follows: Grade is a defined term in BCBC, as such it is not subject of an interpretation at a municipal level to indicate how building height is established. Municipalities take Code definitions and use them, if there is a dispute between designer and AHJ in interpretation of the definition, then the Appeal Board can clarify that Code interpretation. Planning and zoning bylaws can regulate matters primarily relating to "form" and "character", fire safety and building regulations are regulated by the Code. Another issue is that, the Community Charter Act under Section 9 titled "Spheres of Concurrent Authority" prohibits municipalities to pass such bylaws if they are dealt with under an existing Provincial building regulation; of course unless such bylaws are approved by the Minister. As you are aware, the Concurrent Authority provisions were introduced due to concerns that some local bylaws relate to fire safety were inconsistent and sometimes unreasonable. The definition of "grade" is already covered under Part 3 of BCBC, as such it falls under a Provincial building regulation, and therefore subject to "Concurrent Authority" provision of the Community Charter Act.

2) On page 14 it is indicated: Local governments can also choose to enact additional requirements above the building code for the purposes of property protection such as: "requiring staged inspections by a registered professional". My comments on this statement are as follows: Similar to above, "field review" is also a defined term in BCBC. The definition states that field review is left at the discretion of Registered Professional (RP). This for long has been a touchy issue with both APEGBC and AIBC; at the committee level we often come across member complaints that some AHJ's are demanding RP to conduct field reviews at specific stages of construction. As you are aware both Act's of APEGBC and AIBC give the associations the power to regulate their members. Bylaws of both associations are also consistent with the Code's definition of "field review", that is field review frequency and timing is left at the discretion of RP's. Therefore, if a municipality passes a by law to regulate when field reviews are required, this will be in contradiction with definition of the Code, as well as the bylaws of both associations.

Please call or email if you wish to discuss the foregoing.

regards,

Khash Vorell, M Eng, P Eng
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Non-Responsive

****

From: Khash Vorell (GHL) [mailto:kv@ghl.ca]
Sent: Thursday, March 12, 2009 11:31 AM
To: Rotgans, Trudy HSD:EX
Cc: Shelley Craig; Bob Worden; Khash Vorell (GHL)
Subject: Wood Solutions Fair Mid-Rise Panel - coordination

Hi Trudy,
I wanted to touch base with you regarding the March 18th presentation. I was thinking to coordinate with you regarding the items I was going to cover and to make sure that there is not too much fire safety related info.

1) Are you mostly covering the government's process and perspective issues relating to the Code change?
2) Currently my presentation is covering the following topics:
   a) Current Code Provision
      - Overview of the Risk Analysis
      - Technical vs process risks
      - Findings
   b) New Part 3 Building Code Provisions
      - Occupancy limitation
      - Building area limitation
      - Building height limitation
      - Hold-open devices
      - Exterior cladding
   c) Other Design Considerations
      - Sprinkler system design,
      - Combustible concealed spaces
      - Shrinkage & its impacts on fire safety systems
      - APEGBC's upcoming Technical Bulletin
      - Alternative Solutions
   d) Commonly asked questions

Please call or email me, in case there are some overlapping topics
regards,
Khash Vorell, M Eng, P Eng

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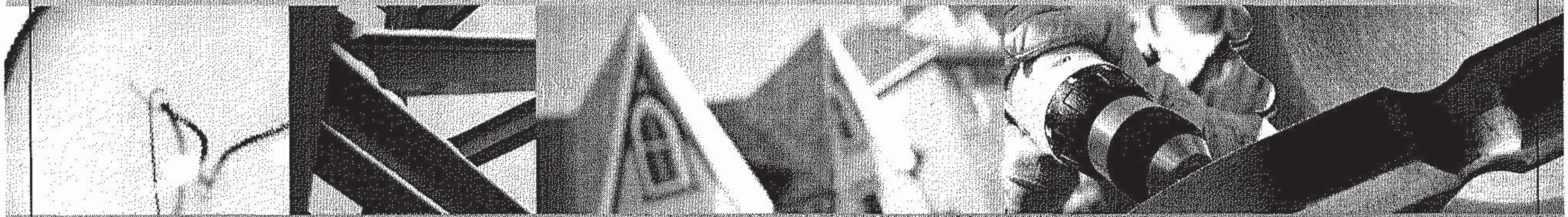

MID-RISE WOOD-FRAME CONSTRUCTION

New Code Provisions

- Building Height – Article 3.2.2.45
- Building Area – Article 3.2.2.45
- Exterior Cladding Materials – Article 3.2.2.45
- Shear Wall Regularity – Article 4.1.8.10
- Hold-Open Devices – Article 3.1.8.12
- Consideration of Structural Wood Shrinkage – Subsection 4.3.1Appendix

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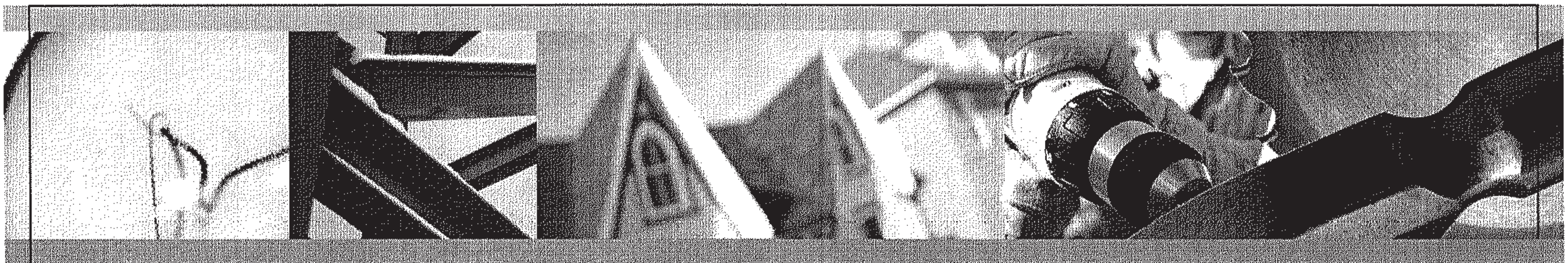

MID-RISE WOOD-FRAME CONSTRUCTION

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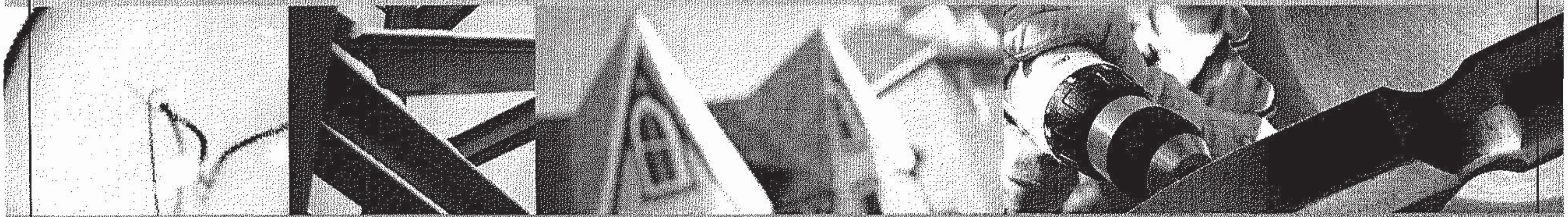
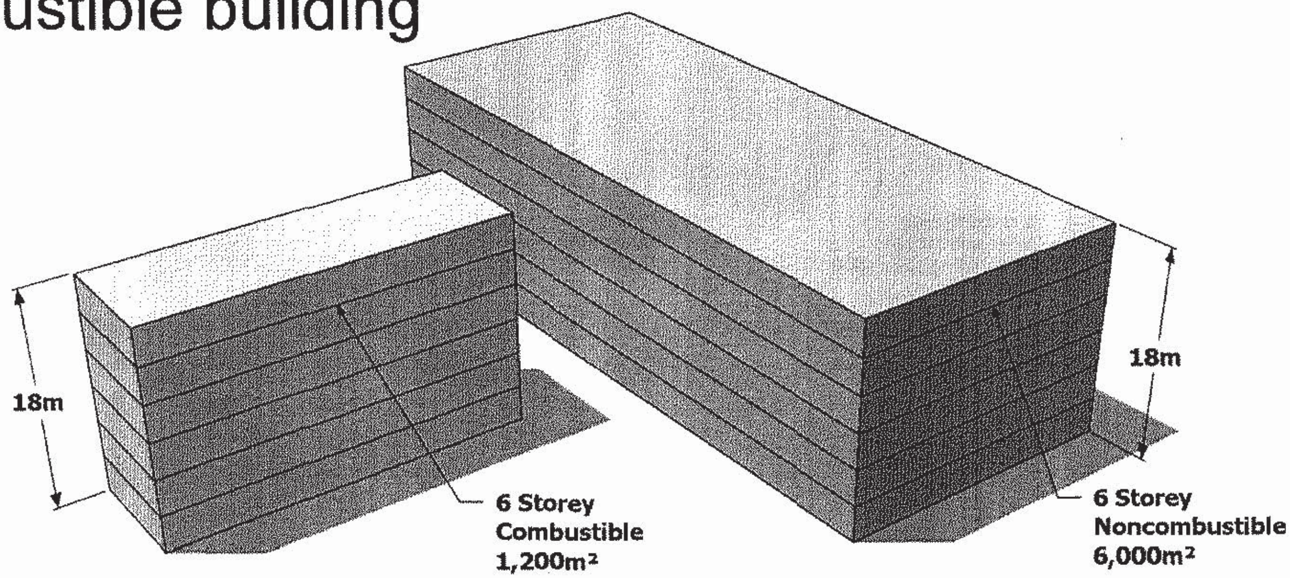


MID-RISE WOOD-FRAME CONSTRUCTION

Volume of building remains proportional to non-combustible building



Building Area Comparison

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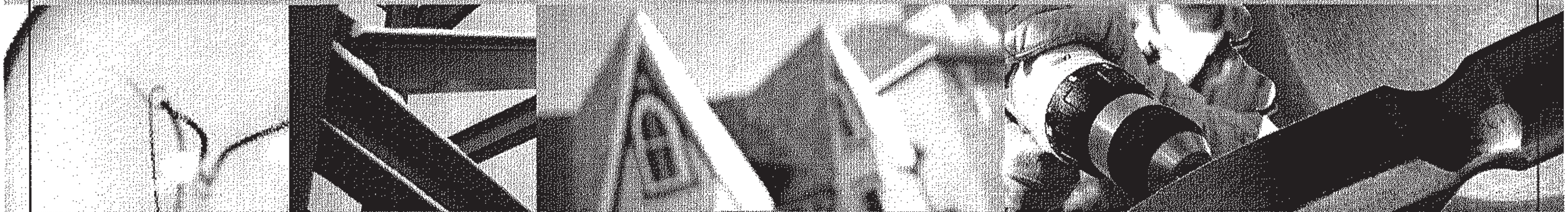
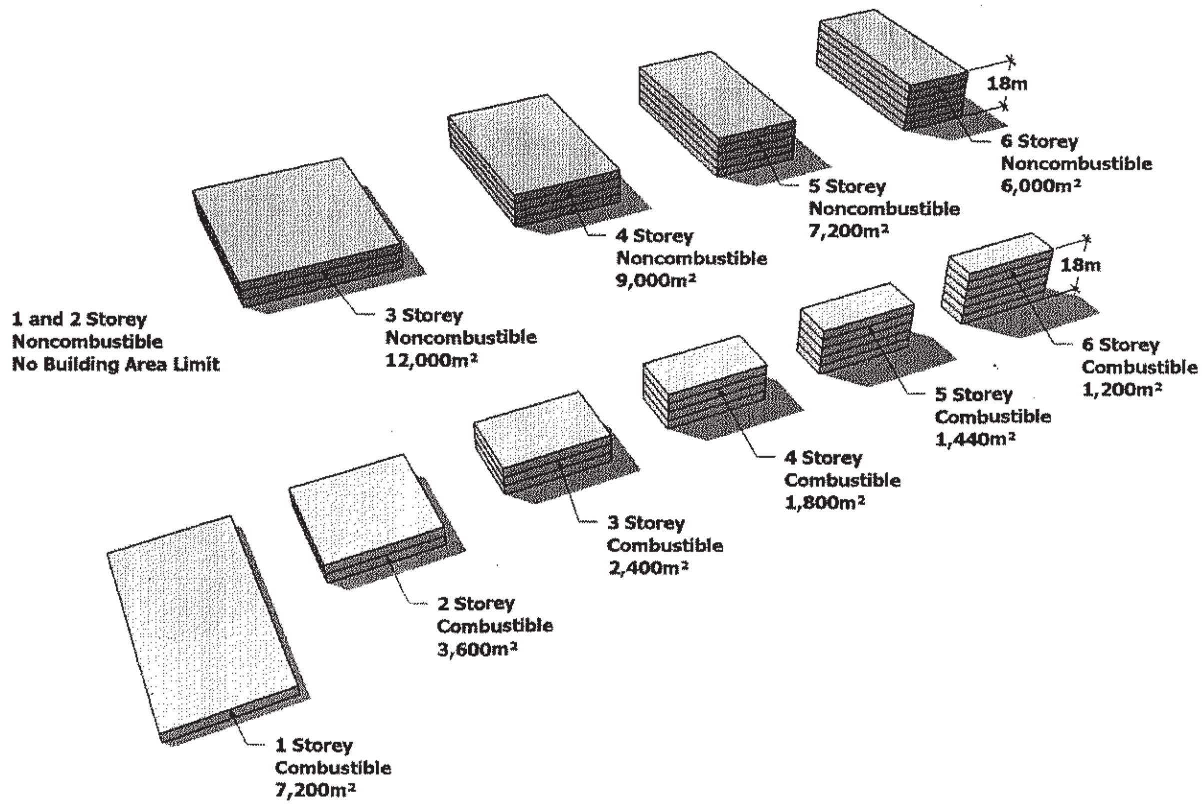


Building Area

MID-RISE WOOD-FRAME CONSTRUCTION



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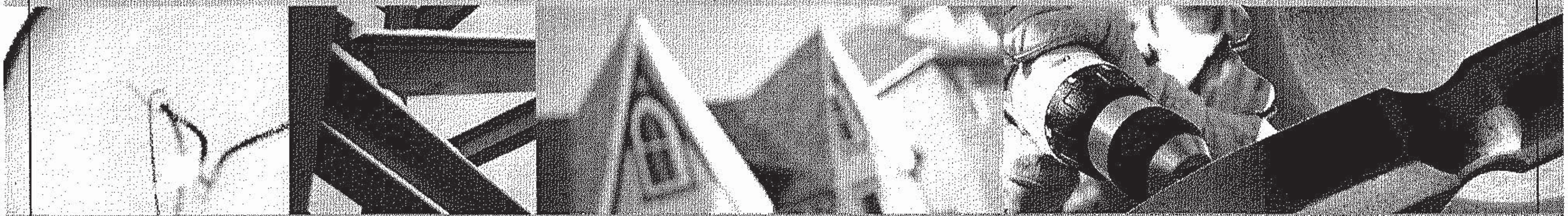
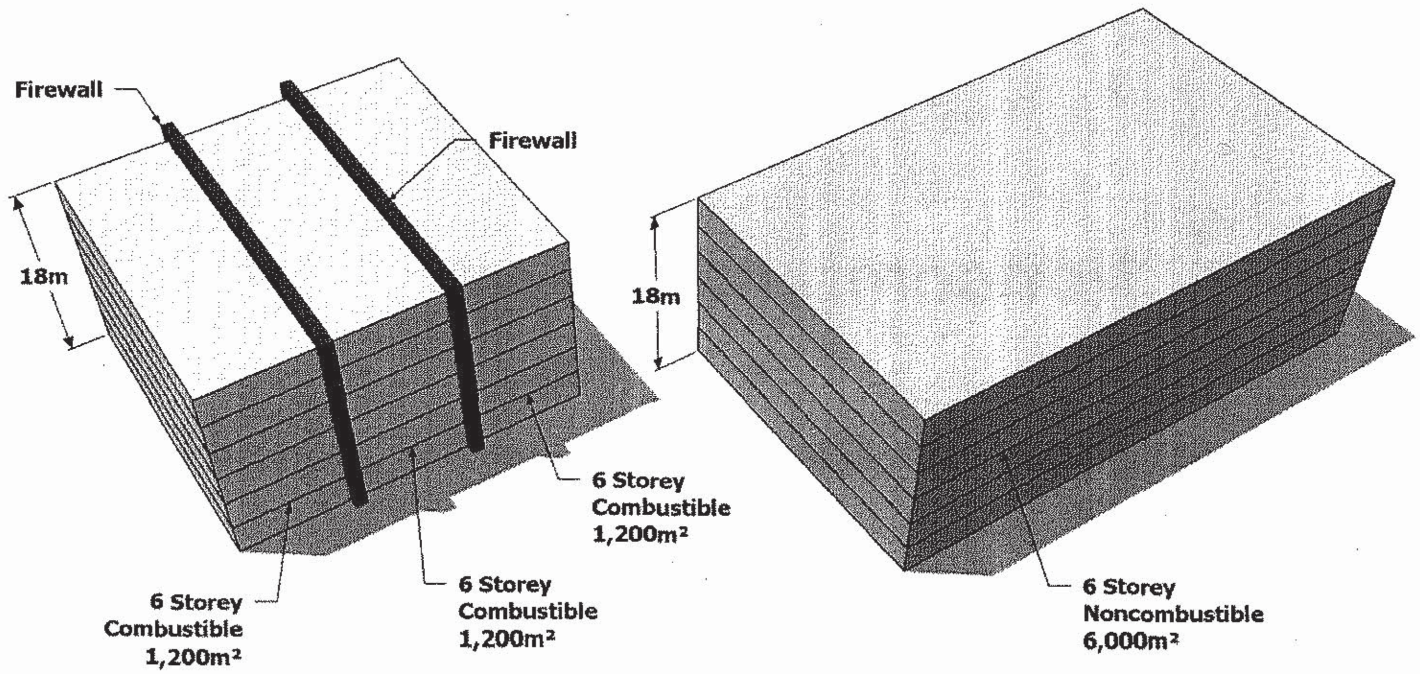


Building Area



Building Area Comparison

(Example of Combustible Buildings separated by Firewalls)

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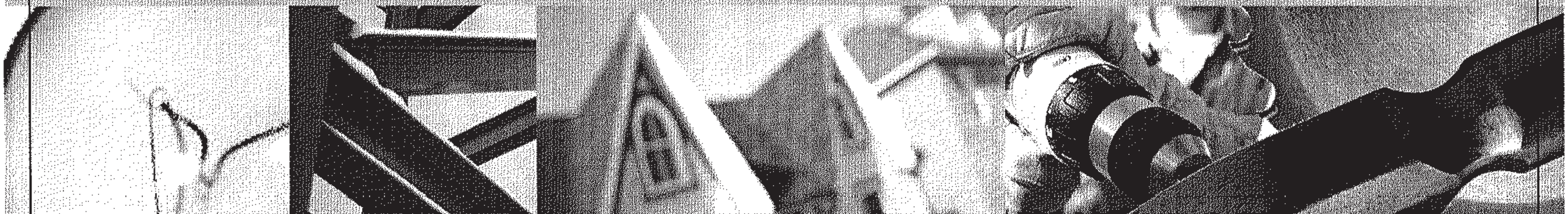

Exterior Cladding

- **Noncombustible** *or*
- **Fire Resistant**

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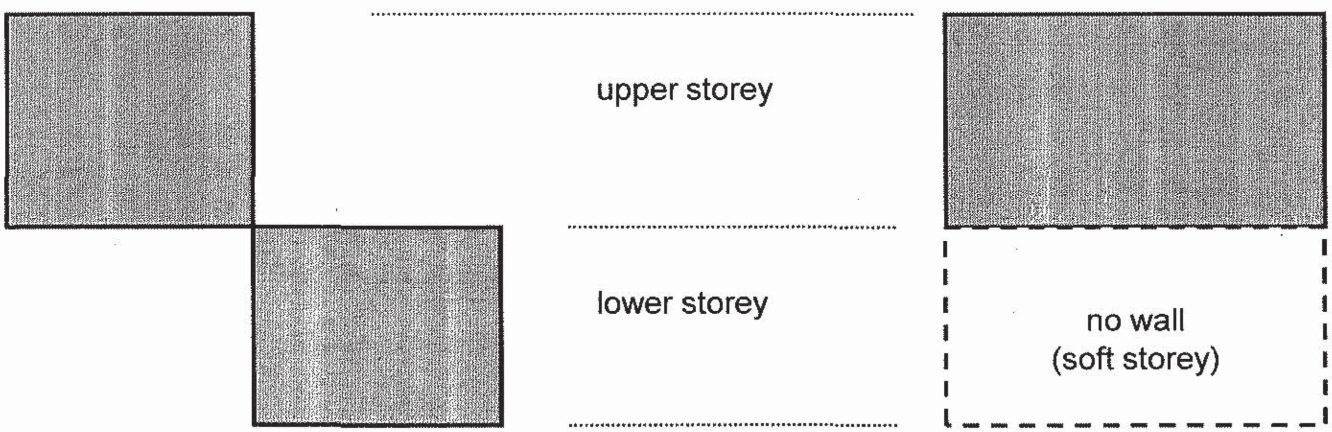
Shear Walls

Type 4 irregularity:
An in-plane offset of a lateral-force-resisting element of the SFRS or a reduction in lateral stiffness of the resisting element in the **storey below**.



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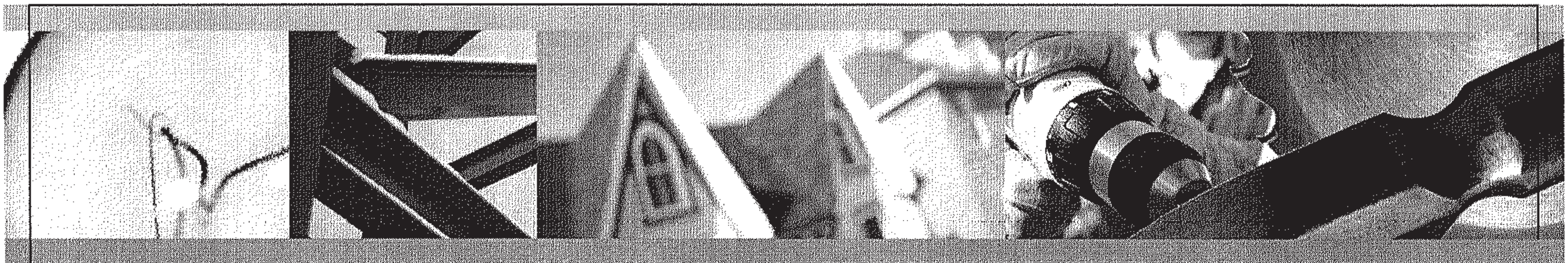
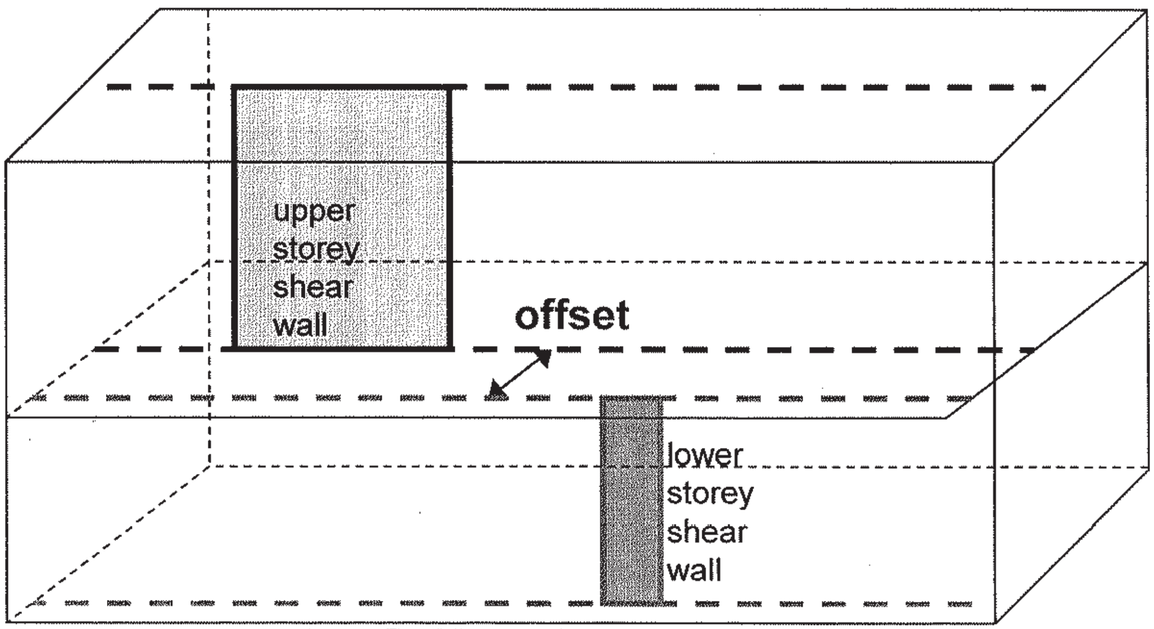


MID-RISE WOOD-FRAME CONSTRUCTION

Type 5 irregularity:
Discontinuities in a lateral force path, such as **out-of-plane** offsets of the vertical elements of the SFRS."



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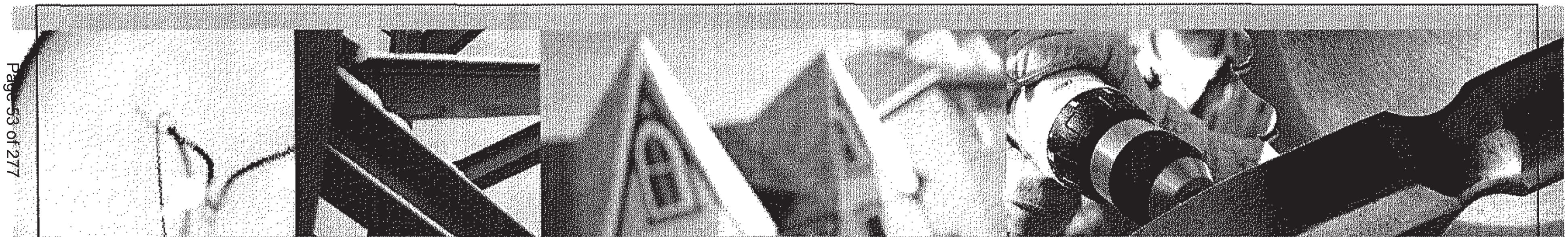

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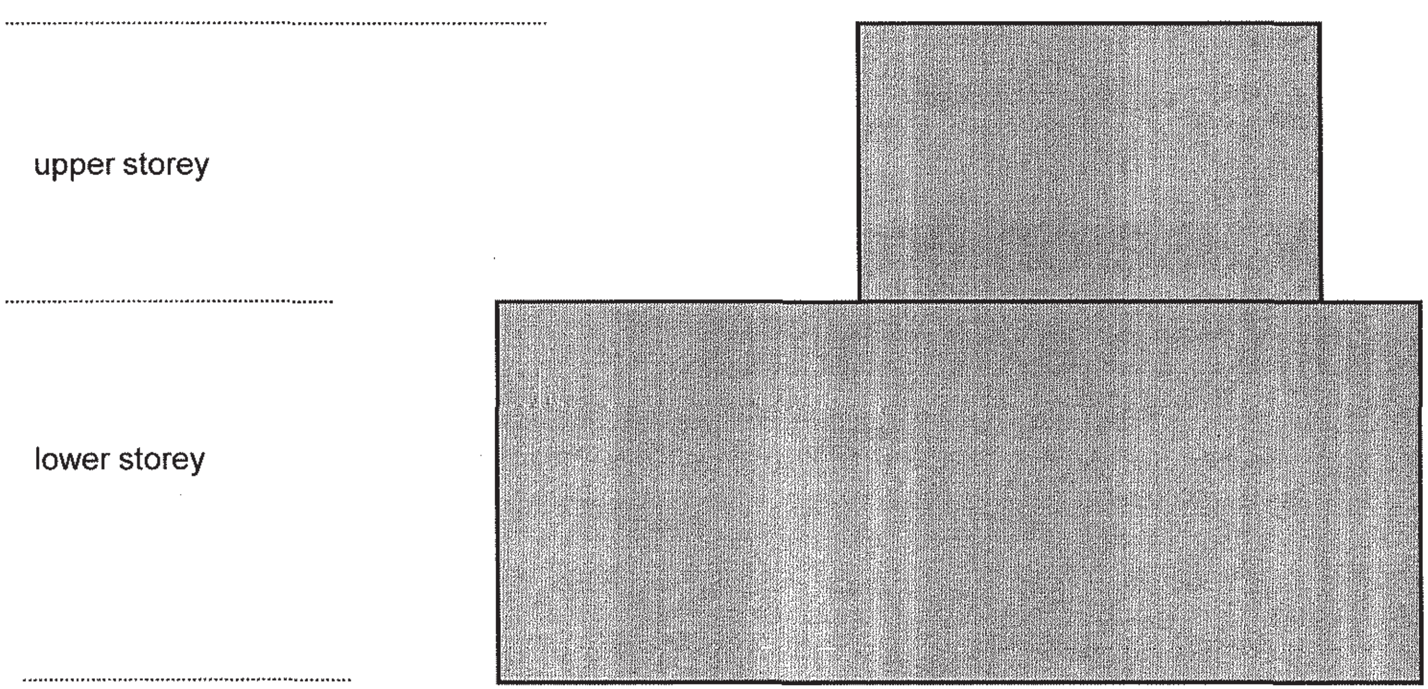

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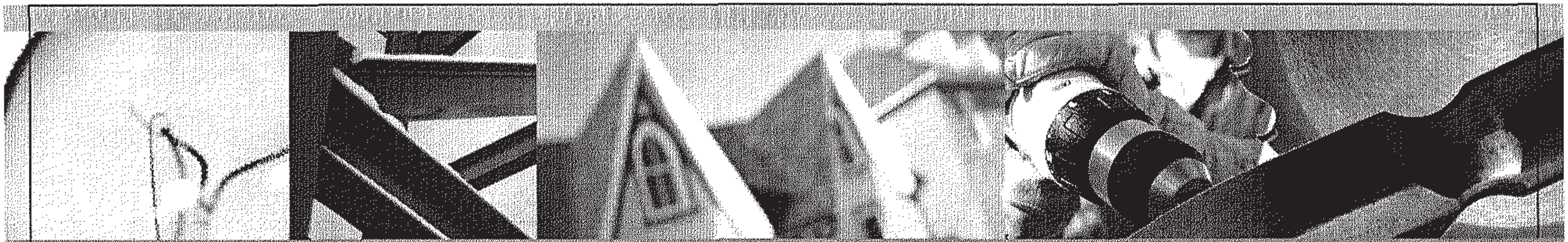

MID-RISE WOOD-FRAME CONSTRUCTION

Hold Open Devices

- Allow use on fire doors except those leading to exit shafts.

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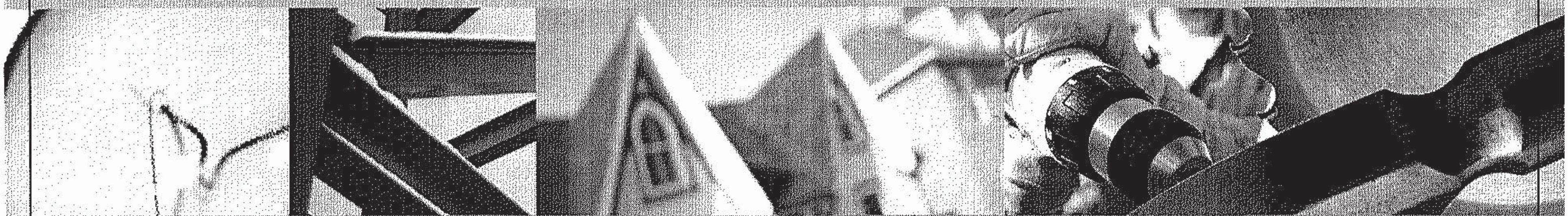

Wood Shrinkage

- Coordinating shrinkage calculations among all component designers

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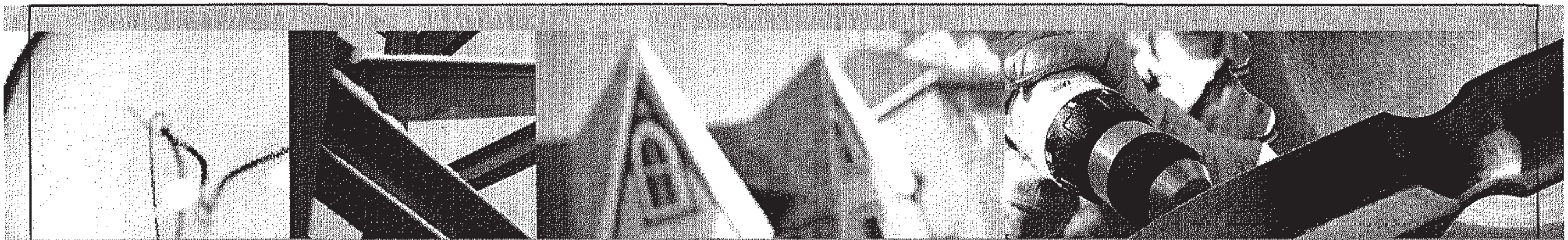

Other Applicable Code Provisions

Sprinklers: NFPA 13, which includes concealed spaces such as attics and crawl spaces as well as balconies wider than four feet.

Energy: ASHRAE 90.1 (2004) standards for insulation/energy efficiency

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Related Undertakings

- **Assisted Living occupancies in mid-rise wood buildings**

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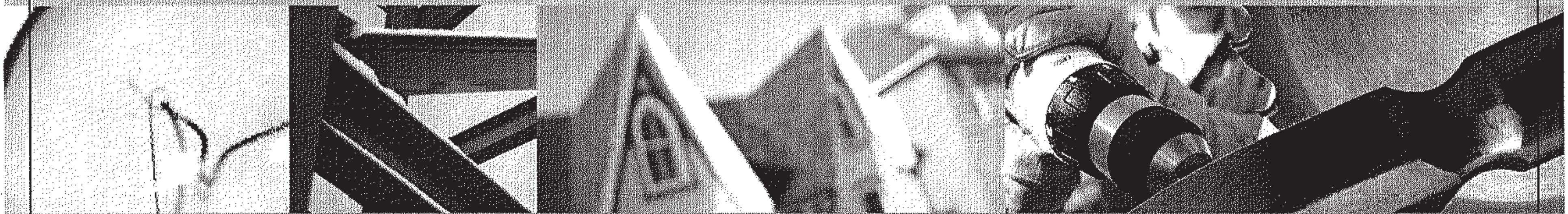

MID-RISE WOOD-FRAME CONSTRUCTION

Related Undertakings

- Local Capacity
  - – fire fighting
  - – building inspection

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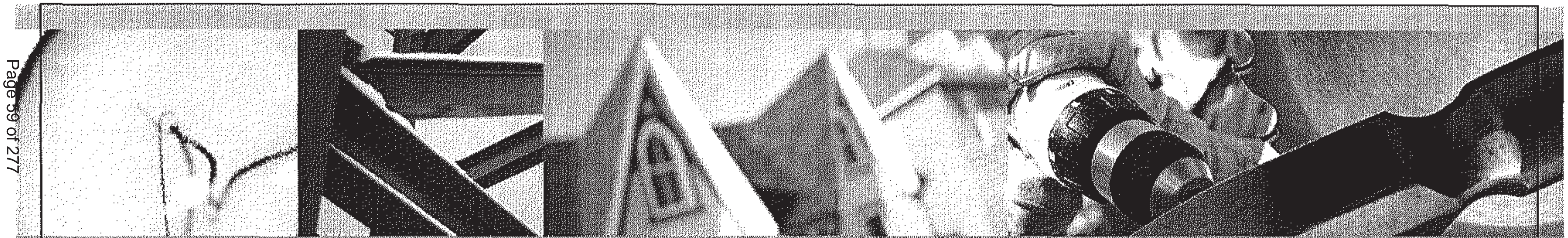

Other Issues

- Systemic problems

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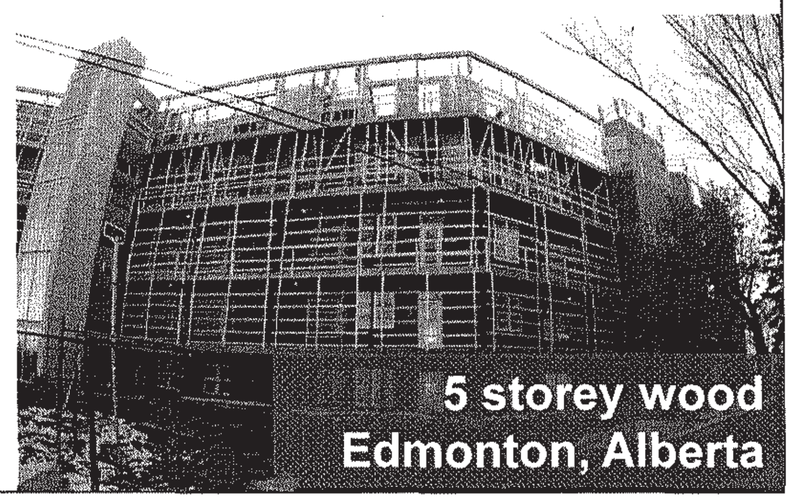

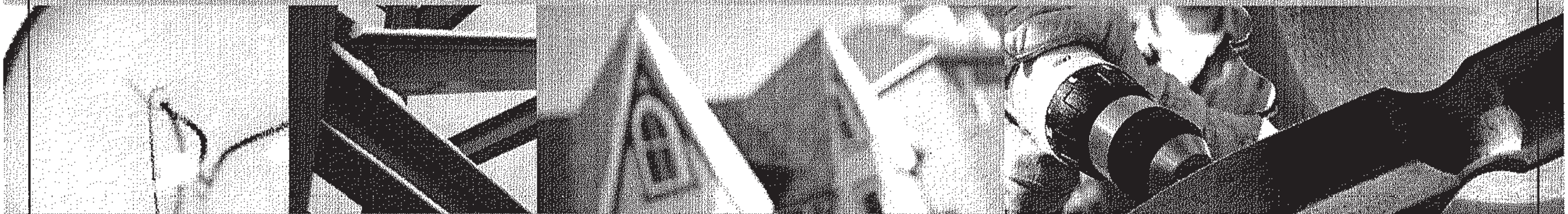

Other Issues

- Design and construction quality

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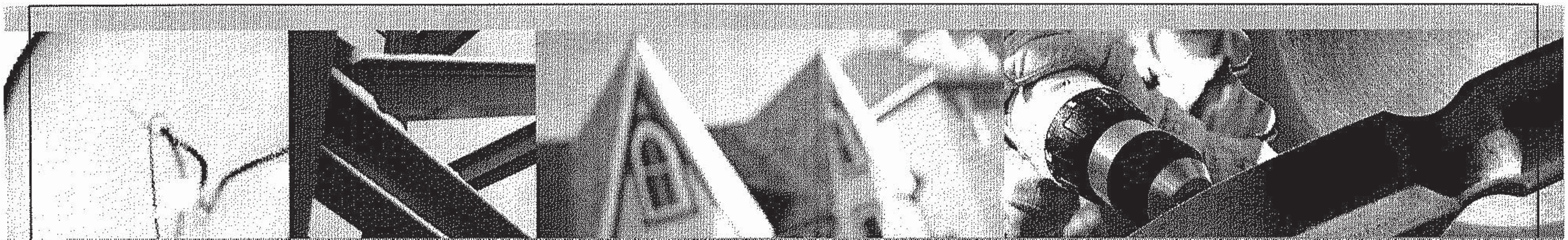

MID-RISE WOOD-FRAME CONSTRUCTION

Other Issues

- Fire Safety concerns

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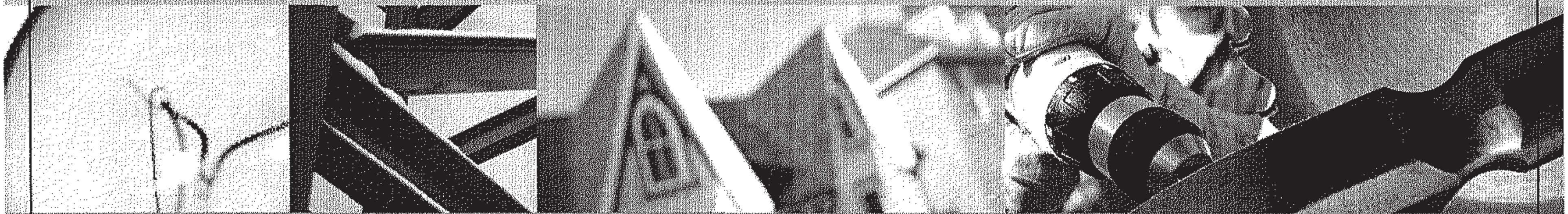

Other Issues

- Construction Fires

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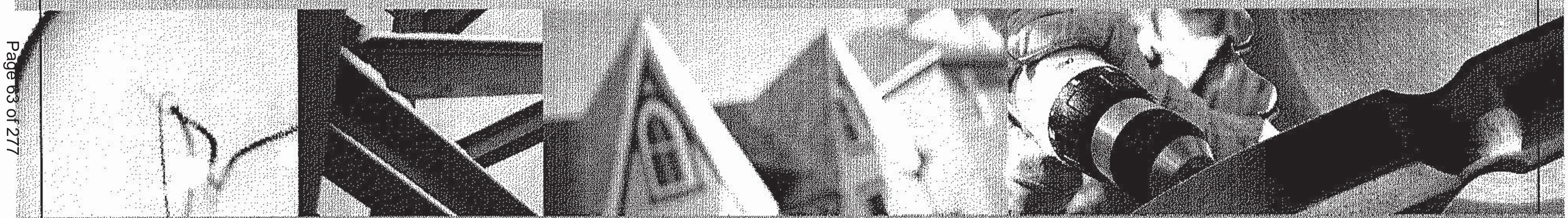

MID-RISE WOOD-FRAME CONSTRUCTION

Other Issues

- 'Fast-Track' process

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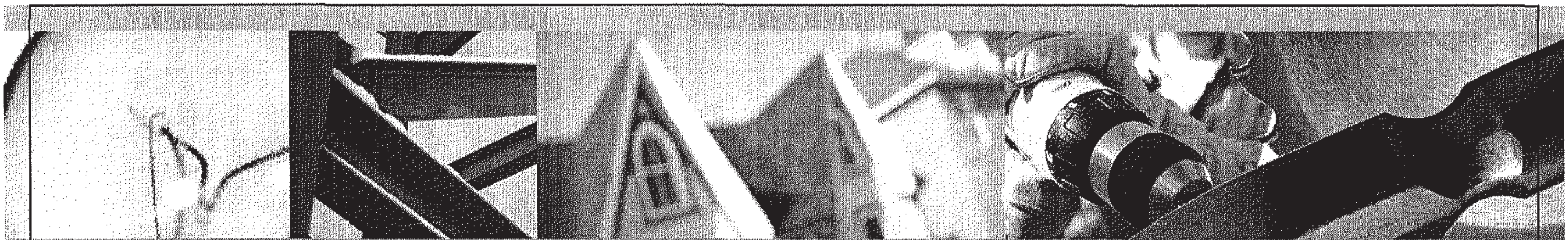

MID-RISE WOOD-FRAME CONSTRUCTION

Recap:

- New provisions come into effect April 6, 2009
- Evidence and expert analysis basis for new provisions
- Systemic concerns deserve further discussion
- We welcome your input
- Visit our website www.housing.gov.bc.ca and click on
- Email address building.safety@gov.bc.ca

Mid-Rise Wood-Framed Construction

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Jensen, Jun'ichi MEM:EX

From: Shelley Craig [craig@urban-arts.ca]
Sent: Thursday, March 12, 2009 5:21 PM
To: Rotgans, Trudy SG:EX
Subject: Re: Wood Solutions Fair Mid-Rise Panel
Attachments: UAA Mail Signature - Shelley.jpg; ATT296572.txt

Trudy,

s.22 The panel is from 8h30 - 12h15, with two breaks. Refer the the timetable that I sent previously.

Best,

Shelley

From: Grant Newfield [GNewfield@rjc.ca]
Sent: Thursday, March 12, 2009 2:49 PM
To: Diane Archibald
Cc: Rotgans, Trudy SG:EX; Douglas Watts
Subject: RE: AIBC conference session on mid rise wood frame building code changes
Attachments: image001.gif

Hi Diane

I am confirming I can make this session. I will look forward to this.

Grant Newfield
Principal

Read Jones Christoffersen Ltd.
Innovative thinking. Practical results.
Suite 300, 1285 West Broadway
Vancouver, BC V6H 3X8
Office: (604) 738 0048
Fax (604) 738 1107
Email: gnewfield@rjc.ca
www.rjc.ca

From: Diane Archibald [mailto:darchibald@aibc.ca]
Sent: March 11, 2009 2:00 PM
To: Michael Ernest; Rotgans, Trudy HSD:EX; Alan Brown; Douglas Watts; Grant Newfield
Cc: Catherine Bolter
Subject: AIBC conference session on mid rise wood frame building code changes

Hello everyone,

s.22 the few continuing education conference sessions that need to be finalized. The format of the presentation is a fifteen minute presentation by each of the four participants followed by a half hour of Q &A.

The participants:

Trudy Rotgans, Ministry, overview of building code changes
Alan Brown, AIBC Regulatory Board
Doug Watts, RJC, building envelope
Grant Newfield, RJC, structural (waiting for confirmation)

Michael and Alan, has a moderator been determined for this session. We are also waiting for a four line description for the session for the catalogue entry, which must go forward now.

On behalf of the continuing education conference committee, I would like to thank you for your participation in this session, which will take place on Friday, May 9th at 3:30-5:00 p.m.

We are already receiving inquiries about this session.

With best regards,

Dr. Diane Archibald Ph.D.
Director, Professional Development

Architectural Institute of British Columbia
100 - 440 Cambie Street
Vancouver, BC V6B 2N5
604 - 683-8588, ext. 334
www.aibc.ca

From: Diane Archibald
Sent: Wednesday, February 18, 2009 4:01 PM
To: Alan Brown
Subject: RE: panelists for AGM discussion on mid rise wood frame

Alan,

Thank you for following up on this.

As per our discussion of participants, we now have the following suggestions:

Trudy Rotgans (confirmed)
Alan Brown (confirmed)
Serge Desmarais (to be confirmed)
Doug Watts (building envelope issues)
Grant Neufeld (structural input) (to be confirmed)

We would need a title and three to four lines on the topic and objectives of the session before the end of this week in order to finalize the program with all panelists confirmed and their designations such as MAIBC, etc.

Thanks,
Diane

Dr. Diane Archibald Ph.D.
Director, Professional Development

Architectural Institute of British Columbia
100 - 440 Cambie Street
Vancouver, BC V6B 2N5
604 - 683-8588, ext. 334
www.aibc.ca

From: Alan Brown s.22
Sent: Wednesday, February 18, 2009 3:45 PM
To: Diane Archibald
Cc: Michael Ernest
Subject: panelists for AGM discussion on mid rise wood frame

Dianne

I talked to Doug Watts at RJC about the panel discussion on mid-rise wood frame. He would be willing to represent envelope issues. His phone number is s.22

He recommended Grant Neufeld from their office for the Structural input. Apparently he has been doing a lot of work with various bodies on this issue and has been giving presentations.

I told Doug Watts you would call him at RJC , to confirm details, etc.

ALAN BROWN ARCHITECT
ph(604)525-5259 fx(604)525-5290
110 - 3 AVE NEW WESTMINSTER BC V3L 1L8

Jensen, Jun'ichi MEM:EX

From: Khash Vorell (GHL) [kv@ghl.ca]
Sent: Thursday, March 12, 2009 11:31 AM
To: Rotgans, Trudy SG:EX
Cc: Shelley Craig; Bob Worden; Khash Vorell (GHL)
Subject: Wood Solutions Fair Mid-Rise Panel - coordination
Attachments: att894f0.jpg

Hi Trudy,

I wanted to touch base with you regarding the March 18th presentation. I was thinking to coordinate with you regarding the items I was going to cover and to make sure that there is not too much fire safety related info.

1) Are you mostly covering the government's process and perspective issues relating to the Code change?

2) Currently my presentation is covering the following topics:

1. a) Current Code Provision
2. 2. - Overview of the Risk Analysis
- Technical vs process risks
- Findings
1. b) New Part 3 Building Code Provisions
- Occupancy limitation
- Building area limitation
- Building height limitation
- Hold-open devices
- Exterior cladding
1. c) Other Design Considerations
- Sprinkler system design,
- Combustible concealed spaces
- Shrinkage & its impacts on fire safety systems
- APEGBC's upcoming Technical Bulletin
- Alternative Solutions

d) Commonly asked questions

Please call or email me, in case there are some overlapping topics

regards,

Khash Vorell, M Eng, P Eng
GHL CONSULTANTS LTD
Building Codes & Fire Science
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Saffire Safety Consultants Inc

www.saffire.ca

Jensen, Jun'ichi MEM:EX

From: Shelley Craig [craig@urban-arts.ca]
Sent: Thursday, March 12, 2009 8:42 AM
To: Rotgans, Trudy SG:EX; kv@ghl.ca; Bob Worden; Paul@Orisconsulting.ca; Grant Newfield; preese@rwa.ca
Cc: Lorna Malone
Subject: Wood Solutions Fair Mid-Rise Panel
Attachments: UAA Mail Signature - Shelley.jpg; CWC WoodWorks Outline Van 09 03 18.doc

Good afternoon!

Please find attached a preliminary outline for the panel discussion at the Wood Solutions Fair. We are looking at a 15 minute presentation from all participants, and then an open panel discussion.
Just a reminder, I will need the following by Friday, March 13, 2009:

1. Brief Bio for introduction, (copied to Lorna and me) 2. CD with PowerPoint presentation

I would like to have them all preloaded on my laptop, prior to the event. Look forward to working with you all! We just completed a similar event last week for UDI, in Vancouver, and it was very successful.
Please review the attached and call me if you have any questions.
Peter Reese from Ramsey Worden will be joining the panel in lieu of Bob.

Best,

Shelley

Urbarts
Architecture * Urban Design

MID-RISE CONSTRUCTION
SUSTAINING WOOD USE IN FUTURE DEVELOPMENT

OUTLINE:

Goal:
To give an overview of the changes to the BC Building Code, from a variety of perspective.

Process:
The moderator will start with intros and then an overview of the project process to date. This will be followed by a brief (15 minute) presentation by Trudy Rotgans outlining the proposed code changes. Paul Dmytriw will follow with the Development perspective, reviewing one of their current projects in Richmond. The remaining participants will each speak to the respective issues and challenges from their particular discipline perspective. (Architectural, Fire and Safety Engineering, Sturctural.)

The session will conclude with an in-depth panel discussion with questions from the floor.

Vancouver: March 18, 2009 **8h30-12h15**

SCHEDULE

INTRODUCTIONS: 8h30-8h45
Moderator to welcome and introduce schedule, and participants, and give brief introduction of the path to the code revisions.

PRESENTATIONS

1. Trudy Rotgans: Building and Safety Policy Branch 8h45 – 9h00
2. Paul Dmytriw, Oris Development: Current Project Overview 9h00 - 9h15
3. Bob Worden: Architectural Perspective 9h15 -9h30

BREAK

4. Khash Vorell, GH Lai Consulting Ltd, Fire Safety 10h00 -10h15
5. Grant Newfield, RJC: Structural Perspective (to be confirmed) 10h15 - 10h30

Canadian Wood Council
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PANEL DISCUSSION:	10H30-11H00
BREAK	11h00-11h15
MODERATOR RECAP:	11h15 – 11h25
PANEL DISCUSSION:	11H25-12H05
MODERATOR WRAP UP:	12H05 – 12H15

PANEL CONTACTS:

MODERATOR

Shelley Craig, MAIBC
Urban Arts Architecture
401 – 134 Abbott St, Vancouver, BC V6B 2K4
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E: craig@urban-arts.ca

PANEL

Trudy Rotgans
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Victoria BC V8W 9R3
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Paul Dmytriw
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Grant Newfield (to be confirmed)
Read Jones Christoffersen
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E: gnewfield@rjc.ca

Jensen, Jun'ichi MEM:EX

From: Helen Griffin [hgriffin@cwc.ca]
Sent: Friday, February 27, 2009 3:43 PM
To: Rotgans, Trudy SG:EX
Subject: Draft Letter to Glenn Gibson For Review
Attachments: Wood Frame Floor Letter (2).pdf; FRR_Wood_Floors_Glen_Gibson_BC_CP_Advisory_Cmtee_Feb_2009.doc

Trudy,
As follow up to our conversation on Monday, attached is the letter from Glenn Gibson (just for reference) and our proposed reply. As discussed, we had thought to put in a reference to the fact that there has been some interaction with the BSPB on the fire ratings. Originally we had thought to say that we had put in a public review comment on this issue but this comment didn't seem as if it furthered the issue very much. Instead, we have crafted a paragraph (2nd paragraph on page 2) that references that the issue was brought up at the BSPB advisory committees on the six-storey. We then say that, in response, we have recently submitted a code change proposal to the BSPB for consideration. I would appreciate it if you could review the letter and, in particular, that paragraph and let me know if you are comfortable with it. If not, perhaps you have a suggestion? I don't want to imply something that you don't feel is correct. We are just trying to respond to the concern raised. As the original letter was copied widely, and so will our response, I want to be comfortable with what is stated.

Rodney sent the draft code change to Roger earlier this week and we will await any feedback on it. I will also put together a letter that identifies other areas that we think you might wish to consider as you move forward.

All the best,
Helen.

February 2, 2009

Helen Griffin
V.P. Codes and Engineering
Canadian Wood Council
99 Bank Street - Suite 400
Ottawa, Ontario
K1P 6B9

RE: FIRE RATINGS FOR WOOD FRAME ASSEMBLIES

Dear Ms. Griffin:

I am writing on behalf of the C.P. Advisory Committee to bring your attention to an issue that is causing difficulty in the specification of wood floors in the Greater Vancouver area and, most likely, the rest of Canada as well. Normally, the C.P. Committee does not seek solutions to technical issues directly, but brings them forward to other professional bodies or task forces. But in this case, the issue is so fundamental to determining code conformance of wood frame building that we have decided to raise it directly with the industry.

SUMMARY OF THE PROBLEM
Minimum one hour rated floors are required in 4 storey wood frame apartment buildings, one of the most common building types in Vancouver and other urban parts of the GVA. This building type is allowed by the BCBC and VBBL under the classification 3.2.2.45. "Group C, up to 4 Storeys, Sprinklered." Wood frame party floors for these buildings are commonly built with the following components:

> 1.5" standard weight concrete topping over a plywood subfloor over dimensional lumber joists, with or without batt insulation in the cavities, with 1 or more layers of g.w.b ceiling, with or without resilient channels.

The problem is: it cannot be demonstrated, without special reports, that the floors commonly used in these buiilding have a 1 hour fire resistance rating, since there is no ULC or UL listing that exactly matches this construction and a 1 hour rating cannot be justified by the use of the additive method in Appendix D.

BACKGROUND
There are a number of factors which have contributed to this problem:

1) Greater scrutiny of references by approval authorities and consultants
2) Lack of testing for locally used assemblies
3) New Table A-9.10.3.1.B is not allowed for us in Part 3 buildings
4) Recent NRC testing reveals errors in common assumptions re: floor components
5) All UL and ULC assemblies are now "Load Restricted for Canadian Applications"

We are aware of the testing program undertaken by the NRC in which the Canadian Wood Council was involved as a partner. This testing program, which resulted in a revised Table A-9.10.3.1.B and the paper "Results of Fire Resistant Tests on Full-Scale Floor Assemblies", has provided much valuable information regarding exactly the kind of information that has been needed. The information can only be used outright, however, in Part 9 buildings. Furthermore, some municipalities even appear reluctant to allow the floor types in the Table to be used when supported by an Alternative Solution proposal. There may be a perception that fire rating information in Part 9 is somehow less reliable than that provided by ULC or other independent testing labs.

SOLUTIONS

There are several actions that can be taken to improve the situation:

1) Testing to ULC S101 of commonly used assemblies
2) Table 9.10.3.1B to be made acceptable for use with Part 3 buildings.
3) Load Restriction issue to be resolved

It is understood that there are several stakeholder groups that will need to be involved in resolving this problem, including the NRC, B.C. Building and Safety Policy Branch, AIBC and APEGBC. It seems to us that the Canadian Wood Council is in a unique position to take a leadership role in resolving this issue, since it affects the ability of wood frame construction to be safe, competitive and consistent across Canada. This is also an issue that should be resolved before advocating wood frame buildings higher than 4 storeys.

SUMMARY

This is an issue that affects designers, approval authorities, contractors, and suppliers. It is taking an inordinate amount of time to determine solutions for common building issues and is resulting in a lack of consistency in the building industry. It does not reflect Canada's image as a world leader in wood frame construction to have such a basic issue be the subject of so much uncertainty and debate. The rating of a floor should be determined by testing, and enough testing should be done so that test results are available for all common floor types. This is an issue that needs immediate attention and action.

Sincerely,

Glenn Gibson, P. Eng., CP: Chairman, C.P. Advisory Committee

cc: Bob Bowen, NRC; Institute for Research in Construction
Bob Thompson, B.C. Building and Safety Policy Branch
Regulatory Coordination Committee, AIBC
Building Code Committee, APEGBC

Canadian Wood Council
Conseil canadien du bois

26th February, 2009

Mr. Glen Gibson, P. Eng., CP
Chairman, C. P. Advisory Committee
xxx
xxxxx
Vancouver, BC xxxxx

Re: Fire Ratings for Wood Frame Assemblies

Dear Mr. Gibson:

Thank you for your letter of February 2nd regarding the important topic of the need for design solutions for specifying fire resistance ratings for wood frame floor assemblies. The CWC is very interested in identifying solutions to this endemic problem.

As you note in your letter, the Canadian Wood Council was a partner with NRC in conducting fire and acoustical research and, in fact, partnered with NRC in not one but two research consortia (Phase I and II), which studied the fire resistance and acoustic performance of light frame floor assemblies between 1995 and 2003. From each phase of that work, a technical research paper was published by NRC.

The results of the fire resistance testing from Phase I are contained in *IRC-IR-764*, the NRC paper you've referenced in your letter. Those results of Phase I were used as a basis for proposed changes to modify the generic fire resistance ratings contained in Table A-9.10.3.1.B of the 1995 NBCC. These proposed changes were formally approved and released as official revisions to the NBCC in the 4th set of *Revisions and Errata*, dated April, 2002 and subsequently are contained in the 2005 NBCC. Many of the design configurations of those assemblies are similar to the one you've described as commonly used in BC.

The results of the fire resistance testing from Phase II, which are contained in the second NRC paper, *IRC-RR-184*, were used as a basis for developing a set of new proposed changes to modify the generic fire resistance ratings currently shown in Table A-9.10.3.1.B of the 2005 NBCC. Just this past November, these proposed changes were included in the public consultation on proposed changes to the 2005 NBCC. Those public comments will be reviewed in April by the NBCC Part 9 Committee.

We are also aware of the fact that, as you've noted, this information on fire resistance ratings of floor assemblies contained in Table A-9.10.3.1.B is not directly applicable to buildings constructed in accordance with Parts 3 & 4 of the NBCC. This is the case, even though the fire tests, which were used to develop the tabulated information, were conducted in accordance with standard fire test method, CAN/ULC S-101, *Fire Endurance Tests of Building Construction and Materials*, which is the fire test standard referenced in Part 3 of the NBCC and required to be used to determine and assign fire resistance ratings to structural materials, assembly of materials or structural members.

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We find interesting the comment that there is possibly a *'...perception that fire rating information in Part 9 is somehow less reliable than that provided by ULC or other independent testing labs."* As noted above, the fire testing conducted by NRC was in accordance with the standard test method required by the NBCC. Also, a comparison of the Part 9 information with that for similar floor assemblies published by test labs, like ULC, shows that in most if not all cases, the assemblies in the Part 9 Tables are assigned lower fire resistance ratings and/or require more or thicker layers of gypsum board protection.

The issue of '*limited availability of code-conforming solutions*' was also raised by experts participating in the *BC Building and Safety Policy Branch* advisory committee discussions regarding the recently approved changes to the BC Building Code for six-storey wood frame construction. In light of that, and since it impacts all types of wood frame buildings designed under Parts 3/4, we recently submitted a code change proposal for consideration to the *BC Building and Safety Policy Branch* proposing changes to Part 3 of the BCBC to include new Tables of fire resistance and sound transmission ratings of wood frame walls and floors for use in Part 3 buildings.

Coincidently, just this past week, the *Canadian Commission on Building and Fire Codes* approved a new work item for the work programme of the *NBCC Standing Committee on Fire Protection* that will look at, amongst others, the possibility of creating a similar Table describing generic fire resistance ratings for light frame assemblies for use in buildings designed in accordance with Part 3 of the NBCC. The CCBFC also approved a new work item for the work programme of the *NBCC Part 4 Standing Committee on Structural Design* that will look at the issue of load restriction factors on wood frame assemblies, which, as you know, only impact the proprietary ratings contained in ULC's listings.

We are hopeful that our efforts both within BC, as well as on the new work items being initiated under the NBCC SC on Fire Protection, will be successful in having a set of 'generic' Tables approved for Part 3 of the BCBC/NBCC. We also are looking further into the question on the ULC load restriction factors and will seek membership on the Part 3/4 Joint Task Group expected to be assigned to the study the issue.

We would be happy to discuss further with you any comments or questions that you may have regarding either the earlier NRC fire research or our work regarding the proposed code changes being considered in BC and similar code issues being worked on at the national code level.

Sincerely,

Helen Griffin, P. Eng.
Vice-President, Codes and Engineering
Canadian Wood Council

cc: Trudy Rotgans, B.C. Building and Safety Policy Branch
Bob Bowen, NRC - Institute for Research in Construction
Bob Thompson, B.C. Building and Safety Policy Branch
Regulatory Coordination Committee, AIBC
Building Code Committee, APEGBC

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From: Helen Griffin [hgriffin@cwc.ca]
Sent: Wednesday, March 11, 2009 11:59 AM
To: Glenn Gibson
Cc: 'bob.bowen@NRC-CNRC.gc.ca'; Thompson, Bob R SG:EX; 'eholt@aibc.ca'; 'lbowser@apeg.bc.ca'; 'Mitchell, Jeff'; 'Mitchell, Jeff'; 'Agren, Soren'; s.22 'dg@ghl.ca'; 'mbruckner@ibigroup.com'; 'Mehran Nazeman \(MRNazeman@city.surrey.bc.ca \)'; s.22 ; 'patrick.shek@burnaby.ca'; s.22 Rotgans, Trudy SG:EX; Rodney McPhee
Subject: RE: Technical Support for 1 hour Wood Frame Floor Assemblies
Attachments: Response_to_Glenn_Gibson_FRR_Wood_Floors.pdf

Dear Glenn,
Please find attached our response to your letter on fire ratings for wood frame assemblies. We have tried to provide you with as current information as possible on work in this area at both the national and provincial levels. Any assistance that the C.P. Advisory Committee can provide in furthering our efforts in this area would, of course, be welcome. If you have any questions or require any further clarification on anything in the letter, please let me know.
Regards,
Helen.

Helen Griffin
V.P., Codes and Engineering
Canadian Wood Council

(800) 463 5091 ext 236
(613) 747 5544 ext 236

From: Glenn Gibson [mailto:ggibson@lmdg.com]
Sent: February-02-09 6:14 PM
To: Helen Griffin
Cc: 'bob.bowen@NRC-CNRC.gc.ca'; 'bob.thompson@gov.bc.ca'; 'eholt@aibc.ca'; 'lbowser@apeg.bc.ca'; 'Mitchell, Jeff'; 'Mitchell, Jeff'; 'Agren, Soren'; 's.22 ; 'dg@ghl.ca'; 'ggibson@lmdg.com'; 'mbruckner@ibigroup.com'; 'Mehran Nazeman \(MRNazeman@city.surrey.bc.ca\)'; s.22 'patrick.shek@burnaby.ca'; s.22
Subject: Technical Support for 1 hour Wood Frame Floor Assemblies

Helen
Please refer to the attached letter regarding the lack of technical information available to support the use of standard wood frame floor assemblies to achieve a 1 hour fire-resistance rating. We believe that it is essential to make available to the building industry typical wood frame floor assemblies that will comply with the 1 hour fire-resistance rating requirements of the building code.

Please let us know your comments and if there is any way we can assist you in this matter.

Glenn A. Gibson, M.Eng., P.Eng., CP
LMDG Building Code Consultants Ltd.
Tel: 604-682-7146
Fax: 604-682-7149

Canadian Wood Council
Conseil canadien du bois

11th March, 2009

Mr. Glen Gibson, P. Eng., CP
Chairman, C. P. Advisory Committee
c/o LMDG Building Code Consultants Ltd.
4th Floor, 780 Beatty Street
Vancouver, BC V6B 2M1

Via E-mail

Re: Fire Ratings for Wood Frame Assemblies

Dear Mr. Gibson:

Thank you for your letter of February 2nd regarding the important topic of the need for design solutions for specifying fire resistance ratings for wood frame floor assemblies. The CWC is very interested in identifying solutions to this endemic problem.

As you note in your letter, the Canadian Wood Council was a partner with NRC in conducting fire and acoustical research and, in fact, partnered with NRC in not one but two research consortia (Phase I and II), which studied the fire resistance and acoustic performance of light frame floor assemblies between 1995 and 2003. From each phase of that work, a technical research paper was published by NRC.

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The results of the fire resistance testing from Phase II, which are contained in the second NRC paper, *IRC-RR-184*, were used as a basis for developing a set of new proposed changes to modify the generic fire resistance ratings currently shown in Table A-9.10.3.1.B of the 2005 NBCC. Just this past November, these proposed changes were included in the public consultation on proposed changes to the 2005 NBCC. Those public comments will be reviewed in April by the NBCC Part 9 Committee.

We are also aware of the fact that, as you've noted, this information on fire resistance ratings of floor assemblies contained in Table A-9.10.3.1.B is not directly applicable to buildings constructed in accordance with Parts 3 & 4 of the NBCC. This is the case, even though the fire tests, which were used to develop the tabulated information, were conducted in accordance with standard fire test method, CAN/ULC S-101, *Fire Endurance Tests of Building Construction and Materials*, which is the fire test standard referenced in Part 3 of the NBCC and required to be used to determine and assign fire resistance ratings to structural materials, assembly of materials or structural members.

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We find interesting the comment in your letter that there is possibly a *"...perception that fire rating information in Part 9 is somehow less reliable than that provided by ULC or other independent testing labs."* As noted above, the fire testing conducted by NRC was in accordance with the standard test method required by the NBCC. Also, a comparison of the Part 9 information with that for similar floor assemblies published by test labs, like ULC, shows that in most if not all cases, the assemblies in the Part 9 Tables are assigned lower fire resistance ratings and/or require more or thicker layers of gypsum board protection.

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Coincidently, just a few weeks ago, the *Canadian Commission on Building and Fire Codes* (CCBFC) approved a new work item for the work programme of the *NBCC Standing Committee on Fire Protection* that will look at, amongst others, the possibility of creating a similar Table describing generic fire resistance ratings for light frame assemblies for use in buildings designed in accordance with Part 3 of the NBCC. The CCBFC also approved a new work item for the work programme of the *NBCC Part 4 Standing Committee on Structural Design* that will look at the issue of load restriction factors on wood frame assemblies, which, as you know, only impact the proprietary ratings contained in ULC's listings.

We are hopeful that our efforts both within BC, as well as on the new work items being initiated under the NBCC SC on Fire Protection, will be successful in having a set of 'generic' Tables approved for Part 3 of the BCBC/NBCC. We also are looking further into the question on the ULC load restriction factors and will seek membership on the Part 3/4 Joint Task Group expected to be assigned to the study the issue.

We would be happy to discuss further with you any comments or questions that you may have regarding either the earlier NRC fire research or our work regarding the proposed code changes being considered in BC and similar code issues being worked on at the national code level.

Sincerely,

Helen Griffin, P. Eng.
Vice-President, Codes and Engineering
Canadian Wood Council

cc: Trudy Rotgans, B.C. Building and Safety Policy Branch
Bob Bowen, NRC - Institute for Research in Construction
Bob Thompson, B.C. Building and Safety Policy Branch
Regulatory Coordination Committee, AIBC
Building Code Committee, APEGBC

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Jensen, Jun'ichi MEM:EX

Non-Responsive

-----Original Message-----
From: Chun Ni [mailto:Chun.Ni@fpinnovations.ca]
Sent: Tuesday, February 24, 2009 9:42 AM
To: Kuan, Steven Y HSD:EX
Subject: 6-storey wood report

Hi Steven,

Attached is the complete interim report. I am still waiting for the design of NEESWood building. I have a business trip to Japan, Korea and China from Mar 15 - April 4. Given the available time, we may not have enough time to complete the dynamic analysis of the NEESWood building by Mar 15th.

Regards,

Chun

FPInnovations – Forintek Division
Western Region
2665 East Mall
Vancouver, British Columbia V6T 1W5

Confidential

SCC Accredited LAB
LAB Accrédité CCN

Seismic Performance of 6-Storey Wood-Frame Buildings

by

Chun Ni and Marjan Popovski

Prepared for
Building and Safety Policy Branch
Office of Housing and Construction Standards
Ministry of Housing and Social Development
PO Box 9844 Stn Prov Govt
Victoria, BC V8W 9T2

February 2009

Project No. 6482

Chun Ni	Bill Deacon	Erol Karacabeyli
Project Leader	Reviewer	Department Manager

Summary

In this report, the seismic performance of a representative 4-storey and a 6-storey wood-frame building are studied. The building, which was based on a floor plan of a existing 4-storey building in the Arbutus Gardens neighborhood in Vancouver, was re-designed by the design consultants in accordance with 2006 BCBC, as well as with 2010 NBCC and 2009 CSA O86.1.

Computer programs DRAIN 3-D and SAPWood were used to evaluate the seismic performance of the buildings. A series of 20 different earthquake records, 14 of them of crustal type and 6 of subcrustal type, were provided by the Earthquake Engineering Research Facility of the University of British Columbia and used in the evaluation. The records were chosen to fit the 2005 NBCC mean PSA and PSV spectrum for city of Vancouver.

For buildings designed in accordance with 2006 BCBC, the seismic performance with and without gypsum wall board (GWB) is studied. Buildings with GWB represent performance of an actual building where GWB is used in partition walls and on the other side of the shearwalls. Ignorance of GWB in partition walls and GWB on the other side of the shearwalls would result in a conservative estimate of the seismic performance of the building.

In 2005 NBCC and 2006 BCBC, the inter-story drift limit is set at 0.025 of the storey height for the very rare earthquake event (1 in 2500 year return period). Limiting inter-story drift is a key parameter for meeting the objective of live safety under a seismic event.

Results show that for both 4-storey and 6-storey wood-frame buildings where only wood-based shearwalls are considered, none of the maximum inter-storey drifts at any storey under any individual earthquake exceed the 2.5% inter-storey drift limit given in the building code. The average maximum inter-storey drifts are approximately 1% and 1.3% for 4-storey and 6-storey buildings, respectively.

For 6-storey building, the distributions of maximum inter-storey drifts at 1st to 3rd storey are similar to those in 4-storey building. The maximum inter-storey drifts at 4th to 6th storeys are greater than those at 1st to 3rd storeys. However, the maximum shearwall deformations at 1st to 3rd storeys in 6-storey building are generally smaller than those in 4-storey building. For the 6-storey building, the largest shearwall deformations occurred at the 5th storey, are similar to those at the 1st story in 4-storey building.

Based on the analyses that were carried out on a representative building situated in the city of Vancouver, the results indicate that when subjected to the 20 earthquake records the 6-storey wood-frame building achieved similar safety level as the 4-storey wood-frame building which is allowed under the current building code and is used as a benchmark in this study.

Acknowledgements

The financial support by the Building and Safety Policy Branch (BSPB) of the Office of Housing and Construction Standards (OHCS) for this project is gratefully acknowledged. We are grateful to the Earthquake Engineering Research Facility of the University of British Columbia for providing the earthquake records suited for the city of Vancouver used in this study.

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1 Objectives

Main objective of the work contained in this report is to evaluate the seismic performance of six-storey wood-frame buildings designed according to the proposed changes in the BC Building Code and the capacity-based design philosophy implemented in the upcoming Canadian Standard for Engineering Design in Wood (CSA O86.1 2009), as well as the next edition of the National Building Code of Canada (NBCC 2010).

2 Introduction

Mid-rise multi-family buildings are within reach of the current technology in wood-frame construction and offer a way to diversify the markets for Canadian wood products. Recently, the Government of BC has expressed interest in the concept of mid-rise wood-frame buildings as a response to the shift towards sustainable densification of urban and suburban centers and to the need for affordable housing. As a result, the Ministry of Housing and Social Development is pursuing regulatory changes to increase the limit on wood-frame construction to six storeys in the BC Building Code.

To prepare for such code revisions, the Building and Safety Policy Branch (BSPB) of the Office of Housing and Construction Standards (OHCS) has engaged consultants to work on developing the required changes to the BC Building Code and to scope out technical and process risks related to six-storey wood-frame construction. Technical advisory groups comprising of a wide range of building sector stakeholders were formed to help identify potential relevant issues related to six-storey wood buildings and to help develop appropriate mitigation and implementation strategies. Based on the reported specific issues and the initial feedback from the technical advisory groups, potential technical impediments and implementation issues related to introduction of six-storey wood-frame buildings in BC were identified. These include fire safety, structural safety (in particular the seismic performance), wood shrinkage, and building envelope integrity. FPInnovations staff has been involved in these technical advisory groups and continue to participate in the stakeholders meetings.

As the demand for higher density housing in BC tends to be in areas with high seismic risk, one of the paramount concerns to designers of six-storey wood-frame construction is the seismic performance of such buildings. To address these concerns, FPInnovations' staff under contract with BSPB carried out a study to assess the performance of six-storey wood-frame buildings in earthquake prone areas. This results of this study that are presented in this report, will not only provide the technical support for the proposed code change, but will also help increase the confidence of the designers and stakeholders in the seismic performance of mid-rise wood-frame construction.

3 Scope

A multi-year research program funded by the US National Science Foundation, called the NEESWood project is currently underway in the US. The project team consists of leading US researchers in the field of seismic performance of wood buildings. Under this program, a series of shake table tests on a six-storey wood-frame structure will be carried out in Japan during the summer of 2009.

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FPInnovations' Forintek Division (Forintek) is one of the contributors to the technical expertise in this research program under financial contributions from the Government of Canada and the Province of BC. A Memorandum of Understanding covering these contributions between Forintek and NEESWood principals has been signed.

The work presented in this report utilises the knowledge, expertise, test data, and numerical tools developed under the NEESWood project for assessing the seismic behaviour of wood-frame buildings and applies them for assessment of 6-storey wood-frame construction (WFC) buildings in BC. The scope of the work consists of a series of non-linear dynamic analyses performed on six different buildings (three 4-storey and three 6-storey) as shown in the table bellow:

No. of Storeys	A representative WFC building, designed with BCBC 2006	A representative WFC building, designed with NBCC 2010 and O86.1-2009	NEESWood test building, designed with NBCC 2010 and O86.1-2009
4	▪ Design by RJC ▪ Assess by Forintek ▪ Check by CSU	▪ Design by RJC ▪ Assess by Forintek ▪ Check by CSU	▪ Design by RJC ▪ Assess by Forintek ▪ Check by CSU
6	▪ Design by RJC ▪ Assess by Forintek ▪ Check by CSU	▪ Design by RJC ▪ Assess by Forintek ▪ Check by CSU	▪ Design by RJC ▪ Assess by Forintek ▪ Check by CSU

4 Project Team

- Dr. Chun Ni, P.Eng, project leader, FPInnovations Forintek Division
- Mr. Grant Newfield, P.Eng, Read Jones Christoffersen Ltd. (RJC)
- Dr. John van de Lindt, P.E., Colorado State University (CSU)
- Mr. Maurizio Follesa, Timber Engineering, Italy
- Dr. Marjan Popovski, P.Eng, FPInnovations Forintek Division
- Mr. Erol Karacabeyli, P.Eng, FPInnovations Forintek Division

5 Seismic Design of the Representative Buildings

A 4-storey building built as a part of Arbutus Gardens neighbourhood on Arbutus Street in Vancouver was used as a representative WFC building in this study (Figure 1). In the original design, sections 2 and 3 of the building (Figure 1) were assumed to be separate units and were analyzed separately. Each section was designed with enough strength to carry the seismic loads associated with its own area.

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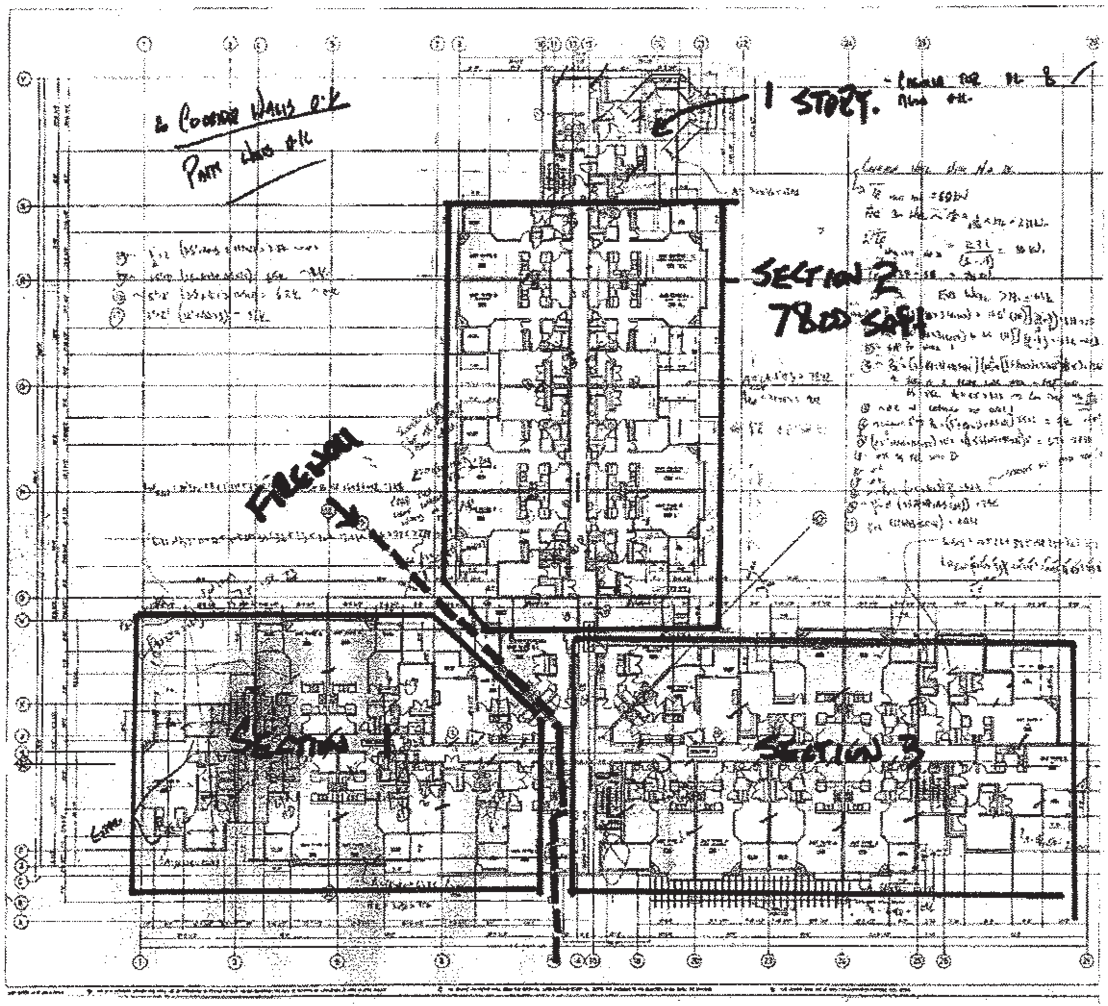

Figure 1 Plan view of the representative building

In discussion with RJC, it was decided that only section 2 of this building is used in this study. Although buildings could be more simple or more complex in practice, it was believed that the section 2 of the building is a reasonable portion of it, and can be seen as being a good representative of the current construction practice. The section 2 of the building includes a double loaded corridor where all the corridor and party walls are used as shearwalls.

In the design, it was assumed that the building is located in Vancouver on a site with soil class C according to NBCC. Instead of using the NBCC formula, the fundamental lateral period was determined based on actual mass and stiffness of wood-based shearwalls. This period was then used to determine the minimum equivalent static earthquake force applied on the building. The dead load at roof and each floor of the building is provided in Table 1. Details of the shearwalls in 4 and 6-storey buildings designed in accordance with BCBC 2006 and NBCC 2010 are provided in Tables 2 and 3. The design drawings of the 4 and 6-storey buildings are provided in Appendix A.

Table 1 ***Dead loads used in the design of the 4 and 6-storey buildings***

	Uniformly distributed load (kPa)	Area (m^2)	Total load (kN)
Roof (dead load + 25% snow load)	1.20	919.74	1103.7
Floor (dead load)	1.92	789.68	1516.2

Table 2 ***Details of the Wood-frame building designed in accordance with BCBC 2006***

		6-storey building				4-storey building			
		SW 1	SW 2	SW 3	SW 4	SW 1	SW 2	SW 3	SW 4
6th storey	Hold-down	SR9	SR5	SR5	SR5				
	End stud	6-2x4	4-2x4	4-2x4	4-2x4				
	sheathing	12.5 mm	12.5 mm	12.5 mm	12.5 mm				
	Nail	8d	8d	8d	8d				
	Nail spacing	150 mm	150 mm	150 mm	150 mm				
5th storey	Hold-down	SR9	SR5	SR5	SR5				
	End stud	6-2x4	4-2x4	4-2x4	4-2x4				
	sheathing	12.5 mm	12.5 mm	12.5 mm	12.5 mm				
	Nail	8d	8d	8d	8d				
	Nail spacing	150 mm	150 mm	150 mm	150 mm				
4th storey	Hold-down	SR9	SR5	SR5	SR5	SR5	SR5	SR5	SR5
	End stud	6-2x4	6-2x4	6-2x4	6-2x4	4-2x4	4-2x4	4-2x4	4-2x4
	sheathing	12.5 mm	12.5 mm	12.5 mm	12.5 mm	9.5 mm	9.5 mm	9.5 mm	9.5 mm
	Nail	8d	8d	8d	8d	8d	8d	8d	8d
	Nail spacing	100 mm	75 mm	100 mm	100 mm	150 mm	150 mm	150 mm	150 mm
3rd storey	Hold-down	SR10	SR7	SR7	SR7	SR7	SR5	SR5	SR5
	End stud	8-2x4	8-2x4	6-2x4	8-2x4	4-2x4	4-2x4	4-2x4	4-2x4
	sheathing	12.5 mm	12.5 mm	12.5 mm	12.5 mm	9.5 mm	9.5 mm	9.5 mm	9.5 mm
	Nail	8d	10d	8d	8d	8d	8d	8d	8d
	Nail spacing	100 mm	75 mm	100 mm	75 mm	150 mm	100 mm	150 mm	150 mm
2nd storey	Hold-down	SR10	SR9	SR7	SR9	SR9	SR7	SR5	SR5
	End stud	8-2x4	8-2x4	8-2x4	8-2x4	6-2x4	6-2x4	6-2x4	6-2x4
	sheathing	12.5 mm	12.5 mm	12.5 mm	12.5 mm	9.5 mm	9.5 mm	9.5 mm	9.5 mm
	Nail	8d	10d	8d	8d	8d	8d	8d	8d
	Nail spacing	75 mm	75 mm	75 mm	65 mm	100 mm	75 mm	100 mm	100 mm
1st storey	Hold-down	SR10	SR9	SR9	SR9	SR9	SR7	SR7	SR7
	End stud	8-2x4	8-2x6	8-2x4	8-2x6	6-2x4	6-2x4	6-2x4	6-2x4
	sheathing	12.5 mm	12.5 mm	12.5 mm	12.5 mm	9.5 mm	12.5 mm	9.5 mm	9.5 mm
	Nail	8d	10d	8d	8d	8d	8d	8d	8d
	Nail spacing	75 mm	65 mm	75 mm	65 mm	100 mm	75 mm	100 mm	100 mm

Table 3 Details of the Wood-frame building designed in accordance with NBCC 2010

		6-storey building				4-storey building			
		SW 1	SW 2	SW 3	SW 4	SW 1	SW 2	SW 3	SW 4
6th storey	Hold-down	SR9	SR5	SR5	SR5				
	End stud	6-2x4	4-2x4	4-2x4	4-2x4				
	sheathing	12.5 mm	12.5 mm	12.5 mm	12.5 mm				
	Nail	8d	8d	8d	8d				
	Nail spacing	150 mm	150 mm	150 mm	150 mm				
5th storey	Hold-down	SR9	SR5	SR5	SR5				
	End stud	6-2x4	4-2x4	4-2x4	4-2x4				
	sheathing	12.5 mm	12.5 mm	12.5 mm	12.5 mm				
	Nail	8d	8d	8d	8d				
	Nail spacing	150 mm	150 mm	150 mm	150 mm				
4th storey	Hold-down	SR9	SR7 [1]	SR5	SR7 [1]	SR5	SR5	SR5	SR5
	End stud	6-2x4	6-2x4	6-2x4	6-2x4	4-2x4	4-2x4	4-2x4	4-2x4
	sheathing	12.5 mm	12.5 mm	12.5 mm	12.5 mm	9.5 mm	9.5 mm	9.5 mm	9.5 mm
	Nail	8d	8d	8d	8d	8d	8d	8d	8d
	Nail spacing	100 mm	75 mm	100 mm	100 mm	150 mm	150 mm	150 mm	150 mm
3rd storey	Hold-down	SR10	SR7	SR7	SR7	SR7	SR5	SR5	SR5
	End stud	8-2x4	8-2x4	6-2x4	8-2x4	4-2x4	4-2x4	4-2x4	4-2x4
	sheathing	12.5 mm	12.5 mm	12.5 mm	12.5 mm	9.5 mm	9.5 mm	9.5 mm	9.5 mm
	Nail	8d	10d	8d	8d	8d	8d	8d	8d
	Nail spacing	100 mm	75 mm	100 mm	75 mm	150 mm	100 mm	150 mm	150 mm
2nd storey	Hold-down	SR10	SR9	SR7	SR9	SR9	SR7	SR7 [1]	SR7 [1]
	End stud	8-2x4	8-2x4	8-2x4	8-2x4	6-2x4	6-2x4	6-2x4	6-2x4
	sheathing	12.5 mm	12.5 mm	12.5 mm	12.5 mm	9.5 mm	9.5 mm	9.5 mm	9.5 mm
	Nail	8d	10d	8d	8d	8d	8d	8d	8d
	Nail spacing	75 mm	75 mm	75 mm	65 mm	100 mm	75 mm	100 mm	100 mm
1st storey	Hold-down	SR10	HSR9 [1]	SR9	HSR9 [1]	SR9	SR7	SR7	SR7
	End stud	8-2x4	8-2x6	8-2x4	8-2x6	6-2x4	6-2x4	6-2x4	6-2x4
	sheathing	12.5 mm	12.5 mm	12.5 mm	12.5 mm	9.5 mm	12.5 mm	9.5 mm	9.5 mm
	Nail	8d	10d	8d	8d	8d	8d	8d	8d
	Nail spacing	75 mm	65 mm	75 mm	65 mm	100 mm	75 mm	100 mm	100 mm

Note [1] – indicates difference between BCBC 2006 and NBCC 2010.

6 Earthquakes used in Analyses

A series of 20 different earthquake records were provided by the Earthquake Engineering Research Facility of the University of British Columbia and used in the evaluation (Table 4). Earthquake records for two types of earthquakes expected for the city of Vancouver were considered: crustal (shallow) and subcrustal (deep) earthquakes. The first 14 records in Table 4 correspond to crustal earthquakes, while the remaining 6 correspond to subcrustal ones.

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Table 4 Earthquake records and their characteristics

Earthquake Record Characteristics						
No.	Epicenter	Date	Magnitude	Record ID	SF [1]	PGA [2] (g)
1	San Fernando	9-Feb-1971	6.6	VAN_I_4	1.26	0.34
2	Friuli, Italy-01	6-May-1976	6.5	VAN_I_12	1.02	0.32
3	Gazli, USSR	17-May-1976	6.8	VAN_I_14	0.72	0.52
4	Tabas, Iran	16-Sep-1978	7.4	VAN_I_16	1.23	0.50
5	Imperial Valley-06	15-Oct-1979	6.5	VAN_I_18	1.25	0.20
6	Irpinia, Italy-01	23-Nov-1980	6.9	VAN_I_24	1.21	0.22
7	Nahanni, Canada	23-Dec-1985	6.8	VAN_I_26	1.22	0.39
8	New Zealand-02	2-Mar-1987	6.6	VAN_I_30	1.45	0.49
9	Loma Prieta	18-Oct-1989	6.9	VAN_I_45	0.92	0.17
10	Landers	28-Jun-1992	7.3	VAN_I_63	0.76	0.21
11	Northridge-01	17-Jan-1994	6.7	VAN_I_76	1.02	0.19
12	Manjil, Iran	20-Jun-1990	7.4	VAN_I_137	1.01	0.52
13	Hector Mine	16-Oct-1999	7.1	VAN_I_139	1.01	0.27
14	E. Honshu, Japan	13-Jun-2008	6.8	VAN_I_158	1.05	0.77
15	Nisqually, WA	28-Feb-2001	6.8	VAN_II_8	1.53	0.25
16	Nisqually, WA	28-Feb-2001	6.8	VAN_II_25	1.69	0.18
17	Nisqually, WA	28-Feb-2001	6.8	VAN_II_27	1.74	0.19
18	Michoacan, Mexico	11-Jan-1997	7.1	VAN_II_48	1.43	0.50
19	S. Honshu, Japan	24-Mar-2001	6.4	VAN_II_53	1.70	0.60
20	S. Honshu, Japan	24-Mar-2001	6.4	VAN_II_70	1.84	0.48

Note: [1] SF = Scaling Factor for Vancouver
[2] PGA = Peak Ground Acceleration (after the scaling)

All records were chosen to satisfy the seismic parameters for a locality such as Vancouver according to the 2005 NBCC. Records were scaled to match the average spectral pseudo-velocity, S_v, of the Uniform Hazard Spectrum (UHS) in NBCC 2005 between the period range of 0.5 and 1.5 s. This was deemed to be the period range in which the structures will be oscillating for the most time of their response. The S_v spectra were computed from the velocity spectra for a 5% damping of each record. A scaling factor, SF, given by the ratio between the average spectral pseudo-velocity of NBCC UHS spectrum within the period range and the average Sv of each record in that period range, was obtained for each record. Each record was than scaled using this SF factor for use in analyses. The pseudo velocity and acceleration response spectra for all of these records compared to the Vancouver design spectrum are shown in Figures 2 and 3. Besides satisfying the NBCC requirements for acceleration, the chosen records had different frequency characteristics throughout the spectrum.

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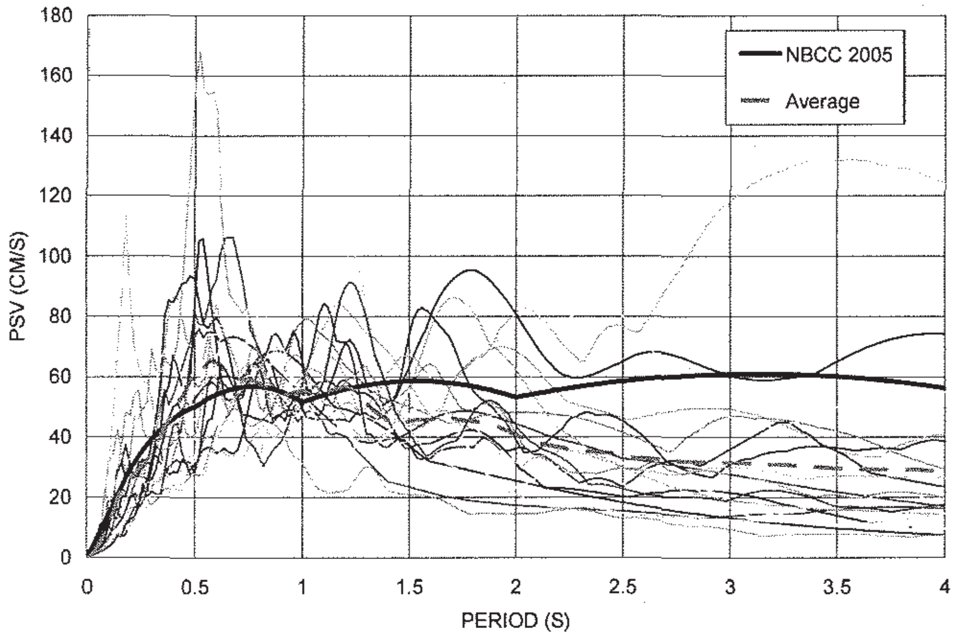

Figure 2 The pseudo velocity response spectra for all records, their average and the 2005NBCC velocity design spectrum for Vancouver

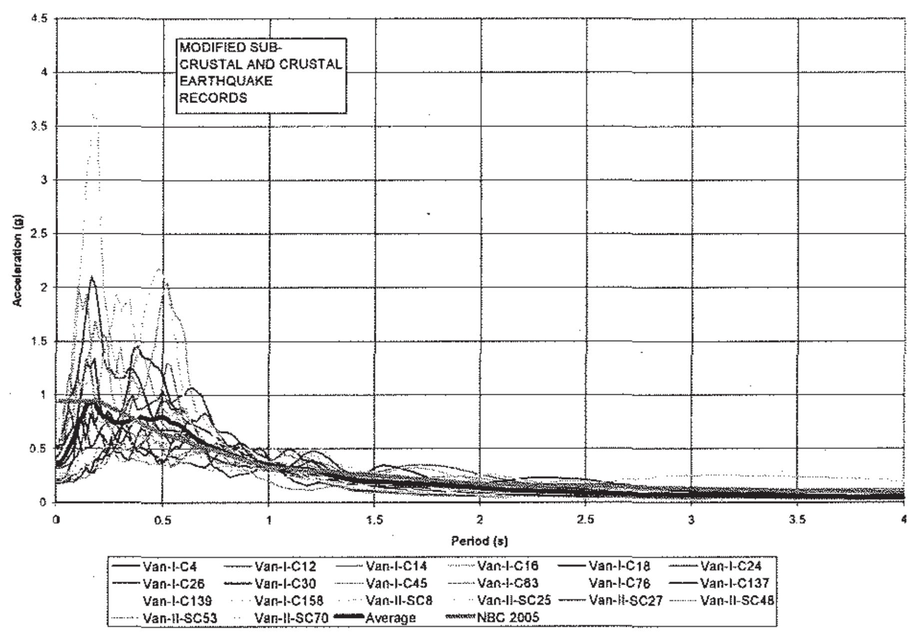

Figure 3 The acceleration response spectra for all records, their average and the 2005 NBCC acceleration design spectrum for Vancouver

7 Seismic Analysis of the Buildings

The seismic analysis of the buildings has been independently carried out by Forintek and Colorado State University (CSU). Computer programs Drain-3D and SAPWood were used by Forintek and CSU, respectively. Both computer programs have been validated with shake table tests of CUREE 2-storey wood-frame buildings and are been used in the prediction of shake table tests of NEESWood 6-storey wood-frame building in Japan during the summer of 2009.

In this section, the following information used in the analysis is provided: a) building modelling, b) shearwall properties, c) hold-down and bearing properties, and d) length and locations of shearwalls. To allow for the comparison of numerical results, the same shearwall properties were used in Forintek and CSU seismic analyses.

7.1 Building Modeling

7.1.1 Drain-3D

Drain-3D is a general structural analysis program. The program contains certain number of inelastic elements to describe the inelastic behavior of concrete and steel structural elements. A pinching hysteresis model, as shown in Figure 4, was developed at the University of Florence (Ceccotti and Vignoli 1989) and was then implemented in Drain-3D for modelling of wood shearwalls.

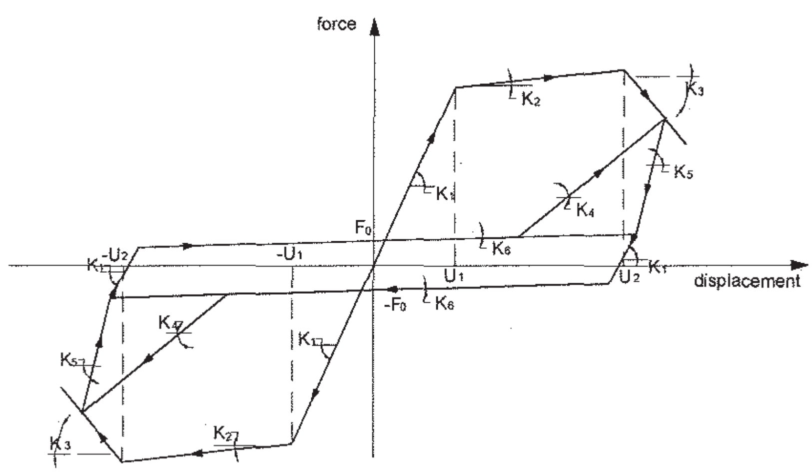

Figure 4 Pinching histeretic behaviour with six inclinations and constant discharge line used for modeling of the semi-rigid rotational springs

The building was modeled with a 3-D space frame composed of rigid straight members. In the model, each shearwall was considered as a fictitious rectangular frame that consists of four straight rigid elements that is able to deform in shear only. Shear deformation in this frame was represented by four identical rotational springs at each corner of the frame. Parameters of the pinching hysteresis model for the shearwalls were developed by fitting to the force–displacement relationship obtained from reversed cyclic tests of the shearwalls, or from fitting hysteresis loops developed analytically using computer programs that generate such loops based on the nail-slip connection properties.

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Figure 5 shows a schematic of the model of the 6-storey building in Drain-3D. In the model, each shear wall is connected to the foundation or to the floor below by means of translational springs to represent hold-downs (Figure 6). The translational spring is composed of two parallel elements, one working only in tension with an elastic-perfectly plastic behaviour to represent the properties of the steel rod, and the other working only in compression with elastic behaviour to represent the bearing properties of the top and bottom plates.

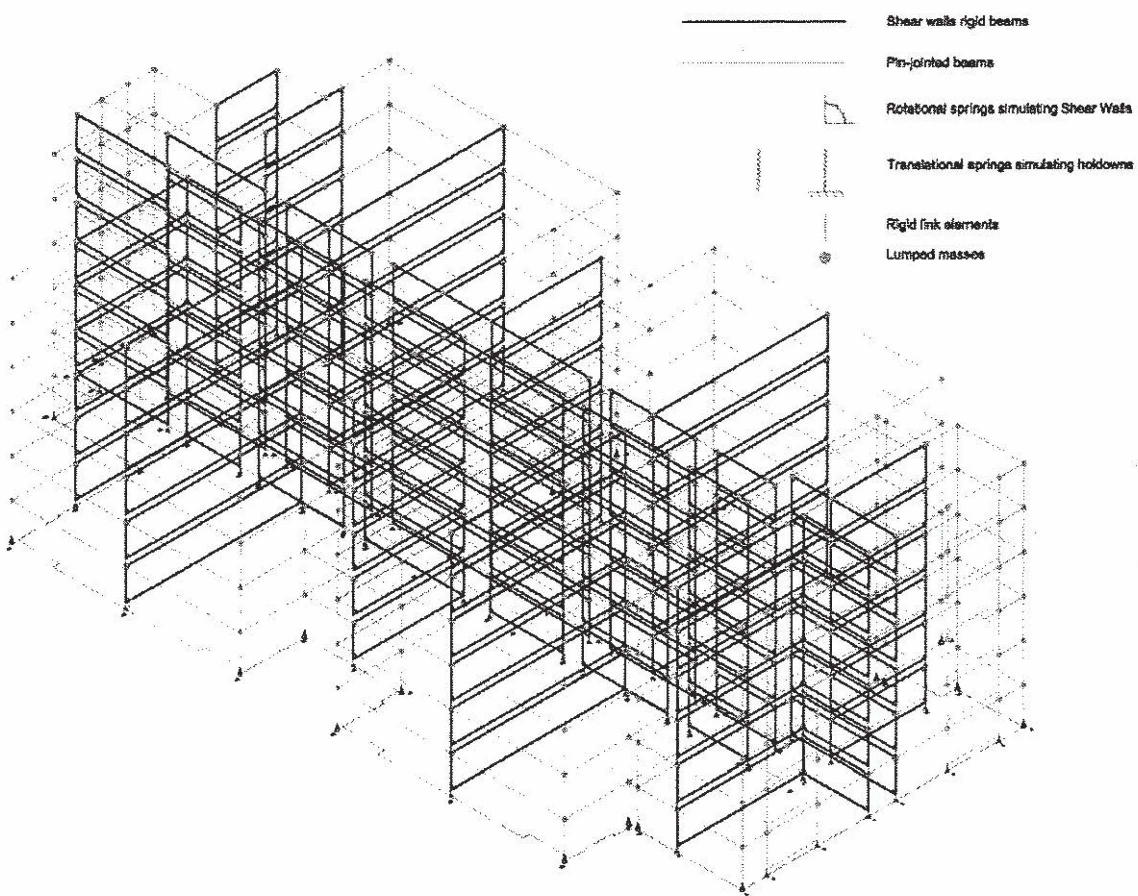

Figure 5 Model of the 6-storey wood-frame building in Drain-3D

At each floor, the top nodes of the shearwalls below that floor and the bottom nodes of shearwalls above that floor have identical (slaved) coordinates. The seismic mass at each storey is equally distributed to all nodes of the floor. Floors were modeled as rigid diaphragms with equivalent cross bracings simulated by rigid pin-jointed linear elements. For the dynamic analyses a 1% stiffness and mass proportional damping ratio was used.

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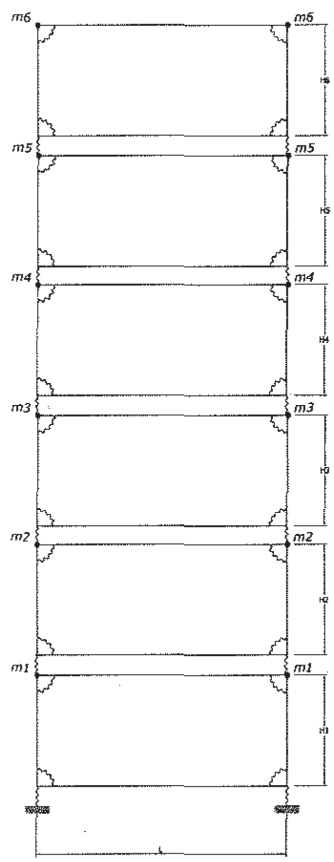

Figure 6 Stacked shearwall assembly model of a 6 storey building with rotational semi-rigid springs and semi rigid axial springs to represent the properties of the hold-downs

7.1.2 SAPWood

The numerical model used in the analyses with SAPWood program was a shear-bending coupled type of nonlinear model specifically designed for analysis of mid-rise wood-frame structures (Pei & van de Lindt, 2008). The model has six degrees of freedom at each storey diaphragm, while each diaphragm is assumed to act as a rigid body in the analyses. The kinematics of the model are illustrated in Figure 7. All lateral or vertical stiffness components (shearwalls, hold-downs, and compression studs.) are represented as nonlinear (or hysteretic) springs connecting point P_i and P_j on the adjacent diaphragms.

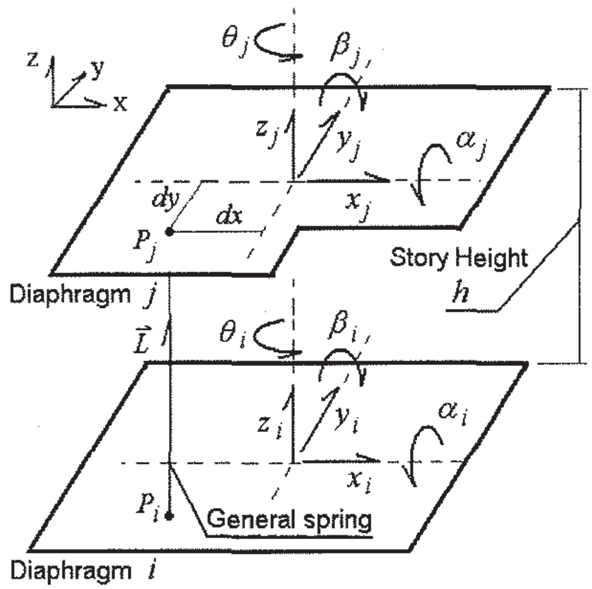

Figure 7 Global degrees of freedom and spring connectivity in the SAPWood model

This formulation allows the model to develop rigid body rotation for the entire storey level without inducing shear deformations. The seismic mass of the building was lumped onto the storey diaphragm, which induces seismic excitation during the ground motion. The dynamic loads cause the diaphragm layers to rotate and translate, while they are held together as a structural system by the nonlinear springs (representing shearwalls, hold-downs, etc.). It should be noted that these nonlinear springs are updated at each time step during the time history integration according to their load-resistance characteristics. This model has been implemented in the analyses of wood-frame buildings and stacked shearwall assemblies and produced good results.

The behavior of the structures modeled using this method depends largely on the hysteretic spring elements used to represent the shearwall components. While the hysteretic elements for shearwalls can be obtained by testing the walls cyclically, it is not always possible to have all different walls in the building subjected to a reversed-cyclic test. Instead, cyclic tests on typical nail-sheathing-stud connections can be performed and a computer program can be used to develop shearwall hysteretic responses based on nail connection responses. The model used to generate such hysteresis curves for the shearwalls in this analysis was the Nail-Pattern (NP) module of the SAPWood program. In the SAPWood-NP model, every framing member and sheathing panel is considered as a component of the assembly system. Each component is assumed to be a rigid body which has three in-plane degrees of freedom. The kinematics assumptions for the SAPWood-NP model are illustrated in Figure 8. These components were connected with nails that were modeled with hysteretic spring elements calibrated from existing nail test data.

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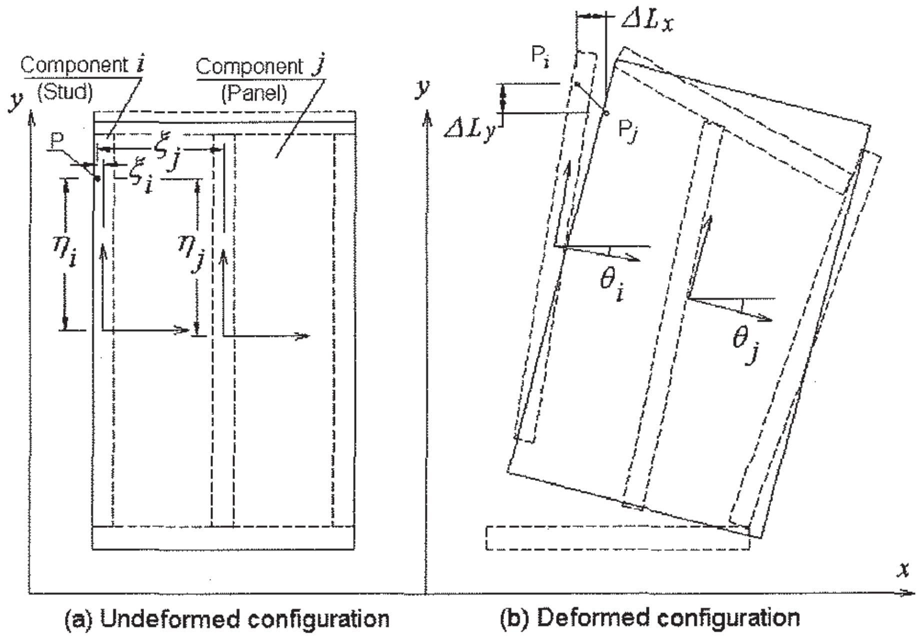

Figure 8 Nail-Pattern (NP) model kinematics

Once the model was established, cyclic displacement protocols can be applied incrementally to the transverse degrees of freedom (DOFs) of the top plate while the bottom plate DOFs are fixed. The displacement of other DOFs are then solved at every displacement step. The resulting force on the top plate undergoing forced deformation is obtained through equilibrium.

An existing 10 parameter hysteretic model used in a number of studies (Folz and Filiatrault, 2004) was used for this analysis. It is a single degree-of-freedom (SDOF) hysteretic model that defines the restoring force response of a wood shearwall under reversed cyclic loading by using exponential backbone curves and linear loading and unloading paths. Ten hysteretic parameters are used to define the loading paths in the CUREE model, which is illustrated in Figure 9. The CUREE model has been shown to be accurate for nail and shearwall behavior and was felt to be suitable for this analysis.

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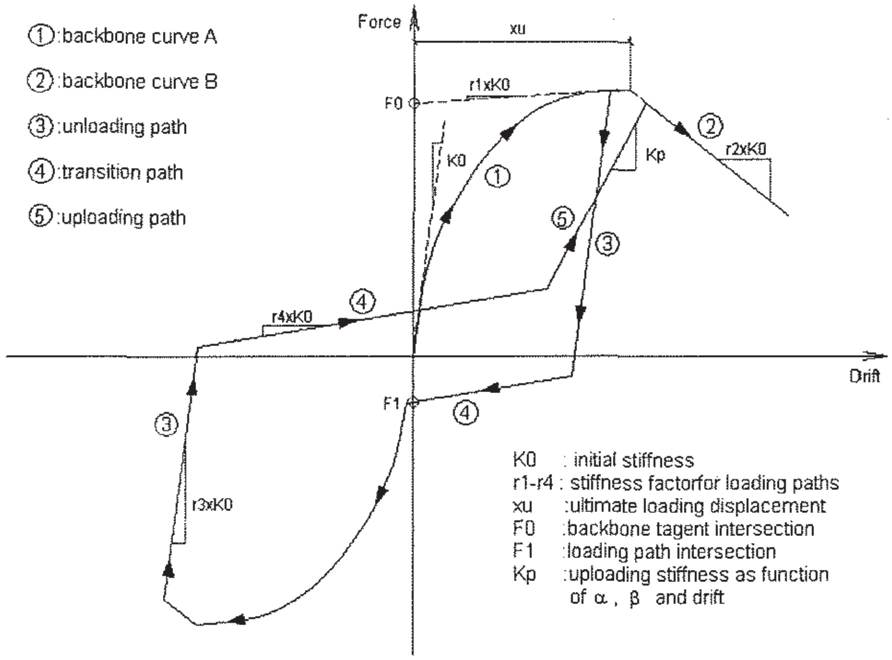

Figure 9 Loading paths and parameters in CUREE model

7.2 Shearwall Properties

7.2.1 Wood-based shearwalls

The hysteresis loops of shearwalls sheathed with plywood were constructed using the SAPWood-NP module. For shearwalls with 8d nails, cyclic tests of nail joints consisting of 8d nail and 9.5 mm and 12.7 mm plywood panels were used to generate the hysteresis loops of the shearwalls. Since the test results of nail joints consisting of 10d nail and 9.5 mm and 12.7 mm plywood panels were not available, the hysteresis loops of shearwalls with 10d nails were assumed to be those of shearwalls with 8d nails, with the load scaled up by a factor which is the ratio of the shear capacity of 10d nail joint to the shear capacity of 8d nail joint.

For shearwalls sheathed with gypsum wallboard (GWB), the average hysteresis loops were calibrated from a group of GWB wall tests (Folz and Filiatrault, 2002; Karacabeyli and Ceccotti, 1996; Ceccotti and Karacabeyli 2002).

Figures 10 to 13 show the hysteresis loops of shearwalls sheathed with plywood and gypsum wallboard. For shearwalls sheathed with plywood on one side and GWB on the other side, it is assumed that the hysteresis loops of the shearwalls sheathed with plywood and gypsum wallboard can be superimposed. The numbers in the legend of the Figures 10 to 13 indicate the nail spacing around the perimeter of the panel vs the nail spacing at the intermediate studs in inches.

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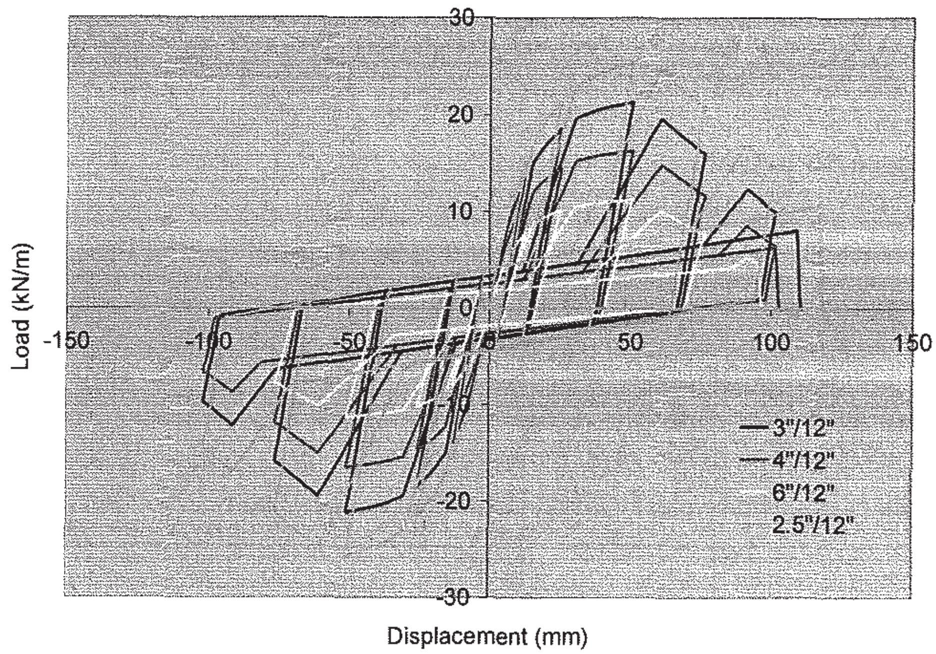

Figure 10 Hysteretic loop for 8d-3/8" ply 4ft x 8ft shearwalls

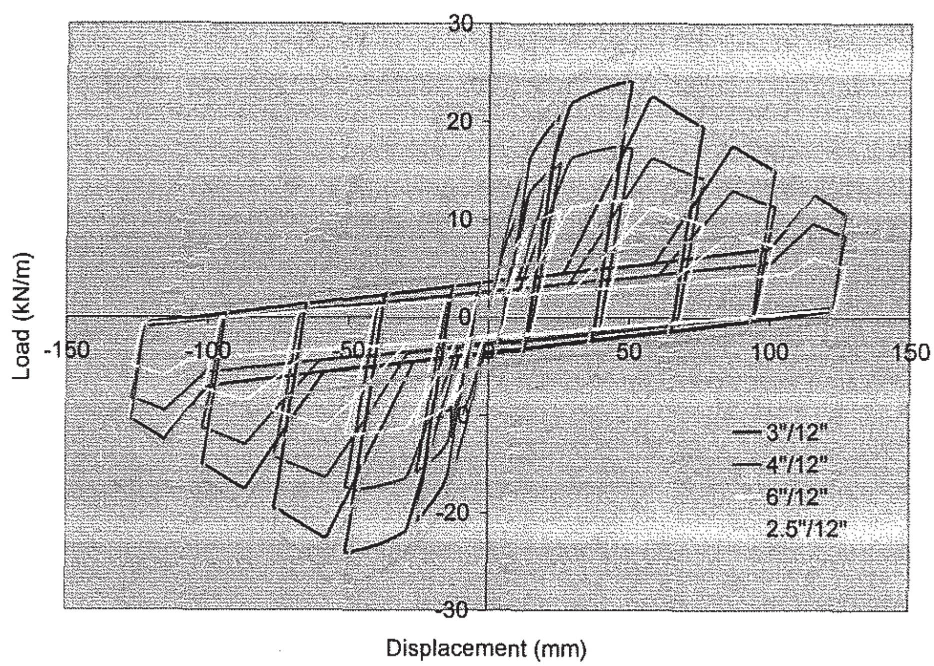

Figure 11 Hysteretic loop for 8d-1/2" ply 4ft x 8ft shearwalls

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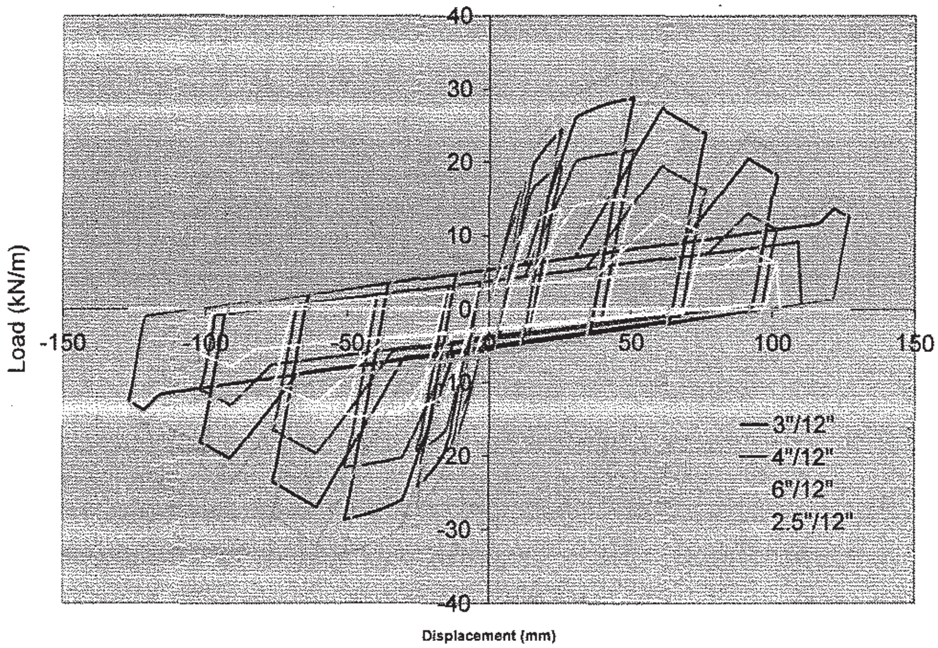

Figure 12 Hysteretic loop for 10d-1/2" ply 4ft x 8ft shearwalls

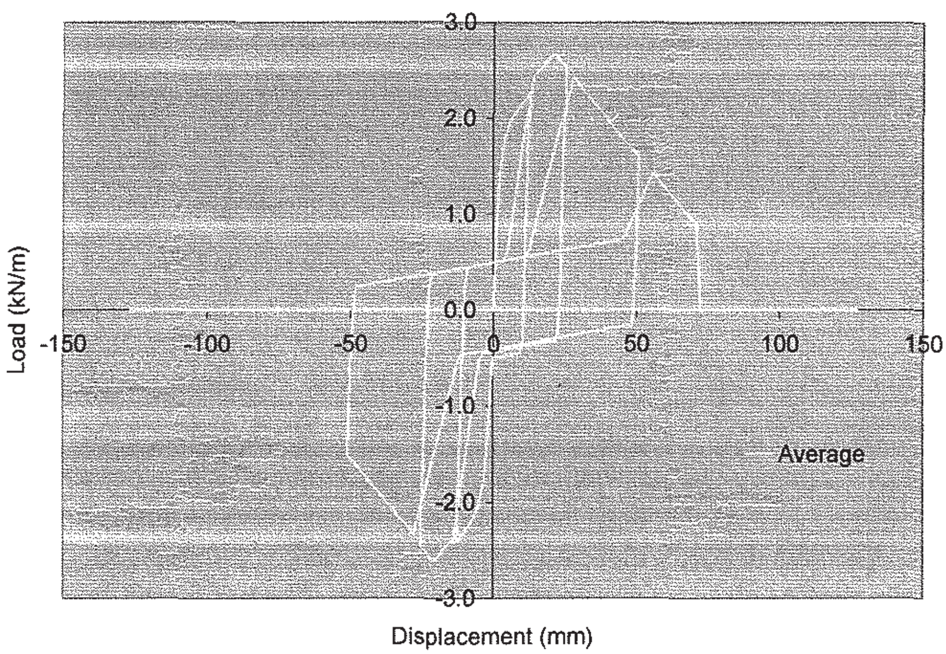

Figure 13 Hysteretic loop for 8ft x 8ft GWB drywall

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7.3 Hold-down and Plate Bearing Properties

Table 5 lists the diameter, Young's modulus, yield strength and ultimate strength of Simpson strong rods. The steel rods were modeled as an elastic-perfectly plastic nonlinear spring elements. The stiffness and yield strength of the spring elements used to represent the steel rods were calculated as follows:

$K = E * A / l$
$F_y = A * f_y$

Where
E – Young's modulus
A – the cross-section of the steel rod
l – the storey height
f_y – the yield strength of the steel rod

Table 5 Material properties of different models of Simpson strong rods

Model No.	Diameter (mm)	Young's modulus (Mpa)	Yield strength (kPa)		Ultimate strength (kPa)	
			(kPa)	(kN)	(kPa)	(kN)
SR5	15.9 (5/8 in.)	200000	296500	58.66	413700	81.84
SR7	22.2 (7/8 in.)	200000	296500	114.97	413700	160.41
SR9	28.6 (1-1/8 in.)	200000	296500	190.05	413700	265.17
HSR9	28.6 (1-1/8 in.)	200000	634300	406.57	827400	530.34
SR10	31.7 (1-1/4 in.)	200000	296500	234.63	413700	327.37

The modulus of elasticity of compression perpendicular to grain for Douglas-fir was taken as 490 Mpa. The plate bearing was modeled as elastic spring element. The stiffness of the spring was calculated as follows:

$K = E * A / l,$

Where
E – elasticity of compression perpendicular to grain
A – cross-section of end studs
l – the thickness of bottom and top plates

7.4 Lengths and Locations of Shearwalls

Shearwalls sheathed with plywood are indicated in the design drawings in Appendix A. For partition walls sheathed with GWB, only the major wall lines were considered. The lateral resistance of door, windows, and transverse walls was not considered in the model. The shearwalls that have been included in the building model are listed as follows:

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Shearwalls in E-W direction

Axis line T:
10' S.W.1, GWB on one side and plywood on the other side

Axis line S:
23' S.W.3 (on the West side), GWB on one side and plywood on the other side
14' S.W.1 (on the East side), GWB on one side and plywood on the other side

Partition walls between axis lines S and R:
23' drywalls with GBW on both sides of the wall (on the West side),
14' drywalls with GBW on both sides of the wall (on the East side),

Axis line R:
32' S.W.3 (on the West side), GWB on one side and plywood on the other side
32' S.W.3 (on the East side), GWB on one side and plywood on the other side

Two partition walls between axis lines R and Q:
23' drywalls with GBW on both sides of the wall (on the West side),
23' drywalls with GBW on both sides of the wall (on the East side),

Axis line Q:
20' S.W.2 (on the West side), GWB on one side and plywood on the other side
20' S.W.2 (on the East side), GWB on one side and plywood on the other side

Two partition walls between axis lines Q and P:
23' drywalls with GBW on both sides of the wall (on the West side),
23' drywalls with GBW on both sides of the wall (on the East side),

Axis line P:
32' S.W.3 (on the West side), GWB on one side and plywood on the other side
32' S.W.3 (on the East side), GWB on one side and plywood on the other side

Two partition walls between axis lines P and O:
23' drywalls with GBW on both sides of the wall (on the West side),
23' drywalls with GBW on both sides of the wall (on the East side),

Axis line O:
22' S.W.3 (on the West side), GWB on one side and plywood on the other side
22' S.W.3 (on the East side), GWB on one side and plywood on the other side

Shearwalls in N-S direction

Axis line 13:
11' + 12' + 15' + 12' + 17' + 15' + 9' + 16' S.W.4, GWB on one side and plywood on the other side

Axis line 15:
19' + 10' + 15' + 18' + 18' + 15' + 17' S.W.4, GWB on one side and plywood on the other side

Schematic of locations of the shearwalls sheathed with wood-based panels are shown in Figure 14. For buildings designed in accordance with 2006 BCBC, seismic performance of buildings without GWB was also studied. Ignorance of GWB in partition walls and GWB on the other side of the shearwalls results in a conservative estimate of the seismic performance of the building.

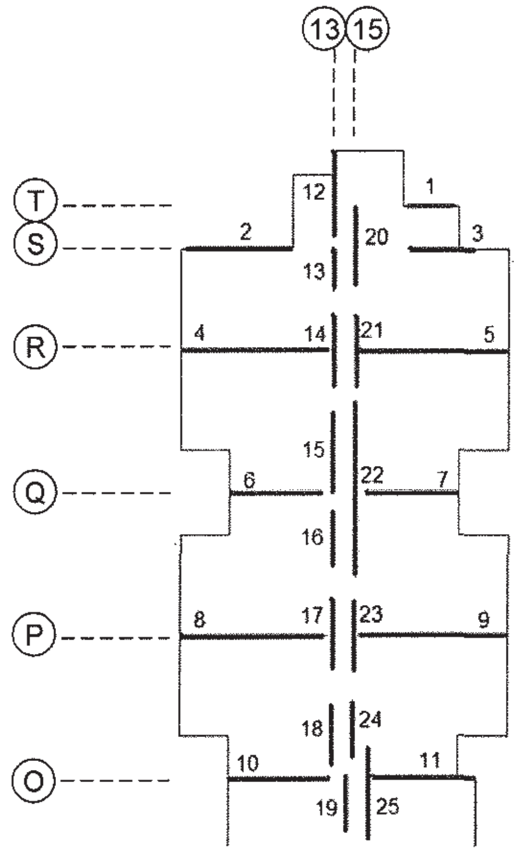

Figure 14 Shearwall identification and location used in this study

8 Results of Non-linear Time History Analyses

For each building analysed, the following results are provided: a) natural frequency; b) maximum base shear; c), maximum displacement and acceleration at each storey; d) maximum inter-storey drift; e) maximum shearwall deformation at each storey; and f) maximum uplift forces and deformations. Detailed results of a representative building designed in accordance with BCBC 2006 and NBCC 2010 are provided in Appendix B and C, respectively. The results of NEESWood building designed in accordance with BCBC 2006 are provided in Appendix D. Selected time history responses and hysteresis loops of selected shearwalls are provided in Appendix E.

Summary of the results of a representative 4-storey and 6-storey buildings designed in accordance with BCBC 2006 are provided in Tables 6 and 7. In general, it was found that for the same buildings, Drain-3D results show higher natural periods, greater base shear, larger maximum displacements and inter-

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storey drifts than results obtained with the Sapwood model. For that reason, results from the Drain-3D model will be used for discussion in this section.

Table 6 Summary of mean results of 4-storey building designed in accordance with BCBC 2006

4-storey building			Drain-3D				Sapwood			
			E-W		N-S		E-W		N-S	
Natural period (s)	With GWB		0.54		0.68		0.52			
	Without GWB		0.73		0.78		0.64			
Base shear (kN)	With GWB		1351		1037		959		845	
	Without GWB		981		893		951		832	
Storey →			1	2	3	4	1	2	3	4
Displacement (mm)	With GWB	E-W	28.7	45.6	59.5	66.4	17.5	32.2	43.3	47.3
		N-S	25.8	49.6	75.2	94.0	23.0	40.9	58.3	63.4
	Without GWB	E-W	28.8	46.3	72.3	80.2	21.5	40.9	60.8	70.5
		N-S	29.0	52.9	81.7	103.4	27.3	45.3	66.9	74.0
Inter-storey drift (%)	With GWB	E-W	1.04	0.64	0.57	0.29	0.64	0.57	0.46	0.19
		N-S	0.94	0.91	0.99	0.74	0.84	0.73	0.77	0.26
	Without GWB	E-W	1.05	0.70	1.08	0.39	0.83	0.74	0.76	0.26
		N-S	1.05	0.96	1.17	0.88	0.83	0.74	0.76	0.26
Shearwall deformation, (mm)	With GWB	E-W	27.5	15.5	12.9	5.0	na	na	na	na
		N-S	21.8	16.1	15.3	7.5	na	na	na	na
	Without GWB	E-W	28.2	18.2	28.4	9.0	na	na	na	na
		N-S	25.8	18.9	22.1	13.5	na	na	na	na
Uplift force (kN)	With GWB	E-W	48.4	27.5	10.4	5.1	53.7	28.9	22.3	11.1
		N-S	85.7	54.7	31.8	13.3	15.4	8.5	8.5	5.4
	Without GWB	E-W	6.4	1.9	0.6	0.7	53.7	28.9	22.3	11.1
		N-S	74.6	51.1	29.3	14.7	15.4	8.5	8.5	5.4
Uplift deformation (mm)	With GWB	E-W	1.69	1.75	0.65	0.11	1.90	2.01	1.55	0.77
		N-S	3.04	4.67	2.21	0.92	0.54	0.59	0.59	0.37
	Without GWB	E-W	0.23	0.14	0.04	0.05	1.90	2.01	1.55	0.77
		N-S	2.65	3.60	2.03	1.02	0.54	0.59	0.59	0.37

Note: For Drain-3D, the results of walls 4 and 25 are presented in E-W and N-S, respectively.
For Sapwood, the uplift forces in the table are based on Method A (please refer to section 8.6 for explanation).

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Table 7 Summary of mean results of 6-storey building designed in accordance with BCBC 2006

6-storey Building			Drain-3D						Sapwood					
			E-W			N-S			E-W			N-S		
Natural period (s)	With GWB		0.78			0.96			0.66					
	Without GWB		0.99			1.07			0.89					
Base shear (kN)	With GWB		1665			1559			995			943		
	Without GWB		1410			1435			1065			1018		
Storey →			1	2	3	4	5	6	1	2	3	4	5	6
Displacement (mm)	With GWB	E-W	18.6	35.5	59.1	76.4	92.8	103.2	13.7	26.3	39.0	49.3	58.0	62.0
		N-S	23.0	43.4	64.5	92.6	124.3	150.8	18.6	33.8	46.9	59.1	72.2	76.2
	Without GWB	E-W	25.2	42.8	70.1	86.9	108.6	119.0	17.9	33.2	48.9	62.4	75.9	83.1
		N-S	23.8	44.2	64.3	89.8	122.4	149.2	19.8	36.8	51.1	66.4	81.1	86.8
Inter-storey drift (%)	With GWB	E-W	0.68	0.63	0.91	0.67	0.65	0.40	0.50	0.50	0.52	0.44	0.37	0.18
		N-S	0.84	0.77	0.87	1.16	1.34	1.05	0.68	0.61	0.58	0.62	0.67	0.24
	Without GWB	E-W	0.91	0.67	1.13	0.71	1.11	0.44	0.50	0.50	0.52	0.44	0.37	0.18
		N-S	0.87	0.78	0.82	1.19	1.49	1.12	0.50	0.50	0.52	0.44	0.37	0.18
Shear wall deformation, (mm)	With GWB	E-W	17.0	14.2	20.7	13.0	11.9	4.7	na	na	na	na	na	na
		N-S	19.1	13.3	11.4	14.8	16.5	7.8	na	na	na	na	na	na
	Without GWB	E-W	24.1	16.6	28.6	16.5	27.5	8.4	na	na	na	na	na	na
		N-S	20.3	14.6	12.4	18.5	24.6	14.4	na	na	na	na	na	na
Uplift force (kN)	With GWB	E-W	111.0	80.7	53.8	29.9	11.3	1.5	95.0	58.1	57.5	36.4	25.0	12.3
		N-S	148.9	115.7	85.5	54.8	32.1	11.0	28.9	26.6	16.8	11.4	8.2	4.5
	Without GWB	E-W	53.6	34.0	17.2	5.4	3.0	0.8	95.0	58.1	57.5	36.4	25.0	12.3
		N-S	136.6	101.4	74.9	51.6	30.7	14.1	28.9	26.6	16.8	11.4	8.2	4.5
Uplift deformation (mm)	With GWB	E-W	2.38	2.86	1.91	2.08	0.79	0.11	2.03	2.05	2.03	2.53	1.73	0.85
		N-S	3.88	2.49	3.03	4.99	2.23	0.77	0.62	0.57	0.59	0.79	0.57	0.31
	Without GWB	E-W	1.15	1.21	0.61	0.37	0.21	0.06	2.03	2.05	2.03	2.53	1.73	0.85
		N-S	3.06	2.18	2.66	3.93	2.13	0.98	0.62	0.57	0.59	0.79	0.57	0.31

Note: For Drain-3D, the results of walls 4 and 25 are presented in E-W and N-S, respectively.
For Sapwood, the uplift forces in the table are based on Method A (please refer to section 8.6 for explanation).

8.1 Natural Periods

For the buildings analyzed, the natural period of the 4-storey building is approximately 0.5 - 0.6 seconds when GWB is considered in the analysis. The natural period of the same building becomes 0.6 - 0.8 seconds when only wood-based shear walls are considered. For 6-storey building, the natural period is approximately 0.6 - 0.9 seconds when GWB is considered and 0.9 - 1.1 seconds when only wood-based shear walls are considered. For both buildings, the natural periods are much greater than those calculated by the Code formula $0.05(h_n)^{3/4}$, according to which, the natural periods of the 4-storey and 6-storey buildings are 0.3 seconds and 0.41 seconds, respectively.

8.2 Base Shear

For the 4-storey building with GWB considered, the average base shears are 1351 kN in E-W direction and 1037 kN in N-S direction, which are 65% of the lateral load capacity of the first story in E-W direction and 83% of the lateral load capacity of the first story in N-S direction. When only the wood-based shearwalls are considered, the average base shears are 72% of the lateral load capacity of the first story in E-W direction and 84% of the lateral load capacity of the first story in N-S direction.

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For the 6-storey building with GWB considered, the average base shears are 1665 kN in E-W direction and 1559 kN in N-S direction, which are 61% of the lateral load capacity of the first story in E-W direction and 79% of the lateral load capacity of the first story in N-S direction. For the same building with only wood-based shearwalls considered, the average base shears are approximately 71% of the lateral load capacity of the first story in E-W direction and 80% of the lateral load capacity of the first story in N-S direction.

8.3 Displacement at the Top of the Buildings

For the 4-storey buildings with GWB considered, the average maximum displacements at the top of the building are approximately 67 mm in E-W direction and 94 mm in N-S direction. Where GWB is not considered, the average maximum displacements at the top of the building are slightly increased, with 80 mm in E-W direction and 103 mm in N-S direction.

For the 6-storey buildings with GWB considered, the average maximum displacements at the top of the building are 103 mm in E-W direction and 151 mm in N-S direction. For the same building with only wood-based shearwalls considered, the average maximum displacements at the top of the building are 119 mm in E-W direction and 149 mm in N-S direction.

8.4 Inter-storey drifts

For 4-storey building when GWB is considered, the average maximum inter-storey drift, which occurs in the first storey, is approximately 1%. This is much smaller than the 2.5% maximum inter-storey drift allowed in BCBC 2006. In addition, none of the maximum inter-storey drifts at any storey under any individual earthquake exceed 2.5% inter-storey limit. For 4-storey building when only wood-based shearwalls are considered, the average maximum inter-storey drift, which occurs in the third storey, is approximately 1.2%. Similarly, none of the maximum inter-storey drifts at any storey under any individual earthquake exceed the 2.5% inter-storey drift limit.

The same conclusions can be made for the 6-storey building. The average maximum inter-storey drifts, which occur at the fifth storey, are approximately 1.3% for building with GWB considered and 1.5% for building with only wood-based shearwalls considered. None of the maximum inter-storey drifts at any storey under any earthquake excitation exceed the 2.5% inter-storey limit.

Figures 15 and 16 show the cumulative distributions of maximum inter-storey drifts at each storey from the Drain-3D model. As noticed, the distribution of maximum inter-storey drifts at 1 - 3 storey in 6-storey building are similar to that in the 4-storey building. For 6-storey building, the maximum inter-storey drifts at 4 - 6 storey are much greater than those obtained at 1 - 3 storey.

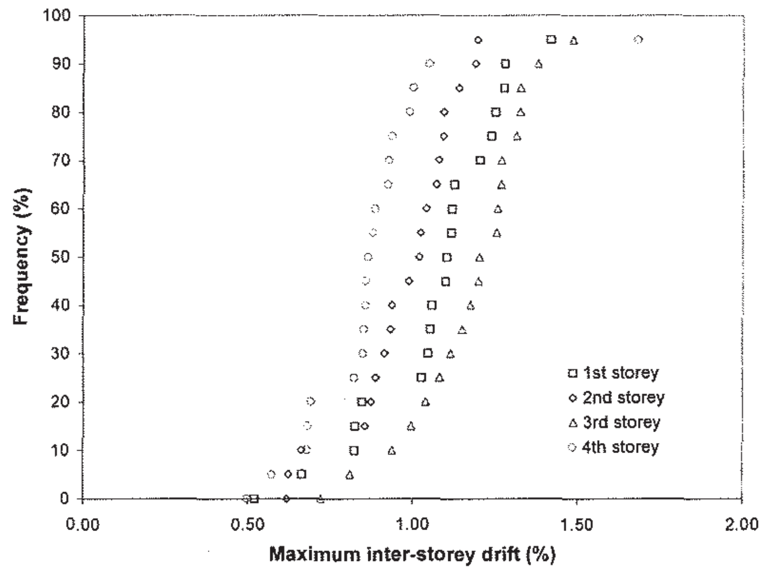

Figure 15 Cumulative distribution of inter-storey drifts for 4-storey buildings without GWB

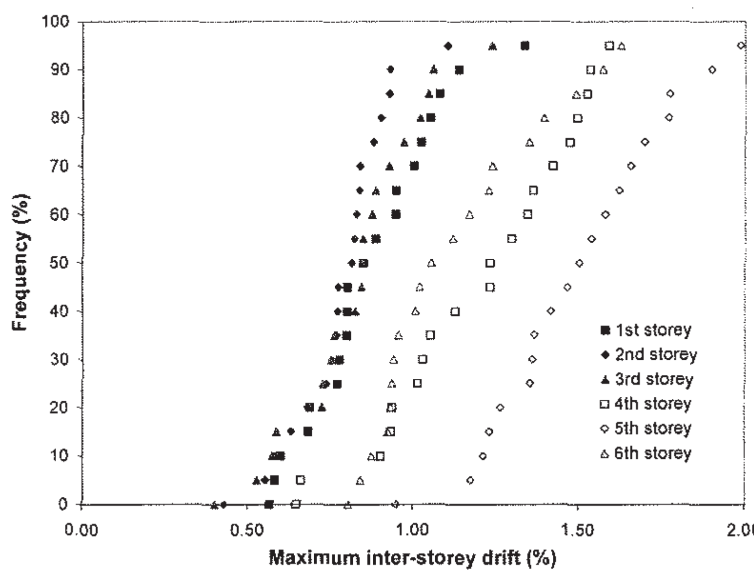

Figure 16 Cumulative distribution of inter-storey drifts for 6-storey buildings without GWB

8.5 Shearwall deformations

Figures 17 and 18 show the cumulative distributions of the maximum shearwall deformation at each storey from Drain-3D. As noticed, the maximum shearwall deformation at 1 - 3 storey in 6-storey building are generally smaller than that in 4-storey building. For the 6-storey building, the largest

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shearwall deformations occurred at the 5th storey. Except the one which is 43 mm, the shearwall deformations at the 5th storey are similar to those at the 1st story in the 4-storey building.

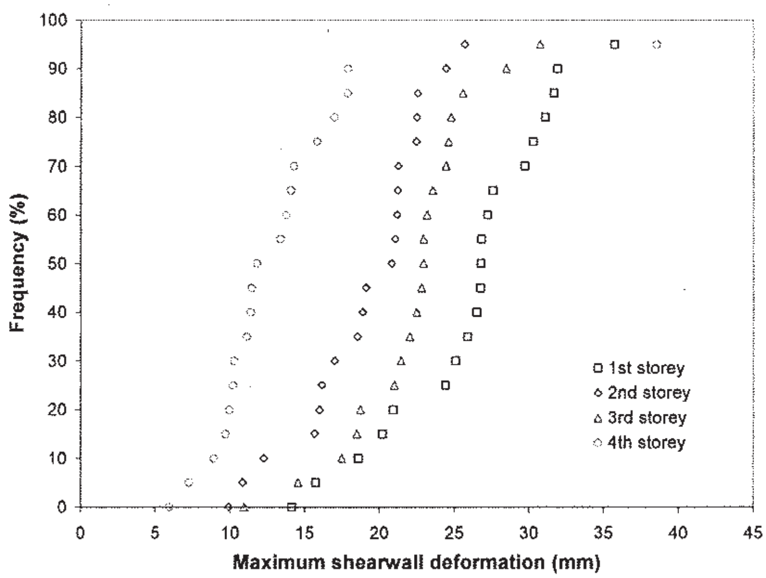

Figure 17 Cumulative distribution of shearwall deformations for 4-storey buildings without GWB

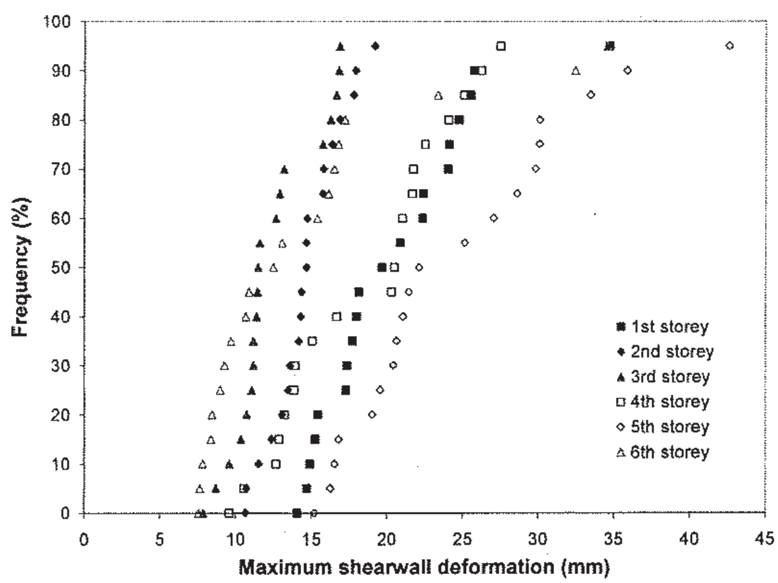

Figure 18 Cumulative distribution of shearwall deformations for 6-storey buildings without GWB

8.6 Hold-down Uplift Forces and Deformations

Large discrepancies were found between the results from Drain-3D and SAPWood. While hold-down stresses calculated by SAPWood did not reach the yield strength of the steel rods, hold-down stresses calculated by Drain-3D reached yield strength in N-S direction in several instances. The differences are believed mainly due to the assumptions used in the analyses. In Drain-3D, it is assumed that a) lumped mass at each storey is equally distributed to the nodes of the floor, and b) floor out-of-plane is flexible.

In SAPWood two methods are used to calculate the maximum tension and compression forces of shearwalls. The first method (termed hereafter as method A) uses the maximum force values (tension and compression) experienced by the hold-down and the compression spring elements directly. The second method (termed hereafter as method B) takes the maximum shear force in each wall element and uses the free-body-diagram equilibrium (illustrated in Figure 19b) to find the tension and compression at each end. Method A considers the over-turning effect of the entire building (as is shown in Figure 19a), thus resulting in high tension/compression forces in the hold-downs and studs close to the edge of the diaphragm. It has been proven to be accurate when the global out-of-plane rotation of the entire diaphragm is significant (Pei and van de Lindt, 2008). However, it does not take into account the out-of-plane flexibility of the diaphragm, i.e. it assumes that the diaphragm will rotate as a rigid plate. Thus it might underestimate the forces for the shearwalls located near the center of the floor plan. On the other hand, method B calculates the tension/compression for each wall individually following basic force equilibrium with no consideration of the overall (global) behavior of the diaphragm. This is the approach used in current force-based design practice such as IBC (2006) to calculate the hold-down forces. It is believed that the maximum hold-down/stud forces in reality are bounded by these two methods.

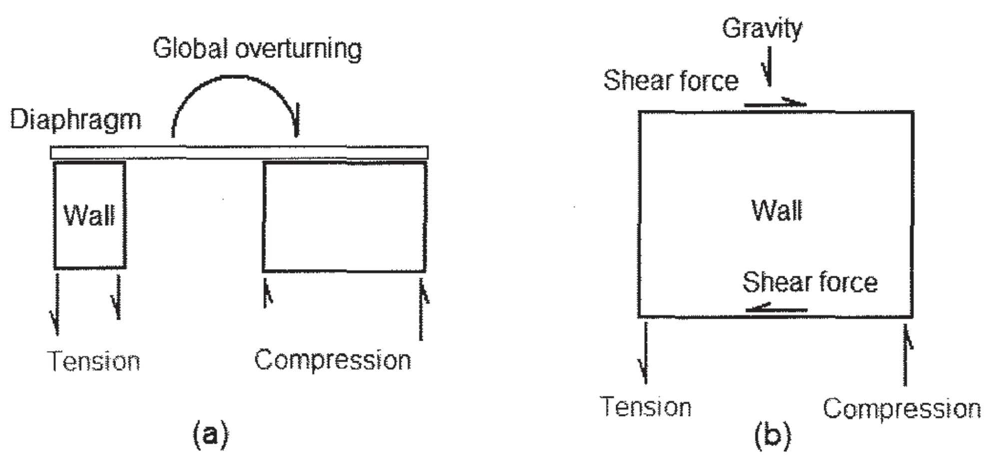

Figure 19 Force equilibrium assumptions for Method A and B

Summary of the results of a representative 4-storey and 6-storey building designed in accordance with NBCC 2010 are provided in Tables 8 and 9. The results are similar to those of 4-storey and 6-storey buildings designed in accordance with BCBC 2006. This was expected, as except for a few hold-downs, shearwalls in 4-storey and 6-storey buildings designed in accordance with BCBC 2006 and NBCC 2010 are identical. Therefore, observations and conclusions for the buildings designed in accordance with BCBC 2006 also apply to the buildings designed in accordance to NBCC 2010.

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Table 8 ***Summary of mean results of 4-storey building designed in accordance with NBCC 2010***

4-storey building with GWB		Drain-3D				Sapwood			
		E-W		N-S		E-W		N-S	
Natural period (s)		0.54		0.68		0.52			
Base shear (kN)		1351		1053		938		842	
Storey →		1	2	3	4	1	2	3	4
Displacement (mm)	E-W	28.6	45.5	59.4	66.2	17.6	32.2	43.5	47.5
	N-S	28.0	50.9	75.1	91.3	22.8	40.9	58.3	63.5
Inter-storey drift (%)	E-W	1.04	0.64	0.57	0.28	0.64	0.57	0.47	0.18
	N-S	1.02	0.86	0.94	0.65	0.83	0.74	0.76	0.26
Shearwall deformation, (mm)	E-W	27.4	15.7	13.1	5.0	na	na	na	na
	N-S	23.9	16.7	16.0	7.2	na	na	na	na
Uplift force (kN)	E-W	48.4	27.5	10.4	5.1	53.2	38.8	22.1	11.3
	N-S	88.4	58.8	31.8	12.7	15.5	12.2	8.5	5.5
Uplift deformation (mm)	E-W	1.71	0.93	0.66	0.11	1.88	1.37	1.53	0.78
	N-S	3.14	2.09	2.21	0.88	0.55	0.43	0.59	0.38

Note: For Drain-3D, the results of walls 4 and 25 are presented in E-W and N-S, respectively.
For Sapwood, the uplift forces in the table are based on Method A.

Table 9 ***Summary of mean results of 6-storey building designed in accordance with NBCC 2010***

6-storey building with GWB		Drain-3D						Sapwood					
		E-W			N-S			E-W			N-S		
Natural period (s)		0.78			0.96			0.66					
Base shear (kN)		1665			1583			987			938		
Storey →		1	2	3	4	5	6	1	2	3	4	5	6
Displacement (mm)	E-W	18.6	35.5	58.5	76.4	92.8	103.1	18.6	33.8	46.9	59.1	72.2	76.2
	N-S	23.4	44.1	67.0	95.4	127.6	152.4	13.8	26.4	39.0	49.4	58.1	62.0
Inter-storey drift (%)	E-W	0.68	0.63	0.92	0.67	0.65	0.40	0.50	0.50	0.52	0.43	0.38	0.17
	N-S	0.87	0.89	1.10	1.42	1.74	1.52	0.68	0.61	0.58	0.62	0.66	0.23
Shear wall deformation (mm)	E-W	17.0	14.2	20.8	13.1	11.9	4.7	na	na	na	na	na	na
	N-S	20.0	13.7	13.2	16.7	19.0	8.0	na	na	na	na	na	na
Uplift force (kN)	E-W	110.9	80.6	53.7	29.6	11.2	1.7	94.7	56.5	56.6	26.4	24.3	11.6
	N-S	162.0	124.0	89.8	63.2	34.8	13.1	27.8	25.7	15.9	15.1	7.9	4.3
Uplift deformation (mm)	E-W	2.38	2.86	1.90	2.05	0.78	0.11	2.03	2.00	2.00	1.83	1.69	0.81
	N-S	3.47	2.65	3.50	2.32	2.40	0.90	0.59	0.55	0.56	0.53	0.55	0.30

Note: For Drain-3D, the results of walls 4 and 25 are presented in E-W and N-S, respectively.
For Sapwood, the uplift forces in the table are based on Method A.

9 Conclusions

In 2005 NBCC and 2006 BCBC, the inter-story drift limit is set at 0.025 of the storey height for the very rare earthquake event (1 in 2500 year return period). Limiting inter-story drift is a key parameter for meeting the objective of live safety under a seismic event.

Results show that for both 4-storey and 6-storey wood-frame buildings where only wood-based shearwalls are considered, none of the maximum inter-storey drifts at any storey under any individual earthquake exceed the 2.5% inter-storey drift limit given in the building code. The average maximum inter-storey drifts are approximately 1% and 1.3% for 4-storey and 6-storey buildings, respectively.

For 6-storey building, the distributions of maximum inter-storey drifts at 1^{st} to 3^{rd} storey are similar to those in 4-storey building. The maximum inter-storey drifts at 4^{th} to 6^{th} storeys are greater than those at 1^{st} to 3^{rd} storeys. However, the maximum shearwall deformations at 1^{st} to 3^{rd} storeys in 6-storey building are generally smaller than those in 4-storey building. For the 6-storey building, the largest shearwall deformations occurred at the 5^{th} storey, are similar to those at the 1^{st} story in 4-storey building.

Based on the analyses that were carried out on a representative building situated in the city of Vancouver, the results indicate that when subjected to the 20 earthquake records the 6-storey wood-frame building achieved similar safety level as the 4-storey wood-frame building which is allowed under the current building code and is used as a benchmark in this study.

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Appendix A

Design drawings of 4- and 6-storey Buildings

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Appendix B

Results of Representative Wood-Frame Buildings Designed in Accordance with BCBC 2006

B.1 Fundamental period of the Building

	4-storey building (sec)				6-storey building (sec)			
	With GWB		Without GWB		With GWB		Without GWB	
	E-W	N-S	E-W	N-S	E-W	N-S	E-W	N-S
Drain-3D	0.54	0.68	0.73	0.78	0.78	0.96	0.99	1.07
Sapwood	0.52		0.64		0.66		0.89	

B.2 Maximum base shear

No.	4-storey building (kN)								6-storey building (kN)							
	Drain-3D				Sapwood				Drain-3D				Sapwood			
	With GWB		Without GWB		With GWB		Without GWB		With GWB		Without GWB		With GWB		Without GWB	
	E-W	N-S	E-W	N-S	E-W	N-S	E-W	N-S	E-W	N-S	E-W	N-S	E-W	N-S	E-W	N-S
1	1410	1034	981	882	883	844	1068	959	1711	1632	1384	1409	1031	748	675	543
2	1428	1019	957	889	680	847	1084	581	1679	1660	1552	1379	1137	1078	1131	707
3	1478	1023	961	855	1187	903	991	823	1666	1457	1173	1321	886	937	996	1079
4	1390	1018	979	898	1339	875	1003	771	1687	1577	1413	1507	1297	978	1231	1194
5	1223	1064	985	912	874	782	875	874	1738	1578	1437	1476	815	928	899	856
6	1357	1020	927	944	869	744	887	812	1732	1527	1449	1406	758	903	1060	1099
7	1204	1084	1082	895	708	596	835	639	1763	1599	1437	1355	1137	999	1376	1064
8	1257	1030	945	933	817	1033	907	1049	1642	1578	1553	1393	885	990	1212	1126
9	1468	1052	1035	885	884	810	995	831	1677	1493	1317	1448	989	1011	1089	1107
10	1319	1001	957	855	833	683	555	575	1658	1625	1423	1464	636	674	1025	972
11	1333	955	872	828	971	807	700	669	1451	1744	1525	1531	885	748	718	1030
12	1262	1042	964	921	1309	736	1027	868	1735	1647	1495	1488	1120	951	1273	1063
13	1280	1034	987	921	719	796	808	764	1706	1615	1397	1495	783	778	985	938
14	1405	1000	937	819	929	1084	1231	912	1340	1098	1311	1357	1293	1250	1364	1425
15	1298	1077	1015	908	972	929	1031	792	1721	1507	1425	1375	1161	945	1028	833
16	1323	1021	1003	888	732	720	825	852	1588	1600	1366	1563	712	847	878	892
17	1502	1047	1035	915	615	708	841	920	1755	1485	1288	1377	722	813	905	1083
18	1529	1088	1012	889	1014	752	1026	844	1622	1446	1228	1306	1127	882	932	936
19	1193	1029	935	869	1244	1070	1093	986	1607	1673	1512	1507	1251	1271	1171	1194
20	1366	1095	1057	947	1604	1179	1244	1124	1815	1629	1511	1537	1284	1126	1351	1228
Mean	1351	1037	981	893	959	845	951	832	1665	1559	1410	1435	995	943	1065	1018

B.3 Maximum displacement and acceleration at each storey

Table B.3.1 Maximum displacements of 4-storey building in E-W direction (with GWB), (mm)

No.	Drain-3D								Sapwood			
	Wall 8				Wall 4				Center of the storey diaphragm			
	st1	st2	st3	st4	st1	st2	st3	st4	st1	st2	st3	st4
1	33.8	58.4	72.9	80.0	35.4	56.8	71.9	78.9	24.5	38.7	49.6	52.0
2	34.9	57.7	71.4	78.9	39.6	59.4	72.5	79.0	32.4	50.3	59.7	62.6
3	32.5	57.5	70.9	77.3	34.8	56.2	70.0	76.4	17.0	39.9	57.8	64.5
4	18.1	36.9	54.1	62.4	16.4	32.0	49.7	57.7	20.4	41.1	56.0	62.6
5	24.2	37.5	46.6	53.0	25.5	37.7	45.8	50.0	10.0	19.0	26.0	29.3
6	15.8	29.0	39.8	45.3	15.0	26.5	37.4	42.8	11.0	21.7	30.2	33.6
7	41.0	70.5	84.5	91.7	42.3	68.9	83.1	90.5	31.6	50.2	62.1	65.0
8	24.2	45.1	65.2	74.0	28.5	45.8	65.4	73.1	19.6	42.9	57.9	62.3
9	18.8	33.0	45.3	52.0	21.5	34.1	46.2	52.7	11.0	20.6	28.0	31.2
10	22.0	37.3	48.6	55.7	23.4	36.3	47.8	53.7	10.3	19.6	26.3	29.1
11	37.2	57.0	74.0	83.2	38.7	57.8	71.2	79.4	15.9	31.2	46.6	51.6
12	44.0	68.3	85.6	94.2	46.9	69.8	87.9	96.8	17.4	35.3	49.3	57.4
13	15.8	29.6	42.0	48.6	17.0	29.5	42.0	48.5	10.6	19.1	25.3	27.4
14	24.4	37.1	45.8	50.6	25.6	36.9	46.2	50.9	21.0	31.3	36.5	38.3
15	32.4	54.3	68.1	75.5	31.9	49.1	61.4	67.9	16.6	32.3	45.3	51.1
16	19.1	33.8	45.9	52.6	20.2	33.0	44.1	49.8	10.0	19.0	26.2	28.8
17	26.7	41.5	52.7	59.4	27.4	40.7	51.5	58.4	16.1	27.7	36.2	38.4
18	19.6	35.0	48.2	56.9	21.3	35.7	49.2	56.7	11.5	22.3	33.9	38.4
19	29.4	53.3	71.3	80.0	31.9	51.3	68.6	76.8	16.2	32.1	48.8	51.7
20	27.8	55.7	79.6	88.5	29.8	54.2	78.0	86.9	26.7	48.8	64.4	69.8
Mean	27.1	46.4	60.6	68.0	28.7	45.6	59.5	66.4	17.5	32.2	43.3	47.3

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Table B.3.2 Maximum displacements of 4-storey building in N-S direction (with GWB), (mm)

No.	Drain-3D								Sapwood			
	Wall 19				Wall 25				Center of the storey diaphragm			
	st1	st2	st3	st4	st1	st2	st3	st4	st1	st2	st3	st4
1	26.8	54.5	89.5	116.2	26.7	54.5	89.3	115.9	26.6	46.6	62.5	66.8
2	22.8	48.3	73.8	90.8	22.8	48.3	73.7	90.6	32.7	51.3	69.6	72.9
3	22.0	46.3	72.7	90.6	22.0	46.3	72.6	90.4	26.1	50.3	77.3	86.9
4	27.2	45.8	76.6	100.3	27.2	45.8	76.5	100.1	23.0	44.3	67.3	74.9
5	25.5	49.6	76.3	95.7	25.5	49.6	76.3	95.6	17.2	31.9	40.4	43.7
6	29.5	55.3	81.6	102.1	29.4	55.2	81.6	102.1	18.1	35.5	54.5	62.4
7	26.6	59.1	91.4	114.4	26.6	59.0	91.3	114.4	32.9	54.7	69.0	71.1
8	15.2	33.6	58.5	79.9	15.2	33.7	58.6	80.0	16.8	36.0	52.6	57.7
9	27.3	54.2	82.2	101.5	27.3	54.1	82.0	101.2	24.1	41.6	56.6	59.2
10	28.7	54.3	78.2	95.1	28.7	54.2	78.2	95.1	20.7	36.7	47.5	49.9
11	31.3	62.0	92.3	114.6	31.3	61.9	92.2	114.5	27.0	45.0	63.1	67.6
12	38.0	70.3	99.7	119.4	37.9	70.1	99.4	119.0	25.8	44.6	69.7	78.7
13	25.2	42.9	61.8	76.0	25.2	42.8	61.7	75.8	17.1	31.6	47.3	53.0
14	29.4	47.3	64.1	75.8	29.4	47.2	64.0	75.6	30.5	48.5	62.2	64.6
15	24.2	47.2	73.1	92.0	24.2	47.3	73.1	92.0	26.0	48.0	74.0	81.0
16	24.5	44.3	65.2	81.0	24.5	44.3	65.2	80.9	15.3	27.1	40.7	47.1
17	21.1	38.2	57.3	71.4	21.1	38.2	57.2	71.3	16.9	32.7	48.9	54.9
18	26.0	47.2	66.5	80.5	26.0	47.2	66.4	80.3	18.1	33.5	47.6	51.5
19	16.7	36.2	60.5	79.3	16.7	36.1	60.4	79.1	17.9	27.9	45.6	49.3
20	28.8	55.1	84.5	105.7	28.9	55.2	84.6	105.8	26.6	50.5	68.9	75.4
Mean	25.8	49.6	75.3	94.1	25.8	49.6	75.2	94.0	23.0	40.9	58.3	63.4

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Table B.3.3 Maximum displacements of 6-storey building in E-W direction (with GWB), (mm)

No.	Drain-3D												Sapwood					
	Wall 8						Wall 4						Center of the storey diaphragm					
	st1	st2	st3	st4	st5	st6	st1	st2	st3	st4	st5	st6	st1	st2	st3	st4	st5	st6
1	20.6	41.4	62.8	87.4	110.3	122.7	18.8	36.7	67.5	91.2	113.1	125.2	14.0	28.5	43.5	56.6	67.2	71.8
2	17.0	33.9	52.2	69.7	86.3	96.8	17.6	33.4	54.3	69.0	85.9	96.8	16.0	32.2	46.5	57.1	65.7	69.6
3	18.4	36.4	56.4	74.3	89.8	99.4	17.8	34.8	60.7	77.7	92.7	102.4	16.3	28.8	45.4	63.1	78.5	84.2
4	20.7	40.4	67.6	93.2	115.9	127.7	20.5	37.0	70.8	95.1	116.7	128.1	14.1	27.4	42.6	55.2	66.6	72.4
5	21.8	43.0	64.1	82.6	98.2	108.2	22.2	39.6	63.1	79.7	94.4	104.1	12.3	22.9	33.3	40.7	47.2	50.2
6	23.7	45.8	65.9	83.3	97.6	107.0	22.3	40.2	61.4	77.7	92.4	102.2	11.5	22.5	32.6	41.5	50.0	54.8
7	18.0	37.5	63.4	86.8	106.8	118.4	17.2	35.0	64.9	84.7	102.4	114.2	17.6	32.8	48.8	61.3	70.2	74.8
8	12.3	26.2	44.8	66.0	87.7	100.4	12.9	27.1	45.8	64.8	86.1	98.9	10.3	22.0	34.8	45.5	54.1	58.5
9	21.3	43.4	68.8	90.6	107.6	117.7	20.9	40.6	71.9	93.1	111.9	123.1	14.5	27.3	40.2	49.2	55.9	59.3
10	18.7	36.7	56.7	74.0	88.7	98.4	20.3	37.1	57.3	72.8	87.3	97.3	12.5	22.5	32.1	39.6	44.7	46.9
11	22.3	45.3	70.4	92.5	111.0	122.3	24.2	43.6	73.3	90.1	105.2	117.4	16.3	30.4	44.3	54.7	63.0	66.5
12	21.4	44.4	68.3	87.7	103.8	114.0	21.8	42.4	71.1	89.0	105.1	115.9	17.3	32.6	47.1	59.6	68.8	73.0
13	16.8	32.7	50.1	65.5	79.1	87.5	14.8	29.5	46.1	60.2	73.2	81.6	11.5	21.4	32.5	41.2	48.0	52.2
14	24.7	42.3	58.5	71.5	80.9	87.4	23.9	40.6	57.4	69.8	79.6	86.7	20.2	33.0	43.5	51.1	56.2	59.2
15	19.3	38.2	58.0	76.9	94.8	105.7	16.6	33.0	56.3	74.1	92.0	103.7	14.2	29.8	45.0	58.1	72.2	78.1
16	17.1	35.0	57.2	77.7	94.9	105.1	16.6	32.9	58.6	77.6	94.9	105.3	10.4	20.0	29.6	37.8	44.8	47.5
17	17.2	32.6	48.5	61.3	71.8	79.5	16.2	30.5	44.9	56.4	66.0	72.5	10.4	21.4	31.0	37.9	45.3	48.8
18	18.2	35.5	53.4	71.8	89.9	101.2	18.8	35.9	56.5	71.8	86.3	96.0	10.1	19.8	29.7	37.5	43.7	46.8
19	11.9	24.8	38.0	52.0	68.3	77.9	12.2	25.4	39.3	52.4	70.6	80.8	10.0	19.4	30.0	39.6	49.5	52.4
20	16.1	34.9	58.0	79.5	98.4	109.9	16.5	34.7	59.9	80.3	99.7	111.8	15.0	30.2	46.4	59.3	68.7	73.0
Mean	18.9	37.5	58.2	77.2	94.1	104.4	18.6	35.5	59.1	76.4	92.8	103.2	13.7	26.3	39.0	49.3	58.0	62.0

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Table B.3.3 Maximum displacements of 6-storey building in E-W direction (with GWB), (mm)

No.	Drain-3D												Sapwood					
	Wall 8						Wall 4						Center of the storey diaphragm					
	st1	st2	st3	st4	st5	st6	st1	st2	st3	st4	st5	st6	st1	st2	st3	st4	st5	st6
1	20.6	41.4	62.8	87.4	110.3	122.7	18.8	36.7	67.5	91.2	113.1	125.2	14.0	28.5	43.5	56.6	67.2	71.8
2	17.0	33.9	52.2	69.7	86.3	96.8	17.6	33.4	54.3	69.0	85.9	96.8	16.0	32.2	46.5	57.1	65.7	69.6
3	18.4	36.4	56.4	74.3	89.8	99.4	17.8	34.8	60.7	77.7	92.7	102.4	16.3	28.8	45.4	63.1	78.5	84.2
4	20.7	40.4	67.6	93.2	115.9	127.7	20.5	37.0	70.8	95.1	116.7	128.1	14.1	27.4	42.6	55.2	66.6	72.4
5	21.8	43.0	64.1	82.6	98.2	108.2	22.2	39.6	63.1	79.7	94.4	104.1	12.3	22.9	33.3	40.7	47.2	50.2
6	23.7	45.8	65.9	83.3	97.6	107.0	22.3	40.2	61.4	77.7	92.4	102.2	11.5	22.5	32.6	41.5	50.0	54.8
7	18.0	37.5	63.4	86.8	106.8	118.4	17.2	35.0	64.9	84.7	102.4	114.2	17.6	32.8	48.8	61.3	70.2	74.8
8	12.3	26.2	44.8	66.0	87.7	100.4	12.9	27.1	45.8	64.8	86.1	98.9	10.3	22.0	34.8	45.5	54.1	58.5
9	21.3	43.4	68.8	90.6	107.6	117.7	20.9	40.6	71.9	93.1	111.9	123.1	14.5	27.3	40.2	49.2	55.9	59.3
10	18.7	36.7	56.7	74.0	88.7	98.4	20.3	37.1	57.3	72.8	87.3	97.3	12.5	22.5	32.1	39.6	44.7	46.9
11	22.3	45.3	70.4	92.5	111.0	122.3	24.2	43.6	73.3	90.1	105.2	117.4	16.3	30.4	44.3	54.7	63.0	66.5
12	21.4	44.4	68.3	87.7	103.8	114.0	21.8	42.4	71.1	89.0	105.1	115.9	17.3	32.6	47.1	59.6	68.8	73.0
13	16.8	32.7	50.1	65.5	79.1	87.5	14.8	29.5	46.1	60.2	73.2	81.6	11.5	21.4	32.5	41.2	48.0	52.2
14	24.7	42.3	58.5	71.5	80.9	87.4	23.9	40.6	57.4	69.8	79.6	86.7	20.2	33.0	43.5	51.1	56.2	59.2
15	19.3	38.2	58.0	76.9	94.8	105.7	16.6	33.0	56.3	74.1	92.0	103.7	14.2	29.8	45.0	58.1	72.2	78.1
16	17.1	35.0	57.2	77.7	94.9	105.1	16.6	32.9	58.6	77.6	94.9	105.3	10.4	20.0	29.6	37.8	44.8	47.5
17	17.2	32.6	48.5	61.3	71.8	79.5	16.2	30.5	44.9	56.4	66.0	72.5	10.4	21.4	31.0	37.9	45.3	48.8
18	18.2	35.5	53.4	71.8	89.9	101.2	18.8	35.9	56.5	71.8	86.3	96.0	10.1	19.8	29.7	37.5	43.7	46.8
19	11.9	24.8	38.0	52.0	68.3	77.9	12.2	25.4	39.3	52.4	70.6	80.8	10.0	19.4	30.0	39.6	49.5	52.4
20	16.1	34.9	58.0	79.5	98.4	109.9	16.5	34.7	59.9	80.3	99.7	111.8	15.0	30.2	46.4	59.3	68.7	73.0
Mean	18.9	37.5	58.2	77.2	94.1	104.4	18.6	35.5	59.1	76.4	92.8	103.2	13.7	26.3	39.0	49.3	58.0	62.0

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Table B.3.2 Maximum displacements of 4-storey building in N-S direction (with GWB), (mm)

No.	Drain-3D								Sapwood			
	Wall 19				Wall 25				Center of the storey diaphragm			
	st1	st2	st3	st4	st1	st2	st3	st4	st1	st2	st3	st4
1	26.8	54.5	89.5	116.2	26.7	54.5	89.3	115.9	26.6	46.6	62.5	66.8
2	22.8	48.3	73.8	90.8	22.8	48.3	73.7	90.6	32.7	51.3	69.6	72.9
3	22.0	46.3	72.7	90.6	22.0	46.3	72.6	90.4	26.1	50.3	77.3	86.9
4	27.2	45.8	76.6	100.3	27.2	45.8	76.5	100.1	23.0	44.3	67.3	74.9
5	25.5	49.6	76.3	95.7	25.5	49.6	76.3	95.6	17.2	31.9	40.4	43.7
6	29.5	55.3	81.6	102.1	29.4	55.2	81.6	102.1	18.1	35.5	54.5	62.4
7	26.6	59.1	91.4	114.4	26.6	59.0	91.3	114.4	32.9	54.7	69.0	71.1
8	15.2	33.6	58.5	79.9	15.2	33.7	58.6	80.0	16.8	36.0	52.6	57.7
9	27.3	54.2	82.2	101.5	27.3	54.1	82.0	101.2	24.1	41.6	56.6	59.2
10	28.7	54.3	78.2	95.1	28.7	54.2	78.2	95.1	20.7	36.7	47.5	49.9
11	31.3	62.0	92.3	114.6	31.3	61.9	92.2	114.5	27.0	45.0	63.1	67.6
12	38.0	70.3	99.7	119.4	37.9	70.1	99.4	119.0	25.8	44.6	69.7	78.7
13	25.2	42.9	61.8	76.0	25.2	42.8	61.7	75.8	17.1	31.6	47.3	53.0
14	29.4	47.3	64.1	75.8	29.4	47.2	64.0	75.6	30.5	48.5	62.2	64.6
15	24.2	47.2	73.1	92.0	24.2	47.3	73.1	92.0	26.0	48.0	74.0	81.0
16	24.5	44.3	65.2	81.0	24.5	44.3	65.2	80.9	15.3	27.1	40.7	47.1
17	21.1	38.2	57.3	71.4	21.1	38.2	57.2	71.3	16.9	32.7	48.9	54.9
18	26.0	47.2	66.5	80.5	26.0	47.2	66.4	80.3	18.1	33.5	47.6	51.5
19	16.7	36.2	60.5	79.3	16.7	36.1	60.4	79.1	17.9	27.9	45.6	49.3
20	28.8	55.1	84.5	105.7	28.9	55.2	84.6	105.8	26.6	50.5	68.9	75.4
Mean	25.8	49.6	75.3	94.1	25.8	49.6	75.2	94.0	23.0	40.9	58.3	63.4

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Table B.3.4 Maximum displacements of 6-storey building in N-S direction (with GWB), (mm)

No.	Drain-3D												Sapwood					
	Wall 19						Wall 25						Center of the storey diaphragm					
	st1	st2	st3	st4	st5	st6	st1	st2	st3	st4	st5	st6	st1	st2	st3	st4	st5	st6
1	23.7	46.6	69.0	92.0	114.5	131.6	23.7	46.5	69.0	91.9	114.5	131.6	18.1	32.2	45.3	64.6	77.7	81.5
2	16.3	29.8	40.0	59.6	91.5	117.2	16.3	29.7	39.8	59.4	91.1	116.7	14.6	32.4	46.5	60.5	73.2	76.0
3	25.6	43.6	59.0	86.2	121.7	147.9	25.6	43.6	58.9	86.0	121.3	147.4	25.4	43.8	62.3	81.7	111.8	121.7
4	20.5	41.3	61.7	83.4	110.5	140.0	20.5	41.3	61.8	83.4	110.5	139.9	22.2	38.4	50.4	61.2	81.1	87.8
5	19.9	42.5	68.1	107.7	150.3	184.8	19.9	42.5	68.1	107.6	150.1	184.7	13.7	25.1	35.5	46.1	57.8	61.3
6	25.1	52.1	81.6	115.5	148.3	176.2	25.1	52.0	81.4	115.2	148.1	176.1	17.0	33.4	45.4	58.4	74.1	79.9
7	20.9	37.8	53.1	75.0	102.7	125.8	20.8	37.8	53.0	74.9	102.8	125.9	23.1	42.8	57.9	69.4	77.4	79.4
8	32.8	54.2	74.9	101.1	128.4	152.4	32.8	54.1	74.8	100.9	128.0	151.8	17.0	31.0	46.1	59.3	66.1	66.8
9	29.8	56.1	81.8	113.9	146.7	172.3	29.8	56.0	81.7	113.4	146.1	171.6	22.2	37.2	52.0	65.5	75.8	78.2
10	18.6	38.1	61.6	100.6	144.5	178.4	18.5	37.9	61.5	100.5	144.1	178.0	15.3	27.8	40.3	49.5	55.8	57.6
11	20.1	37.5	59.7	91.7	124.6	149.0	20.0	37.3	59.8	91.7	124.5	148.8	14.0	30.1	44.9	60.5	73.2	76.1
12	14.9	29.1	41.3	59.0	79.6	96.7	14.9	29.0	41.3	58.9	79.5	96.4	18.5	33.8	47.3	56.7	71.8	77.7
13	29.9	59.9	92.9	131.4	168.5	199.8	29.8	59.8	92.7	131.2	168.4	199.7	18.0	32.2	44.9	60.5	77.5	83.7
14	27.9	50.6	71.6	95.4	127.9	150.9	27.9	50.5	71.5	95.2	127.6	150.4	26.5	41.5	52.2	62.4	69.9	73.1
15	20.7	43.9	70.3	104.6	141.0	168.7	20.7	43.8	70.2	104.3	140.6	168.2	22.2	40.4	56.7	75.9	93.4	98.8
16	23.7	48.7	78.1	113.9	148.7	176.4	23.7	48.6	78.0	113.9	148.6	176.3	15.1	28.1	41.5	52.5	62.2	64.2
17	26.8	47.0	72.1	113.7	155.2	187.1	26.8	46.9	71.9	113.4	154.7	186.5	15.4	30.9	44.3	58.5	72.4	78.1
18	20.4	40.8	65.1	97.5	131.6	159.5	20.4	40.8	65.0	97.3	131.4	159.3	12.6	22.9	33.0	41.8	54.6	57.0
19	12.0	20.4	26.4	38.5	56.7	78.7	12.0	20.3	26.4	38.4	56.8	78.9	16.4	28.9	35.7	43.0	49.9	52.3
20	30.8	49.0	63.0	75.1	98.4	127.5	30.8	49.0	63.0	74.9	98.1	127.0	25.4	43.6	55.1	54.9	68.3	72.8
Mean	23.0	43.4	64.6	92.8	124.6	151.0	23.0	43.4	64.5	92.6	124.3	150.8	18.6	33.8	46.9	59.1	72.2	76.2

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Table B.3.5 Maximum displacements of 4-storey building in E-W direction (without GWB), (mm)

No.	Drain-3D								Sapwood			
	Wall 8				Wall 4				Center of the storey diaphragm			
	st1	st2	st3	st4	st1	st2	st3	st4	st1	st2	st3	st4
1	28.1	55.8	81.8	93.6	29.5	51.3	84.6	95.9	25.6	48.1	70.1	77.6
2	27.5	52.4	80.1	87.9	29.7	50.3	79.7	86.2	26.0	48.5	69.1	75.3
3	27.4	50.9	80.3	87.3	29.9	44.4	80.0	87.3	23.1	46.8	74.0	88.6
4	30.4	46.6	74.5	84.1	30.3	42.5	76.9	86.7	22.7	41.3	65.3	80.7
5	20.3	39.2	63.1	71.6	21.7	38.7	62.5	70.5	15.2	32.2	46.2	54.3
6	39.5	55.5	71.2	78.5	42.0	56.6	72.7	79.9	16.9	35.7	52.5	62.3
7	32.9	64.7	84.0	91.0	36.1	62.7	82.8	89.5	30.4	60.4	79.5	88.3
8	13.5	29.4	63.0	74.1	13.4	25.1	63.3	72.9	15.7	31.1	52.7	61.4
9	25.5	48.3	73.9	82.3	26.3	44.4	73.2	80.3	21.8	40.3	59.3	67.4
10	34.0	58.3	74.5	81.9	31.9	53.1	70.9	77.8	23.2	39.1	50.4	57.4
11	34.4	61.6	77.5	86.2	37.6	61.3	77.7	85.0	29.3	49.0	70.4	84.7
12	38.5	67.3	92.8	100.5	30.3	58.8	91.5	98.6	23.9	50.2	74.3	89.5
13	22.4	41.3	57.6	65.4	22.9	36.8	61.1	67.0	15.1	30.9	49.0	60.8
14	37.0	51.9	64.2	70.8	38.1	51.4	64.1	69.6	28.8	45.2	61.6	67.7
15	24.6	46.4	73.5	82.9	27.1	45.7	75.4	83.8	24.1	45.2	72.6	85.1
16	21.9	39.0	56.0	64.8	22.4	37.4	56.1	64.1	15.7	28.6	44.8	52.9
17	28.3	45.5	59.9	67.6	25.6	40.0	61.8	70.9	16.8	34.1	52.0	60.8
18	25.8	44.5	58.1	68.1	30.6	43.9	57.8	66.2	15.6	32.0	48.0	56.8
19	16.9	31.4	62.5	73.9	18.8	28.0	65.0	76.6	16.6	33.5	50.7	55.7
20	32.7	61.4	90.4	98.4	32.1	54.4	88.1	95.7	24.3	46.6	74.2	82.1
Mean	28.1	49.6	71.9	80.5	28.8	46.3	72.3	80.2	21.5	40.9	60.8	70.5

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Table B.3.6 Maximum displacements of 4-storey building in N-S direction (without GWB), (mm)

No.	Drain-3D								Sapwood			
	Wall 19				Wall 25				Center of the storey diaphragm			
	st1	st2	st3	st4	st1	st2	st3	st4	st1	st2	st3	st4
1	30.3	56.4	90.5	118.6	30.3	56.4	90.4	118.4	29.7	48.2	67.1	74.9
2	22.7	46.5	78.5	100.2	22.7	46.5	78.5	100.2	29.2	51.0	73.7	77.0
3	29.0	53.4	82.6	100	29.0	53.4	82.6	99.9	38.3	56.6	97.4	111.2
4	34.0	55.4	86.9	107.8	34.0	55.4	86.8	107.7	32.4	48.8	77.6	90.0
5	39.0	70.1	100.9	123.5	38.9	70.0	100.7	123.3	21.0	39.8	59.7	61.8
6	30.9	58.1	84.2	102.9	30.9	58.1	84.2	102.8	19.7	37.5	62.1	72.0
7	29.1	54.3	90.7	112.1	29.1	54.3	90.8	112.1	36.0	54.4	73.2	76.8
8	18.3	38.2	71.6	95.1	18.3	38.2	71.6	95.1	23.5	44.5	63.3	69.9
9	33.1	59.8	90.5	113.1	33.1	59.7	90.6	113.2	33.4	51.7	73.2	77.2
10	30.7	58.0	91.1	117.5	30.7	58.0	91.1	117.5	27.7	44.3	56.8	60.8
11	35.2	66.5	96.8	121.6	35.1	66.3	96.7	121.5	22.6	45.9	64.8	71.7
12	30.8	60.2	90.7	108.4	30.8	60.1	90.4	108.1	26.9	44.7	70.2	80.7
13	23.3	40.2	61.9	77.6	23.3	40.2	61.8	77.6	22.5	39.3	67.1	80.1
14	35.1	54.4	77.0	94.7	35.1	54.4	76.9	94.6	37.8	54.3	70.6	79.8
15	28.2	49.0	74.7	93.3	28.3	49.1	74.7	93.3	29.2	55.6	84.2	95.4
16	34.5	61.9	90.9	117.1	34.4	61.8	90.8	117.0	20.1	39.0	59.8	61.3
17	22.7	37.4	54.5	66.5	22.7	37.3	54.6	66.6	19.4	36.9	58.4	65.7
18	30.2	51.9	77.7	99.7	30.2	52.0	77.8	99.8	19.5	36.7	55.1	60.8
19	14.3	29.7	53.1	84.9	14.3	29.8	53.2	84.7	24.8	34.7	41.6	44.2
20	28.8	56.3	90.4	114.8	28.8	56.4	90.5	114.8	32.8	41.4	62.3	69.8
Mean	29.0	52.9	81.8	103.7	29.0	52.9	81.7	103.4	27.3	45.3	66.9	74.0

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Table B.3.7 Maximum displacements of 6-storey building in E-W direction (without GWB), (mm)

No.	Drain-3D												Sapwood					
	Wall 8						Wall 4						Center of the storey diaphragm					
	st1	st2	st3	st4	st5	st6	st1	st2	st3	st4	st5	st6	st1	st2	st3	st4	st5	st6
1	21.0	43.5	66.3	85.5	112.0	121.3	22.0	39.1	67.3	84.4	103.4	111.2	21.5	33.0	48.3	63.3	78.7	86.3
2	13.2	26.2	42.9	63.8	87.8	100.0	12.4	24.0	43.5	63.2	87.2	98.6	15.0	28.6	45.2	62.6	76.4	81.3
3	22.5	41.2	60.0	74.6	107.1	119.7	22.6	38.8	63.8	78.5	118.4	131.0	24.6	43.6	64.7	84.0	114.9	132.4
4	25.2	49.2	72.1	88.2	102.7	112.8	26.1	43.5	70.9	85.4	101.1	112.8	22.3	41.1	55.4	66.1	79.2	87.4
5	35.2	66.9	97.0	114.9	133.1	142.6	28.9	50.2	89.2	108.3	133.9	144.9	14.1	25.6	41.4	55.6	68.9	73.4
6	29.6	58.0	83.3	99.4	113.3	121.7	26.4	45.4	75.6	90.2	108.5	119.8	14.8	29.8	47.6	61.7	79.8	89.5
7	16.1	33.6	55.7	74.6	99.0	109.3	15.9	32.0	58.0	75.3	93.2	103.0	18.7	37.8	56.9	70.4	80.7	86.1
8	32.0	54.0	71.0	86.4	101.2	111.3	33.7	50.4	68.2	81.7	96.3	106.3	17.2	33.8	51.2	65.1	72.2	74.7
9	35.0	64.7	89.7	106.3	120.3	131.9	32.7	54.0	89.5	107.8	129.1	141.4	27.6	42.7	61.0	71.0	85.4	96.2
10	28.2	51.0	71.9	88.2	104.7	111.1	24.2	42.1	71.3	89.6	117.7	128.7	14.8	28.7	43.7	55.4	64.5	69.2
11	15.9	34.9	59.3	83.4	118.1	131.0	13.9	30.2	55.5	75.7	110.4	122.3	12.3	25.5	41.4	59.0	73.6	84.0
12	15.9	31.2	48.7	68.5	89.2	98.8	15.6	30.5	50.1	70.1	97.2	107.5	14.6	29.0	44.4	57.0	69.5	75.8
13	37.1	69.4	99.3	120.4	141.1	151.5	32.0	54.7	91.8	111.3	137.9	148.1	21.8	38.6	57.0	72.6	87.7	97.6
14	33.1	57.2	81.9	99.1	118.9	127.0	33.0	52.9	81.9	99.3	118.4	127.1	22.5	39.1	53.4	66.3	77.5	85.4
15	39.7	74.3	106.4	127.5	148.5	157.8	36.8	60.4	102.4	122.0	142.2	151.3	17.9	36.4	58.9	78.1	94.0	102.8
16	35.4	64.1	85.0	98.2	109.9	118.4	35.5	56.1	83.2	95.8	109.0	119.7	15.8	31.1	42.1	54.2	63.6	68.8
17	27.5	49.8	71.9	91.8	111.0	121.6	23.4	41.0	69.5	86.4	109.1	118.7	14.5	31.9	50.6	65.5	81.7	90.9
18	20.5	39.6	65.6	86.9	109.4	119.9	21.8	36.6	65.9	83.2	103.6	113.7	12.8	23.3	33.7	44.8	54.6	57.4
19	14.8	25.2	33.4	45.8	59.0	66.5	14.8	25.4	33.0	43.7	62.7	70.3	12.6	23.5	33.8	41.2	46.7	50.7
20	31.6	52.2	70.0	84.9	95.5	108.9	31.3	49.5	72.0	85.8	92.3	103.5	22.3	40.8	47.4	53.4	67.7	72.1
Mean	26.5	49.3	71.6	89.4	109.1	119.2	25.2	42.8	70.1	86.9	108.6	119.0	17.9	33.2	48.9	62.4	75.9	83.1

Table B.3.8 Maximum displacements of 6-storey building in N-S direction (without GWB), (mm)

No.	Drain-3D												Sapwood					
	Wall 19						Wall 25						Center of the storey diaphragm					
	st1	st2	st3	st4	st5	st6	st1	st2	st3	st4	st5	st6	st1	st2	st3	st4	st5	st6
1	22.0	44.5	67.6	92.0	121.1	138.5	21.9	44.5	67.6	92.0	121.2	138.6	20.9	35.0	48.3	62.7	74.4	83.2
2	16.5	31.0	42.8	54.5	80.7	107.1	16.5	31.0	42.7	54.4	80.7	106.8	16.1	31.6	44.5	58.4	77.2	80.1
3	28.2	49.1	65.7	92.1	131.6	160.9	28.2	49.0	65.5	91.8	131.3	160.5	30.8	54.4	75.6	101.2	137.7	150.9
4	23.4	43.6	65.6	90.9	117.9	139.2	23.4	43.5	65.6	90.9	118.0	139.3	17.9	37.2	53.6	71.5	97.3	105.9
5	19.0	38.3	60.1	86.5	112.2	135.9	18.8	38.4	60.3	86.5	112.3	136.2	15.0	29.4	42.1	53.4	68.6	74.2
6	21.4	43.9	69.3	103.8	148.2	185.2	21.4	43.7	69.0	103.5	147.8	184.8	20.3	36.0	49.1	61.2	77.2	83.1
7	24.4	42.1	57.1	75.7	101.3	122.3	24.4	42.0	57.1	75.6	101.2	122.5	21.7	41.5	58.1	73.2	88.4	91.9
8	28.9	49.2	75.2	109.0	143.9	170.1	28.9	49.2	75.1	108.9	143.6	169.7	19.3	38.5	56.1	65.8	70.4	71.9
9	29.6	54.3	78.6	113.9	146.5	169.9	29.6	54.3	78.7	113.7	146.1	169.4	25.8	47.0	63.9	79.8	90.3	98.4
10	21.3	42.1	64.6	102.4	149.4	185.8	21.2	42.0	64.3	101.7	148.5	184.6	15.2	30.3	46.4	58.4	69.0	72.4
11	26.1	44.8	61.9	87.8	124.9	150.7	26.0	44.7	61.8	87.7	124.8	150.4	16.1	30.5	43.8	66.4	82.7	88.0
12	15.6	31.2	45.2	57.3	73.7	92.5	15.6	31.0	45.0	57.0	73.4	92.0	16.2	28.7	41.9	58.1	73.5	79.1
13	31.3	61.3	95.1	138.4	180.7	213.9	31.2	61.1	94.8	138.1	180.3	213.4	24.1	47.6	63.5	81.0	101.3	108.1
14	27.5	50.9	73.4	105.5	146.4	171.6	27.6	50.9	73.4	105.4	146.1	171.2	27.9	46.1	61.4	77.1	94.8	99.6
15	18.9	36.2	52.5	75.6	113.9	148.1	18.9	36.3	52.6	75.0	113.4	147.4	22.0	40.9	58.0	83.4	101.2	109.1
16	22.2	46.5	74.9	113.4	151.8	180.8	22.0	46.2	74.5	112.7	150.9	179.7	15.0	29.6	40.1	49.4	59.7	65.3
17	22.1	44.6	67.7	99.0	145.5	185.3	22.0	44.4	67.4	98.2	144.4	184.4	14.8	30.7	43.8	63.2	78.1	85.2
18	26.1	46.9	66.9	90.5	113.7	132.4	26.0	46.9	66.7	90.3	113.4	131.9	13.9	28.2	40.7	50.9	64.7	70.3
19	16.0	26.7	32.4	34.4	61.3	85.4	16.0	26.7	32.3	34.4	61.1	85.0	19.6	32.9	40.7	44.0	49.3	49.8
20	36.7	58.8	72.5	78.2	90.1	117.0	36.7	58.7	72.5	78.2	89.9	116.8	23.2	40.2	51.3	68.0	65.7	69.7
Mean	23.9	44.3	64.5	90.0	122.7	149.6	23.8	44.2	64.3	89.8	122.4	149.2	19.8	36.8	51.1	66.4	81.1	86.8

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Table B.3.9 Maximum accelerations of 4-storey building (with GWB), (g)

No.	Sapwood															
	With GWB								Without GWB							
	E-W				N-S				E-W				N-S			
	st1	st2	st3	st4	st1	st2	st3	st4	st1	st2	st3	st4	st1	st2	st3	st4
1	0.32	0.31	0.37	0.39	0.34	0.35	0.28	0.35	0.44	0.45	0.34	0.41	0.38	0.26	0.28	0.33
2	0.26	0.37	0.36	0.38	0.32	0.25	0.28	0.31	0.39	0.37	0.34	0.38	0.20	0.31	0.26	0.26
3	0.42	0.39	0.46	0.54	0.37	0.42	0.33	0.46	0.37	0.42	0.43	0.55	0.41	0.37	0.35	0.48
4	0.44	0.42	0.41	0.44	0.31	0.35	0.30	0.39	0.33	0.35	0.35	0.50	0.28	0.27	0.25	0.38
5	0.28	0.26	0.25	0.27	0.32	0.29	0.24	0.27	0.32	0.32	0.28	0.36	0.33	0.34	0.27	0.35
6	0.28	0.29	0.28	0.33	0.34	0.35	0.32	0.36	0.34	0.37	0.36	0.45	0.34	0.35	0.30	0.40
7	0.29	0.34	0.40	0.41	0.20	0.27	0.27	0.27	0.27	0.30	0.34	0.37	0.26	0.20	0.26	0.30
8	0.31	0.32	0.42	0.47	0.33	0.29	0.28	0.34	0.36	0.26	0.34	0.39	0.43	0.38	0.24	0.31
9	0.31	0.29	0.26	0.28	0.33	0.29	0.27	0.27	0.34	0.31	0.29	0.38	0.40	0.37	0.25	0.31
10	0.27	0.25	0.27	0.27	0.27	0.24	0.23	0.26	0.17	0.29	0.28	0.36	0.22	0.26	0.25	0.30
11	0.29	0.42	0.39	0.51	0.30	0.34	0.31	0.41	0.24	0.31	0.40	0.56	0.29	0.29	0.28	0.41
12	0.40	0.38	0.38	0.44	0.23	0.35	0.32	0.39	0.30	0.38	0.32	0.47	0.32	0.30	0.30	0.42
13	0.23	0.23	0.24	0.28	0.34	0.32	0.27	0.34	0.35	0.38	0.34	0.42	0.40	0.37	0.30	0.43
14	0.36	0.34	0.29	0.39	0.39	0.30	0.25	0.28	0.38	0.38	0.33	0.36	0.30	0.27	0.26	0.36
15	0.36	0.38	0.39	0.45	0.42	0.43	0.32	0.40	0.46	0.45	0.35	0.47	0.40	0.42	0.30	0.42
16	0.21	0.24	0.23	0.27	0.28	0.27	0.27	0.31	0.29	0.31	0.34	0.40	0.33	0.35	0.28	0.37
17	0.20	0.26	0.31	0.33	0.30	0.28	0.29	0.33	0.29	0.27	0.26	0.37	0.31	0.31	0.25	0.33
18	0.34	0.29	0.32	0.41	0.33	0.30	0.29	0.37	0.32	0.30	0.33	0.42	0.31	0.32	0.27	0.37
19	0.49	0.42	0.39	0.47	0.42	0.31	0.31	0.33	0.46	0.48	0.35	0.47	0.46	0.40	0.26	0.29
20	0.46	0.35	0.43	0.51	0.46	0.34	0.32	0.40	0.51	0.46	0.34	0.38	0.57	0.46	0.26	0.33
Mean	0.33	0.33	0.34	0.39	0.33	0.32	0.29	0.34	0.35	0.36	0.34	0.42	0.35	0.33	0.27	0.36

Note:
The acceleration is the moving average acceleration over 0.1 sec relative to stationary reference coordinates. The reason the moving average is used is that sudden spikes in acceleration over a very short time will not have significant impact on the contents or residents in the building, while the moving average value is felt to be more correlated with content damage and human comfort.

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Table B.3.10 Maximum accelerations of 6-storey building (with GWB), (g)

No.	Sapwood																							
	With GWB												With GWB											
	E-W						E-W						E-W						E-W					
	st1	st2	st3	st4	st5	st6	st1	st2	st3	st4	st5	st6	st1	st2	st3	st4	st5	st6	st1	st2	st3	st4	st5	st6
1	0.33	0.29	0.38	0.34	0.33	0.40	0.22	0.27	0.22	0.30	0.26	0.32	0.24	0.23	0.22	0.28	0.30	0.35	0.23	0.21	0.21	0.24	0.29	0.37
2	0.31	0.28	0.26	0.28	0.34	0.37	0.27	0.21	0.25	0.24	0.27	0.30	0.28	0.25	0.21	0.32	0.32	0.35	0.24	0.24	0.22	0.22	0.27	0.28
3	0.31	0.35	0.39	0.41	0.39	0.47	0.32	0.34	0.31	0.40	0.37	0.49	0.31	0.34	0.34	0.38	0.43	0.62	0.50	0.39	0.36	0.31	0.36	0.50
4	0.40	0.36	0.32	0.30	0.31	0.36	0.33	0.31	0.24	0.27	0.26	0.35	0.36	0.30	0.32	0.23	0.29	0.39	0.45	0.32	0.27	0.30	0.29	0.33
5	0.23	0.26	0.28	0.26	0.24	0.31	0.29	0.23	0.23	0.28	0.26	0.31	0.26	0.27	0.26	0.30	0.30	0.39	0.27	0.27	0.28	0.25	0.25	0.34
6	0.24	0.27	0.31	0.28	0.28	0.36	0.31	0.23	0.23	0.29	0.30	0.35	0.28	0.30	0.29	0.34	0.36	0.44	0.34	0.22	0.29	0.27	0.26	0.35
7	0.32	0.26	0.29	0.34	0.32	0.40	0.28	0.21	0.23	0.26	0.25	0.26	0.36	0.29	0.20	0.30	0.29	0.35	0.27	0.21	0.24	0.21	0.27	0.30
8	0.32	0.28	0.22	0.26	0.32	0.34	0.37	0.32	0.27	0.30	0.25	0.32	0.39	0.42	0.29	0.32	0.29	0.42	0.33	0.36	0.36	0.31	0.23	0.32
9	0.30	0.25	0.21	0.25	0.28	0.31	0.36	0.24	0.26	0.34	0.28	0.36	0.37	0.28	0.34	0.30	0.31	0.46	0.41	0.19	0.21	0.22	0.24	0.33
10	0.15	0.19	0.19	0.21	0.23	0.24	0.17	0.15	0.17	0.19	0.18	0.21	0.25	0.17	0.19	0.21	0.21	0.23	0.25	0.20	0.22	0.19	0.22	0.25
11	0.25	0.23	0.31	0.28	0.29	0.33	0.26	0.21	0.19	0.28	0.29	0.36	0.21	0.26	0.27	0.30	0.31	0.47	0.25	0.22	0.29	0.33	0.25	0.30
12	0.29	0.29	0.27	0.34	0.32	0.36	0.30	0.26	0.23	0.28	0.28	0.38	0.36	0.31	0.24	0.26	0.28	0.36	0.28	0.27	0.26	0.31	0.25	0.36
13	0.25	0.26	0.31	0.30	0.27	0.34	0.26	0.24	0.29	0.41	0.33	0.42	0.27	0.33	0.29	0.31	0.34	0.44	0.32	0.24	0.26	0.32	0.30	0.33
14	0.40	0.45	0.36	0.28	0.26	0.29	0.34	0.30	0.31	0.29	0.24	0.26	0.39	0.39	0.37	0.31	0.28	0.38	0.36	0.33	0.34	0.32	0.27	0.32
15	0.34	0.39	0.38	0.35	0.38	0.44	0.33	0.33	0.41	0.41	0.32	0.41	0.32	0.41	0.46	0.42	0.34	0.48	0.30	0.33	0.35	0.33	0.26	0.36
16	0.20	0.22	0.22	0.24	0.25	0.27	0.31	0.26	0.33	0.33	0.25	0.28	0.26	0.24	0.32	0.32	0.27	0.37	0.24	0.22	0.21	0.24	0.24	0.29
17	0.22	0.22	0.25	0.23	0.24	0.27	0.28	0.27	0.30	0.33	0.30	0.37	0.25	0.31	0.37	0.36	0.31	0.42	0.31	0.33	0.34	0.25	0.27	0.37
18	0.26	0.28	0.31	0.27	0.27	0.35	0.28	0.22	0.23	0.27	0.24	0.30	0.28	0.30	0.26	0.23	0.24	0.36	0.31	0.28	0.30	0.24	0.23	0.34
19	0.39	0.35	0.28	0.26	0.32	0.36	0.39	0.36	0.33	0.28	0.26	0.37	0.57	0.47	0.32	0.25	0.32	0.45	0.44	0.41	0.42	0.36	0.24	0.31
20	0.53	0.42	0.30	0.34	0.35	0.40	0.44	0.52	0.55	0.31	0.29	0.37	0.61	0.53	0.38	0.35	0.37	0.40	0.48	0.42	0.48	0.39	0.28	0.32

Note:
The acceleration is the moving average acceleration over 0.1 sec relative to stationary reference coordinates. The reason the moving average is used is that sudden spikes in acceleration over a very short time will not have significant impact on the contents or residents in the building, while the moving average value is felt to be more correlated with content damage and human comfort.

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B.4 Maximum inter-storey drift

Table B.4.1 Inter-storey drift of 4-storey building in E-W direction (with GWB), (%)

No.	Drain-3D								Sapwood			
	Wall 8				Wall 4				Center of the storey diaphragm			
	st1	st2	st3	st4	st1	st2	st3	st4	st1	st2	st3	st4
1	1.23	0.90	0.67	0.31	1.29	0.78	0.69	0.33	0.89	0.52	0.40	0.13
2	1.27	0.87	0.61	0.30	1.44	0.76	0.63	0.31	1.18	0.66	0.35	0.14
3	1.18	0.91	0.51	0.25	1.27	0.78	0.52	0.27	0.62	0.84	0.68	0.25
4	0.66	0.69	0.67	0.32	0.60	0.57	0.70	0.33	0.74	0.86	0.68	0.27
5	0.88	0.52	0.46	0.27	0.93	0.47	0.44	0.26	0.36	0.41	0.31	0.13
6	0.57	0.48	0.41	0.22	0.54	0.44	0.41	0.22	0.40	0.40	0.37	0.16
7	1.49	1.09	0.53	0.27	1.54	0.98	0.52	0.27	1.15	0.68	0.45	0.13
8	0.88	0.99	0.75	0.34	1.04	0.85	0.72	0.34	0.71	0.87	0.62	0.18
9	0.68	0.54	0.45	0.25	0.78	0.46	0.44	0.24	0.40	0.42	0.30	0.12
10	0.80	0.55	0.51	0.30	0.85	0.51	0.49	0.28	0.37	0.39	0.31	0.12
11	1.35	0.80	0.63	0.34	1.41	0.72	0.61	0.30	0.58	0.57	0.59	0.27
12	1.60	0.95	0.63	0.33	1.70	0.89	0.66	0.34	0.63	0.72	0.55	0.31
13	0.57	0.51	0.45	0.24	0.62	0.46	0.47	0.24	0.39	0.35	0.24	0.10
14	0.89	0.46	0.47	0.29	0.93	0.42	0.46	0.27	0.76	0.44	0.43	0.22
15	1.18	0.83	0.57	0.30	1.16	0.64	0.58	0.29	0.60	0.60	0.56	0.21
16	0.70	0.54	0.46	0.25	0.73	0.48	0.47	0.24	0.36	0.35	0.31	0.11
17	0.97	0.54	0.41	0.24	1.00	0.48	0.41	0.25	0.59	0.43	0.31	0.13
18	0.71	0.60	0.54	0.31	0.78	0.55	0.58	0.31	0.42	0.40	0.44	0.23
19	1.07	0.87	0.66	0.32	1.16	0.71	0.66	0.32	0.59	0.73	0.75	0.30
20	1.01	1.05	0.87	0.38	1.08	0.91	0.87	0.38	0.97	0.81	0.59	0.20
Mean	0.98	0.73	0.56	0.29	1.04	0.64	0.57	0.29	0.64	0.57	0.46	0.19

Note:
Storey height = 2750 mm

Table B.4.2 Inter-storey drift of 4-storey building in N-S direction (with GWB), (%)

No.	Drain-3D								Sapwood			
	Wall 19				Wall 25				Center of the storey diaphragm			
	st1	st2	st3	st4	st1	st2	st3	st4	st1	st2	st3	st4
1	0.97	1.14	1.34	0.98	0.97	1.14	1.33	0.98	0.97	0.81	0.79	0.28
2	0.83	0.94	0.99	0.68	0.83	0.94	0.99	0.68	1.19	0.76	0.75	0.19
3	0.80	0.90	0.98	0.72	0.80	0.90	0.98	0.72	0.95	0.91	1.07	0.35
4	0.99	0.90	1.14	0.86	0.99	0.90	1.14	0.86	0.84	0.81	0.96	0.28
5	0.93	0.89	0.99	0.74	0.93	0.89	0.99	0.74	0.63	0.68	0.55	0.22
6	1.07	0.96	0.97	0.76	1.07	0.96	0.97	0.76	0.66	0.72	0.77	0.30
7	0.97	1.19	1.17	0.86	0.97	1.19	1.17	0.86	1.20	0.80	0.55	0.11
8	0.55	0.72	1.04	0.78	0.55	0.73	1.04	0.78	0.61	0.70	0.81	0.21
9	0.99	1.01	1.02	0.70	0.99	1.00	1.01	0.70	0.88	0.67	0.56	0.13
10	1.05	0.94	0.97	0.74	1.04	0.94	0.97	0.74	0.75	0.63	0.56	0.20
11	1.14	1.15	1.13	0.82	1.14	1.14	1.12	0.82	0.98	0.76	0.88	0.29
12	1.38	1.21	1.10	0.86	1.38	1.21	1.10	0.86	0.94	0.71	0.99	0.39
13	0.92	0.67	0.70	0.52	0.92	0.67	0.70	0.51	0.62	0.67	0.63	0.23
14	1.07	0.72	0.69	0.56	1.07	0.72	0.68	0.56	1.11	0.76	0.67	0.29
15	0.88	0.87	0.98	0.72	0.88	0.87	0.98	0.72	0.95	0.83	1.16	0.25
16	0.89	0.74	0.80	0.59	0.89	0.74	0.80	0.59	0.56	0.57	0.58	0.26
17	0.77	0.65	0.72	0.51	0.77	0.65	0.72	0.51	0.61	0.67	0.60	0.28
18	0.95	0.78	0.81	0.71	0.95	0.78	0.81	0.71	0.66	0.61	0.76	0.28
19	0.61	0.73	1.09	0.84	0.61	0.73	1.10	0.84	0.65	0.65	0.87	0.29
20	1.05	1.03	1.16	0.82	1.05	1.03	1.16	0.82	0.97	0.91	0.79	0.29
Mean	0.94	0.91	0.99	0.74	0.94	0.91	0.99	0.74	0.84	0.73	0.77	0.26

Note:
Storey height = 2750 mm

Table B.4.3 Inter-storey drift of 6-storey building in E-W direction (with GWB), (%)

No.	Drain-3D												Sapwood					
	Wall 8						Wall 4						Center of the storey diaphragm					
	st1	st2	st3	st4	st5	st6	st1	st2	st3	st4	st5	st6	st1	st2	st3	st4	st5	st6
1	0.75	0.77	0.98	0.92	0.84	0.47	0.68	0.66	1.26	0.88	0.80	0.45	0.51	0.55	0.63	0.53	0.48	0.19
2	0.62	0.62	0.79	0.75	0.66	0.39	0.64	0.60	0.88	0.68	0.64	0.40	0.58	0.62	0.63	0.45	0.32	0.16
3	0.67	0.67	0.75	0.69	0.70	0.70	0.65	0.63	0.95	0.64	0.65	0.42	0.59	0.49	0.61	0.71	0.61	0.21
4	0.75	0.79	0.99	0.93	0.84	0.47	0.74	0.70	1.23	0.88	0.82	0.47	0.51	0.59	0.60	0.52	0.43	0.21
5	0.79	0.78	0.77	0.67	0.57	0.37	0.81	0.64	0.87	0.61	0.54	0.35	0.45	0.43	0.42	0.35	0.32	0.17
6	0.86	0.81	0.74	0.68	0.64	0.41	0.81	0.65	0.79	0.63	0.66	0.41	0.42	0.43	0.43	0.38	0.39	0.20
7	0.65	0.73	0.95	0.85	0.73	0.43	0.63	0.68	1.09	0.72	0.65	0.43	0.64	0.62	0.73	0.47	0.36	0.17
8	0.45	0.54	0.74	0.84	0.84	0.47	0.47	0.55	0.79	0.75	0.82	0.47	0.37	0.44	0.52	0.54	0.37	0.19
9	0.77	0.83	0.93	0.79	0.63	0.39	0.76	0.72	1.19	0.77	0.70	0.44	0.53	0.48	0.47	0.33	0.25	0.13
10	0.68	0.68	0.73	0.66	0.55	0.35	0.74	0.61	0.81	0.59	0.55	0.37	0.45	0.37	0.36	0.27	0.20	0.12
11	0.81	0.88	0.98	0.83	0.67	0.42	0.88	0.79	1.11	0.73	0.68	0.44	0.59	0.61	0.53	0.45	0.32	0.14
12	0.78	0.86	0.89	0.72	0.69	0.43	0.79	0.75	1.07	0.68	0.62	0.39	0.63	0.56	0.55	0.49	0.45	0.23
13	0.61	0.59	0.66	0.59	0.50	0.32	0.54	0.54	0.66	0.52	0.50	0.33	0.42	0.40	0.43	0.38	0.38	0.16
14	0.90	0.68	0.68	0.55	0.49	0.32	0.87	0.63	0.73	0.51	0.50	0.30	0.73	0.56	0.57	0.36	0.32	0.19
15	0.70	0.69	0.75	0.73	0.68	0.43	0.60	0.61	0.86	0.67	0.67	0.43	0.52	0.60	0.60	0.50	0.59	0.22
16	0.62	0.66	0.81	0.74	0.64	0.39	0.60	0.60	0.97	0.69	0.65	0.40	0.38	0.38	0.37	0.32	0.29	0.15
17	0.63	0.57	0.59	0.53	0.47	0.31	0.59	0.53	0.56	0.49	0.46	0.30	0.38	0.40	0.38	0.33	0.27	0.13
18	0.66	0.65	0.70	0.70	0.66	0.41	0.68	0.62	0.82	0.58	0.61	0.39	0.37	0.39	0.39	0.38	0.31	0.17
19	0.43	0.50	0.52	0.62	0.76	0.44	0.44	0.51	0.56	0.61	0.78	0.47	0.36	0.44	0.49	0.49	0.38	0.19
20	0.59	0.70	0.93	0.87	0.73	0.42	0.60	0.67	1.09	0.81	0.74	0.44	0.55	0.60	0.67	0.50	0.46	0.20
Mean	0.69	0.70	0.79	0.73	0.66	0.42	0.68	0.63	0.91	0.67	0.65	0.40	0.50	0.50	0.52	0.44	0.37	0.18

Note:
Storey height = 2750 mm

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Table B.4.4 Inter-storey drift of 6-storey building in N-S direction (with GWB), (%)

No.	Drain-3D												Sapwood					
	Wall 19						Wall 25						Center of the storey diaphragm					
	st1	st2	st3	st4	st5	st6	st1	st2	st3	st4	st5	st6	st1	st2	st3	st4	st5	st6
1	0.86	0.83	0.82	0.90	1.06	0.82	0.86	0.83	0.82	0.90	1.05	0.81	0.66	0.55	0.67	0.81	0.60	0.15
2	0.59	0.51	0.60	0.89	1.39	1.06	0.59	0.51	0.60	0.88	1.39	1.06	0.53	0.69	0.60	0.64	0.59	0.14
3	0.93	0.69	0.78	1.18	1.42	1.05	0.93	0.68	0.78	1.18	1.42	1.04	0.92	0.72	0.68	0.73	1.33	0.36
4	0.75	0.76	0.77	1.03	1.38	1.10	0.75	0.76	0.77	1.03	1.38	1.10	0.81	0.65	0.64	0.64	0.75	0.25
5	0.72	0.83	1.00	1.49	1.59	1.28	0.72	0.83	1.00	1.49	1.59	1.27	0.50	0.52	0.47	0.43	0.58	0.21
6	0.91	0.98	1.08	1.27	1.25	1.02	0.91	0.98	1.08	1.27	1.25	1.02	0.62	0.63	0.53	0.57	0.60	0.28
7	0.76	0.65	0.74	0.93	1.18	0.92	0.76	0.65	0.73	0.93	1.18	0.92	0.84	0.73	0.61	0.59	0.41	0.10
8	1.19	0.87	0.92	1.17	1.36	0.99	1.19	0.87	0.92	1.16	1.36	0.98	0.62	0.60	0.58	0.65	0.66	0.23
9	1.08	0.96	1.08	1.30	1.24	0.99	1.08	0.96	1.07	1.29	1.23	0.98	0.81	0.64	0.58	0.53	0.62	0.21
10	0.68	0.73	0.91	1.43	1.62	1.29	0.67	0.73	0.90	1.43	1.62	1.28	0.56	0.48	0.47	0.34	0.35	0.13
11	0.73	0.72	0.87	1.17	1.24	1.00	0.73	0.72	0.87	1.17	1.24	0.99	0.51	0.60	0.59	0.57	0.64	0.21
12	0.54	0.54	0.60	0.70	0.84	0.70	0.54	0.54	0.60	0.70	0.84	0.70	0.67	0.61	0.53	0.59	0.68	0.31
13	1.09	1.09	1.20	1.41	1.36	1.14	1.08	1.09	1.20	1.41	1.36	1.14	0.65	0.59	0.52	0.62	0.86	0.33
14	1.01	0.86	0.92	1.21	1.18	0.91	1.01	0.86	0.92	1.20	1.18	0.91	0.96	0.66	0.57	0.63	0.52	0.25
15	0.75	0.86	1.01	1.41	1.41	1.16	0.75	0.86	1.01	1.41	1.41	1.16	0.81	0.67	0.69	0.71	1.04	0.28
16	0.86	0.96	1.07	1.35	1.44	1.15	0.86	0.95	1.07	1.35	1.44	1.15	0.55	0.58	0.56	0.61	0.59	0.25
17	0.98	0.80	1.02	1.54	1.57	1.30	0.97	0.80	1.02	1.53	1.57	1.29	0.56	0.60	0.57	0.64	0.59	0.29
18	0.74	0.79	0.93	1.26	1.27	1.04	0.74	0.79	0.93	1.26	1.27	1.04	0.46	0.45	0.45	0.46	0.54	0.21
19	0.44	0.38	0.41	0.62	1.06	0.88	0.44	0.38	0.41	0.62	1.06	0.88	0.60	0.54	0.51	0.63	0.69	0.27
20	1.12	0.68	0.63	1.04	1.93	1.33	1.12	0.67	0.63	1.03	1.92	1.33	0.92	0.68	0.74	0.92	0.79	0.31
Mean	0.84	0.77	0.87	1.16	1.34	1.06	0.84	0.77	0.87	1.16	1.34	1.05	0.68	0.61	0.58	0.62	0.67	0.24

Note:
Storey height = 2750 mm

Table B.4.5 Inter-storey drift of 4-storey building in E-W direction (without GWB), (%)

No.	Drain-3D								Sapwood			
	Wall 8				Wall 4				Center of the storey diaphragm			
	st1	st2	st3	st4	st1	st2	st3	st4	st1	st2	st3	st4
1	1.02	1.04	1.50	0.45	1.07	0.85	1.67	0.42	0.97	0.81	0.79	0.27
2	1.00	0.95	1.06	0.39	1.08	0.78	1.13	0.41	1.20	0.76	0.68	0.18
3	1.00	0.93	1.09	0.41	1.09	0.67	1.29	0.36	0.93	0.89	1.12	0.37
4	1.11	1.01	1.15	0.38	1.10	0.76	1.42	0.36	0.84	0.83	0.92	0.30
5	0.74	0.76	0.93	0.40	0.79	0.64	0.91	0.36	0.63	0.68	0.58	0.24
6	1.43	0.66	0.82	0.39	1.53	0.58	0.84	0.38	0.66	0.72	0.76	0.29
7	1.20	1.18	0.70	0.32	1.31	1.01	0.73	0.30	1.21	0.80	0.52	0.11
8	0.49	0.62	1.48	0.44	0.49	0.44	1.79	0.41	0.60	0.70	0.82	0.24
9	0.93	0.87	0.96	0.41	0.95	0.70	1.10	0.37	0.87	0.65	0.57	0.13
10	1.24	0.89	0.60	0.34	1.16	0.77	0.71	0.33	0.76	0.59	0.55	0.21
11	1.25	1.00	0.60	0.32	1.37	0.86	0.63	0.31	0.92	0.78	0.87	0.31
12	1.40	1.06	1.06	0.45	1.10	1.04	1.32	0.46	0.88	0.76	0.98	0.37
13	0.81	0.70	0.79	0.42	0.83	0.61	0.94	0.38	0.60	0.67	0.63	0.23
14	1.35	0.67	0.60	0.34	1.39	0.58	0.62	0.35	1.12	0.73	0.68	0.29
15	0.89	0.82	1.02	0.43	0.98	0.72	1.11	0.41	0.95	0.86	1.16	0.25
16	0.80	0.65	0.68	0.33	0.81	0.62	0.75	0.31	0.56	0.57	0.59	0.27
17	1.03	0.66	0.60	0.35	0.93	0.55	0.82	0.34	0.61	0.69	0.57	0.27
18	0.94	0.69	0.65	0.60	1.11	0.52	0.68	0.58	0.67	0.64	0.77	0.27
19	0.61	0.71	1.53	0.46	0.68	0.51	1.76	0.46	0.66	0.65	0.83	0.29
20	1.19	1.10	1.14	0.44	1.17	0.84	1.36	0.44	0.95	0.93	0.80	0.29
Mean	1.02	0.85	0.95	0.40	1.05	0.70	1.08	0.39	0.83	0.74	0.76	0.26

Note:
Storey height = 2750 mm

Table B.4.6 Inter-storey drift of 4-storey building in N-S direction (without GWB), (%)

No.	Drain-3D								Sapwood			
	Wall 19				Wall 25				Center of the storey diaphragm			
	st1	st2	st3	st4	st1	st2	st3	st4	st1	st2	st3	st4
1	1.10	1.09	1.49	1.05	1.10	1.09	1.49	1.05	0.97	0.81	0.79	0.27
2	0.82	0.94	1.25	0.86	0.82	0.94	1.25	0.86	1.20	0.76	0.68	0.18
3	1.06	0.92	1.12	0.69	1.05	0.92	1.11	0.69	0.93	0.89	1.12	0.37
4	1.24	1.02	1.20	0.88	1.24	1.02	1.20	0.88	0.84	0.83	0.92	0.30
5	1.42	1.19	1.26	0.93	1.42	1.19	1.26	0.92	0.63	0.68	0.58	0.24
6	1.12	0.99	1.17	0.86	1.12	0.99	1.17	0.86	0.66	0.72	0.76	0.29
7	1.06	1.14	1.33	0.82	1.06	1.14	1.33	0.82	1.21	0.80	0.52	0.11
8	0.66	0.89	1.31	0.89	0.66	0.89	1.31	0.89	0.60	0.70	0.82	0.24
9	1.20	1.04	1.20	0.85	1.20	1.04	1.20	0.85	0.87	0.65	0.57	0.13
10	1.12	1.08	1.27	0.99	1.12	1.08	1.27	0.99	0.76	0.59	0.55	0.21
11	1.28	1.20	1.33	0.93	1.28	1.19	1.33	0.93	0.92	0.78	0.87	0.31
12	1.12	1.07	1.15	0.85	1.12	1.07	1.15	0.85	0.88	0.76	0.98	0.37
13	0.85	0.66	0.81	0.57	0.85	0.66	0.81	0.57	0.60	0.67	0.63	0.23
14	1.28	0.94	0.94	0.68	1.28	0.94	0.94	0.68	1.12	0.73	0.68	0.29
15	1.03	0.85	0.99	0.68	1.03	0.85	1.00	0.68	0.95	0.86	1.16	0.25
16	1.25	1.02	1.27	1.00	1.25	1.02	1.27	1.00	0.56	0.57	0.59	0.27
17	0.83	0.62	0.72	0.50	0.82	0.62	0.72	0.50	0.61	0.69	0.57	0.27
18	1.10	0.87	1.04	0.86	1.10	0.87	1.04	0.86	0.67	0.64	0.77	0.27
19	0.52	0.62	1.08	1.68	0.52	0.62	1.08	1.68	0.66	0.65	0.83	0.29
20	1.05	1.09	1.38	0.94	1.05	1.09	1.38	0.94	0.95	0.93	0.80	0.29
Mean	1.05	0.96	1.17	0.88	1.05	0.96	1.17	0.88	0.83	0.74	0.76	0.26

Note:
Storey height = 2750 mm

Table B.4.7 Inter-storey drift of 6-storey building in E-W direction (without GWB), (%)

No.	Drain-3D												Sapwood					
	Wall 8						Wall 4						Center of the storey diaphragm					
	st1	st2	st3	st4	st5	st6	st1	st2	st3	st4	st5	st6	st1	st2	st3	st4	st5	st6
1	0.76	0.83	0.83	0.75	1.35	0.52	0.80	0.63	1.04	0.81	1.11	0.48	0.51	0.55	0.63	0.53	0.48	0.19
2	0.48	0.51	0.78	0.89	1.62	0.50	0.45	0.49	0.91	0.77	1.43	0.49	0.58	0.62	0.63	0.45	0.32	0.16
3	0.82	0.72	0.78	0.75	1.58	0.49	0.82	0.61	0.96	0.72	1.75	0.48	0.59	0.49	0.61	0.71	0.61	0.21
4	0.92	0.90	0.84	0.72	1.19	0.45	0.95	0.65	1.05	0.64	1.26	0.45	0.51	0.59	0.60	0.52	0.43	0.21
5	1.28	1.21	1.12	0.67	0.66	0.38	1.05	0.79	1.47	0.76	0.93	0.43	0.45	0.43	0.42	0.35	0.32	0.17
6	1.08	1.05	0.92	0.62	0.74	0.40	0.96	0.69	1.13	0.67	1.05	0.42	0.42	0.43	0.43	0.38	0.39	0.20
7	0.58	0.65	0.91	0.97	0.92	0.41	0.58	0.59	1.17	0.83	0.67	0.38	0.64	0.62	0.73	0.47	0.36	0.17
8	1.16	0.82	0.72	0.64	1.04	0.41	1.23	0.64	0.81	0.57	0.91	0.40	0.37	0.44	0.52	0.54	0.37	0.19
9	1.27	1.08	1.05	0.71	0.74	0.42	1.19	0.88	1.43	0.74	0.90	0.47	0.53	0.48	0.47	0.33	0.25	0.13
10	1.03	0.90	0.85	0.64	0.81	0.40	0.88	0.66	1.22	0.77	1.03	0.42	0.45	0.37	0.36	0.27	0.20	0.12
11	0.58	0.71	1.01	0.98	1.37	0.54	0.51	0.61	1.12	0.81	1.39	0.48	0.59	0.61	0.53	0.45	0.32	0.14
12	0.58	0.57	0.78	0.80	0.86	0.48	0.57	0.54	0.90	0.81	1.02	0.49	0.63	0.56	0.55	0.49	0.45	0.23
13	1.35	1.19	1.11	0.77	0.75	0.42	1.16	0.83	1.39	0.72	0.97	0.47	0.42	0.40	0.43	0.38	0.38	0.16
14	1.21	0.94	0.99	0.76	0.76	0.43	1.20	0.76	1.31	0.71	0.75	0.43	0.73	0.56	0.57	0.36	0.32	0.19
15	1.44	1.32	1.26	0.78	0.76	0.43	1.34	0.90	1.63	0.74	0.74	0.41	0.52	0.60	0.60	0.50	0.59	0.22
16	1.29	1.10	0.77	0.61	0.73	0.41	1.29	0.76	1.03	0.65	0.80	0.40	0.38	0.38	0.37	0.32	0.29	0.15
17	1.00	0.83	1.07	0.78	0.79	0.43	0.85	0.65	1.35	0.67	0.89	0.44	0.38	0.40	0.38	0.33	0.27	0.13
18	0.75	0.75	0.98	0.78	0.82	0.43	0.79	0.65	1.22	0.65	0.75	0.39	0.37	0.39	0.39	0.38	0.31	0.17
19	0.54	0.42	0.54	0.52	2.04	0.45	0.54	0.42	0.49	0.47	2.01	0.48	0.36	0.44	0.49	0.49	0.38	0.19
20	1.15	0.82	0.72	0.89	1.91	0.51	1.14	0.70	1.00	0.73	1.93	0.42	0.55	0.60	0.67	0.50	0.46	0.20
Mean	0.96	0.87	0.90	0.75	1.07	0.45	0.91	0.67	1.13	0.71	1.11	0.44	0.50	0.50	0.52	0.44	0.37	0.18

Note:
Storey height = 2750 mm

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Table B.4.8 Inter-storey drift of 6-storey building in N-S direction (without GWB), (%)

No.	Drain-3D												Sapwood					
	Wall 19						Wall 25						Center of the storey diaphragm					
	st1	st2	st3	st4	st5	st6	st1	st2	st3	st4	st5	st6	st1	st2	st3	st4	st5	st6
1	0.80	0.83	0.84	0.90	1.21	0.88	0.80	0.83	0.84	0.90	1.21	0.87	0.51	0.55	0.63	0.53	0.48	0.19
2	0.60	0.55	0.59	0.94	1.47	1.02	0.60	0.55	0.59	0.94	1.47	1.02	0.58	0.62	0.63	0.45	0.32	0.16
3	1.03	0.77	0.73	1.24	1.66	1.17	1.02	0.77	0.73	1.23	1.66	1.17	0.59	0.49	0.61	0.71	0.61	0.21
4	0.85	0.82	0.85	1.03	1.36	1.01	0.85	0.82	0.85	1.03	1.36	1.01	0.51	0.59	0.60	0.52	0.43	0.21
5	0.69	0.75	0.85	1.12	1.26	0.95	0.68	0.75	0.85	1.13	1.26	0.96	0.45	0.43	0.42	0.35	0.32	0.17
6	0.78	0.84	0.93	1.47	1.70	1.39	0.78	0.84	0.93	1.47	1.70	1.39	0.42	0.43	0.43	0.38	0.39	0.20
7	0.89	0.68	0.75	1.05	1.35	0.94	0.89	0.68	0.75	1.05	1.35	0.94	0.64	0.62	0.73	0.47	0.36	0.17
8	1.05	0.88	1.02	1.54	1.63	1.12	1.05	0.88	1.02	1.53	1.62	1.12	0.37	0.44	0.52	0.54	0.37	0.19
9	1.08	0.93	1.06	1.36	1.23	0.93	1.08	0.93	1.06	1.36	1.23	0.92	0.53	0.48	0.47	0.33	0.25	0.13
10	0.77	0.77	0.89	1.50	1.78	1.36	0.77	0.77	0.89	1.49	1.77	1.35	0.45	0.37	0.36	0.27	0.20	0.12
11	0.95	0.74	0.83	1.30	1.37	0.94	0.95	0.74	0.82	1.29	1.37	0.93	0.59	0.61	0.53	0.45	0.32	0.14
12	0.57	0.59	0.53	0.65	0.95	0.81	0.57	0.58	0.53	0.65	0.95	0.81	0.63	0.56	0.55	0.49	0.45	0.23
13	1.14	1.10	1.24	1.59	1.54	1.23	1.14	1.10	1.24	1.59	1.54	1.23	0.42	0.40	0.43	0.38	0.38	0.16
14	1.00	0.93	0.97	1.35	1.51	0.94	1.00	0.93	0.97	1.34	1.50	0.94	0.73	0.56	0.57	0.36	0.32	0.19
15	0.69	0.63	0.72	1.24	1.58	1.24	0.69	0.63	0.72	1.23	1.58	1.24	0.52	0.60	0.60	0.50	0.59	0.22
16	0.81	0.91	1.05	1.43	1.42	1.06	0.80	0.90	1.04	1.42	1.41	1.06	0.38	0.38	0.37	0.32	0.29	0.15
17	0.81	0.82	0.88	1.53	1.90	1.58	0.80	0.81	0.88	1.52	1.90	1.57	0.38	0.40	0.38	0.33	0.27	0.13
18	0.95	0.78	0.76	1.02	1.17	0.84	0.95	0.77	0.76	1.01	1.17	0.84	0.37	0.39	0.39	0.38	0.31	0.17
19	0.58	0.43	0.40	0.66	1.77	1.49	0.58	0.43	0.40	0.66	1.77	1.49	0.36	0.44	0.49	0.49	0.38	0.19
20	1.33	0.84	0.57	0.93	1.99	1.63	1.33	0.84	0.57	0.93	1.98	1.63	0.55	0.60	0.67	0.50	0.46	0.20
Mean	0.87	0.78	0.82	1.19	1.49	1.13	0.87	0.78	0.82	1.19	1.49	1.12	0.50	0.50	0.52	0.44	0.37	0.18

Note:
Storey height = 2750 mm

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B.5 Maximum shear wall deformation at each storey

Table B.5.1 Shear wall deformation of 4-storey building in E-W direction (with GWB), (mm)

No.	Drain-3D							
	Wall 8				Wall 4			
	st1	st2	st3	st4	st1	st2	st3	st4
1	32.9	23.3	16.2	6.0	34.1	19.0	16.3	5.9
2	33.9	22.5	14.7	6.0	38.3	18.5	14.1	4.9
3	31.5	23.4	11.7	5.1	33.6	19.3	11.4	5.4
4	17.1	17.4	16.1	6.8	15.3	13.5	16.8	6.0
5	23.5	13.1	10.9	5.7	24.8	11.6	10.0	5.1
6	15.0	12.0	9.4	3.9	14.0	10.1	9.2	3.7
7	40.0	28.5	12.4	5.1	40.8	24.3	11.3	3.9
8	23.2	25.7	18.6	6.8	27.3	20.8	16.9	6.0
9	17.8	13.4	10.4	4.9	20.4	10.9	9.6	4.0
10	21.2	13.8	12.2	6.1	22.5	11.9	10.9	4.8
11	36.2	20.4	15.5	6.9	37.5	17.8	13.8	4.8
12	42.8	24.4	15.0	6.5	45.4	22.1	15.3	6.2
13	15.0	12.5	10.6	4.7	15.8	10.5	10.4	3.7
14	23.5	11.3	11.6	6.7	24.6	10.0	11.0	5.5
15	31.5	21.3	13.4	5.8	30.7	15.3	13.1	5.0
16	18.3	13.4	10.5	4.8	19.0	11.4	10.4	3.8
17	25.8	13.5	9.4	4.6	26.1	11.2	9.0	4.3
18	18.8	14.9	12.9	6.5	20.2	12.8	13.0	5.3
19	28.5	22.4	16.1	6.3	30.6	17.2	14.9	5.2
20	26.8	27.4	21.8	7.8	28.3	22.4	20.4	6.3
Mean	26.2	18.7	13.5	5.8	27.5	15.5	12.9	5.0

Table B.5.2 Shear wall deformation of 4-storey building in N-S direction (with GWB), (mm)

No.	Drain-3D							
	Wall 19				Wall 25			
	st1	st2	st3	st4	st1	st2	st3	st4
1	21.5	17.6	20.0	8.1	22.0	20.7	22.8	11.3
2	18.0	16.1	13.3	5.6	18.7	17.4	14.8	7.5
3	17.4	14.9	14.5	5.4	18.1	16.2	16.0	7.0
4	23.6	14.4	17.3	8.8	24.1	16.5	19.2	11.4
5	20.9	15.3	14.7	6.9	21.6	16.4	16.2	8.2
6	24.8	16.2	14.7	7.1	25.4	17.3	16.2	8.4
7	22.2	18.2	13.6	4.4	22.8	20.9	16.6	6.7
8	10.5	9.0	13.7	5.3	11.1	10.3	15.7	6.8
9	22.2	17.3	14.7	5.0	22.9	18.9	16.5	6.6
10	23.8	14.6	11.9	5.4	24.5	16.2	13.9	6.4
11	25.2	15.5	11.6	3.7	26.1	19.0	15.1	6.0
12	32.7	22.3	16.4	7.6	33.4	24.2	18.6	9.6
13	21.0	10.5	9.2	4.4	21.5	11.4	10.3	5.0
14	25.4	12.5	10.4	7.0	25.9	13.4	11.5	7.9
15	19.3	14.2	13.3	5.4	20.1	15.6	14.9	6.9
16	20.4	11.9	11.0	4.4	21.0	13.0	12.3	5.7
17	16.6	8.7	8.0	3.2	17.1	9.6	9.0	3.7
18	21.6	13.0	10.2	6.5	22.2	14.0	11.7	7.7
19	14.1	11.8	15.8	7.8	14.2	12.9	17.7	9.0
20	23.0	14.3	14.4	7.6	23.8	17.2	17.5	8.5
Mean	21.2	14.4	13.4	6.0	21.8	16.1	15.3	7.5

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Table B.5.3 Shear wall deformation of 6-storey building in E-W direction (with GWB), (mm)

No.	Drain-3D											
	Wall 8						Wall 4					
	st1	st2	st3	st4	st5	st6	st1	st2	st3	st4	st5	st6
1	19.5	19.0	23.1	20.8	17.6	7.0	17.0	14.6	29.9	18.2	15.0	5.0
2	15.6	14.9	18.7	17.1	14.3	6.8	16.0	13.3	19.7	13.3	12.1	5.5
3	17.0	16.2	16.8	14.4	15.0	7.4	16.1	14.3	21.6	12.0	12.0	5.2
4	19.5	19.1	23.2	20.9	17.6	6.8	18.9	15.9	29.1	18.4	15.7	5.5
5	20.3	18.8	17.4	14.1	10.7	5.0	20.6	14.4	19.5	11.4	9.3	4.0
6	22.5	20.1	17.2	14.8	12.6	5.9	20.6	14.5	17.5	11.7	11.7	4.6
7	16.5	17.7	22.6	19.2	15.3	6.7	15.7	15.0	24.7	13.4	10.7	4.4
8	11.7	12.7	17.1	19.5	19.1	8.1	11.7	11.8	17.0	15.0	16.1	5.7
9	19.7	20.1	22.0	17.3	12.2	5.2	19.0	16.4	28.1	15.6	12.4	4.8
10	17.3	16.5	16.9	14.3	10.8	5.2	18.6	13.9	17.6	10.9	8.9	3.6
11	20.8	21.8	23.4	19.0	13.7	6.4	22.5	18.3	25.5	14.0	11.8	4.7
12	19.9	20.7	20.6	15.5	14.6	7.3	20.0	17.2	24.9	13.3	11.0	4.6
13	15.4	13.8	14.7	12.2	9.2	4.6	13.3	11.9	14.2	9.7	8.5	3.6
14	23.5	16.4	15.8	11.7	10.0	5.9	22.4	14.7	16.7	10.2	9.9	4.6
15	18.3	17.1	17.5	16.0	14.1	6.8	15.1	13.3	18.9	12.1	11.4	4.6
16	15.6	15.6	18.5	16.0	12.3	6.0	14.9	13.2	22.3	13.5	11.4	4.4
17	16.0	13.8	13.3	11.2	9.2	4.5	14.8	11.9	11.9	8.9	7.8	3.3
18	17.1	15.3	16.1	15.5	13.7	6.9	17.1	13.9	18.5	11.0	11.6	5.1
19	10.8	11.6	11.5	13.8	17.2	8.0	10.9	11.4	12.1	11.6	16.0	6.5
20	14.8	17.0	22.5	20.6	16.5	7.6	14.7	14.8	25.1	16.8	14.0	5.4
Mean	17.6	16.9	18.5	16.2	13.8	6.4	17.0	14.2	20.7	13.0	11.9	4.7

Table B.5.4 Shear wall deformation of 6-storey building in N-S direction (with GWB), (mm)

No.	Drain-3D											
	Wall 19						Wall 25					
	st1	st2	st3	st4	st5	st6	st1	st2	st3	st4	st5	st6
1	17.9	12.7	8.9	9.8	11.6	3.9	18.7	13.9	10.2	11.1	12.9	5.3
2	13.3	9.7	7.8	9.6	19.5	8.3	13.7	10.0	8.4	11.0	21.3	10.4
3	22.5	12.7	9.8	14.8	19.1	7.5	23.0	13.4	10.6	17.3	21.6	9.8
4	15.6	11.9	8.6	9.6	15.8	6.4	16.1	12.7	9.4	10.9	17.3	7.8
5	14.8	13.3	11.1	12.2	11.4	3.7	15.3	14.1	12.2	16.0	14.9	5.1
6	17.0	13.6	11.1	13.0	9.6	3.0	18.6	15.4	13.3	15.2	11.5	4.4
7	16.4	10.6	9.3	10.6	11.7	4.0	16.9	11.2	10.1	11.7	13.3	5.2
8	28.5	14.3	11.2	14.2	17.9	6.3	29.0	15.1	12.6	16.3	20.2	8.3
9	21.7	14.1	12.4	13.8	10.3	3.3	24.0	16.3	15.3	17.0	13.4	5.9
10	14.8	12.1	10.4	15.1	18.5	7.6	15.2	12.7	11.5	18.6	21.3	10.3
11	15.6	10.2	10.0	13.5	12.8	5.7	16.1	11.1	11.3	15.1	14.5	7.3
12	13.9	10.4	9.2	9.5	9.7	7.1	14.0	10.6	9.7	10.2	10.5	7.9
13	21.2	14.0	11.0	11.5	9.8	3.2	21.8	15.8	13.7	14.1	11.4	4.5
14	23.4	14.7	12.3	16.4	13.6	5.8	23.9	15.6	13.7	18.2	15.5	7.3
15	15.4	13.1	11.9	17.8	15.3	6.9	16.7	14.1	13.9	20.6	18.3	9.7
16	18.4	13.3	10.5	11.0	10.8	4.1	19.2	14.1	11.8	13.9	13.1	5.8
17	22.3	12.3	12.0	18.6	15.5	6.5	22.8	13.0	13.5	21.8	19.0	9.6
18	15.8	12.4	9.4	12.7	9.4	3.7	16.3	13.2	11.0	15.2	11.8	5.5
19	11.8	9.6	6.0	6.8	12.9	7.0	11.9	9.8	6.1	7.4	14.3	7.9
20	27.7	13.9	8.5	11.6	31.0	13.4	28.2	14.5	9.2	14.1	34.7	17.4
Mean	18.4	12.4	10.1	12.6	14.3	5.9	19.1	13.3	11.4	14.8	16.5	7.8

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Table B.5.5 Shear wall deformation of 4-storey building in E-W direction (without GWB), (mm)

No.	Drain-3D							
	Wall 8				Wall 4			
	st1	st2	st3	st4	st1	st2	st3	st4
1	27.6	27.5	39.7	10.3	28.8	22.1	44.8	9.8
2	26.8	25.3	28.0	9.1	28.9	20.1	29.8	9.4
3	26.7	24.4	28.2	9.2	29.2	17.4	34.2	8.3
4	29.9	26.7	30.1	8.7	29.8	19.9	37.7	8.4
5	19.7	19.8	23.8	9.0	21.1	16.4	23.7	8.3
6	38.9	17.0	21.6	9.2	41.5	15.1	22.1	9.1
7	32.2	31.3	18.0	7.3	35.5	26.6	18.5	6.6
8	12.9	16.1	39.5	10.3	12.7	11.1	48.0	9.8
9	24.9	22.7	24.9	9.5	25.8	18.3	28.9	8.5
10	33.4	23.5	15.1	7.7	31.2	20.0	18.3	7.4
11	33.8	26.4	15.3	7.2	36.8	22.5	16.0	7.0
12	37.8	28.0	28.1	10.9	29.6	27.6	35.0	10.8
13	21.7	18.0	20.4	10.0	22.3	15.7	24.4	8.5
14	36.3	17.9	15.2	8.3	37.5	15.3	15.8	8.2
15	23.8	21.4	26.6	10.2	26.4	18.8	29.2	9.2
16	21.3	16.6	17.1	7.7	21.8	16.1	19.2	6.7
17	27.7	17.2	15.2	8.2	24.9	14.0	21.1	7.5
18	25.4	18.2	16.8	15.2	30.0	13.2	17.3	14.5
19	16.7	18.5	41.0	11.7	18.5	13.0	47.3	10.9
20	32.0	29.3	30.1	10.5	31.2	21.8	36.1	10.7
Mean	27.5	22.3	24.7	9.5	28.2	18.2	28.4	9.0

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Table B.5.6 Shear wall deformation of 4-storey building in N-S direction (without GWB), (mm)

No.	Drain-3D							
	Wall 19				Wall 25			
	st1	st2	st3	st4	st1	st2	st3	st4
1	25.8	21.0	28.7	15.6	26.5	22.5	30.7	17.9
2	17.8	15.3	20.7	12.5	18.6	17.0	23.2	14.1
3	26.3	17.8	20.8	8.7	26.8	18.9	22.0	9.7
4	29.7	20.2	23.1	14.1	30.3	21.2	24.8	15.8
5	35.2	24.5	23.8	15.1	35.7	25.7	25.6	17.0
6	26.2	16.7	21.0	12.0	26.8	19.1	22.9	13.7
7	25.3	20.7	22.4	8.2	25.9	22.5	24.6	10.3
8	15.2	14.0	21.6	8.5	15.7	15.7	24.4	11.4
9	29.2	19.9	19.1	7.8	29.7	21.0	21.0	10.0
10	27.0	19.8	19.3	9.7	27.6	21.2	22.5	13.4
11	31.1	23.3	20.6	7.9	31.7	24.4	23.6	11.1
12	26.7	21.4	21.7	9.9	27.2	22.5	23.0	11.8
13	20.5	11.4	13.4	6.6	20.9	12.3	14.6	7.3
14	31.4	17.2	17.4	9.1	31.9	18.5	18.5	10.2
15	24.5	15.0	17.5	7.6	25.1	16.1	18.7	8.9
16	30.5	20.2	19.5	10.3	31.1	21.3	22.8	14.3
17	19.8	10.1	9.8	5.2	20.2	10.9	10.9	5.9
18	26.1	15.1	15.2	9.5	26.7	16.0	17.5	11.4
19	14.1	9.1	20.0	36.9	14.1	9.9	21.4	38.5
20	23.6	18.1	26.8	16.2	24.4	20.8	28.5	17.9
Mean	25.2	17.5	20.1	11.6	25.8	18.9	22.1	13.5

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Table B.5.7 Shear wall deformation of 6-storey building in E-W direction (without GWB), (mm)

No.	Drain-3D											
	Wall 8						Wall 4					
	st1	st2	st3	st4	st5	st6	st1	st2	st3	st4	st5	st6
1	20.1	21.3	20.7	17.8	33.7	10.2	21.0	15.2	26.3	19.1	27.7	9.3
2	12.5	12.6	19.2	22.0	42.1	10.9	11.9	11.6	22.4	18.0	37.4	10.3
3	21.8	18.3	18.7	17.6	40.4	10.1	21.9	15.3	24.4	16.5	44.9	9.0
4	24.2	23.0	20.8	16.6	29.1	8.3	24.9	15.6	26.0	14.6	31.5	8.3
5	34.2	31.5	28.6	15.7	15.0	7.8	27.6	19.2	37.3	17.7	21.4	7.5
6	28.7	27.2	23.2	14.3	16.9	7.5	25.2	16.8	28.6	15.4	25.3	7.5
7	15.0	16.0	22.6	23.9	23.0	9.1	14.8	14.2	29.9	19.3	15.2	6.9
8	31.2	20.7	17.3	15.0	26.3	8.3	32.7	15.6	20.2	13.3	22.5	7.6
9	34.1	28.3	26.0	16.4	17.1	7.6	31.5	22.1	36.3	17.6	21.9	8.5
10	27.2	23.1	21.3	14.7	19.6	7.7	23.0	16.0	30.3	17.2	24.4	7.8
11	15.0	17.9	25.2	24.4	35.0	11.1	12.9	14.8	27.7	18.7	35.0	8.6
12	15.0	14.1	18.9	19.1	21.0	10.3	14.8	13.4	22.3	19.4	24.9	10.4
13	36.1	30.9	28.1	18.3	17.4	8.2	30.6	20.4	35.4	16.0	22.4	8.1
14	32.2	24.4	24.7	18.1	18.6	9.0	31.7	19.4	33.7	17.0	17.9	7.7
15	38.6	34.3	32.1	18.5	17.3	8.7	35.5	22.6	42.3	17.4	16.4	7.6
16	34.6	28.5	18.8	13.9	17.8	7.9	34.8	18.9	25.6	15.1	19.5	7.7
17	26.4	21.1	27.1	18.7	18.0	8.1	22.2	15.8	34.3	14.7	21.3	8.0
18	19.5	18.9	24.5	18.6	19.3	8.7	20.9	15.8	30.6	14.4	16.5	7.2
19	14.6	10.8	13.1	12.2	55.1	11.5	14.4	11.2	11.7	10.8	54.0	11.5
20	30.7	21.1	17.9	22.2	50.6	10.7	30.6	17.8	25.8	16.9	50.7	9.4
Mean	25.6	22.2	22.4	17.9	26.7	9.1	24.1	16.6	28.6	16.5	27.5	8.4

Table B.5.8 Shear wall deformation of 6-storey building in N-S direction (without GWB), (mm)

No.	Drain-3D											
	Wall 19						Wall 25					
	st1	st2	st3	st4	st5	st6	st1	st2	st3	st4	st5	st6
1	16.8	13.3	10.3	12.0	19.1	8.3	17.4	14.3	11.5	13.2	20.4	9.7
2	13.7	10.0	7.4	11.1	27.0	13.7	14.1	10.6	7.9	12.7	28.6	15.4
3	25.4	15.7	10.2	18.9	27.8	13.6	25.7	16.4	11.2	20.9	30.1	16.1
4	19.4	13.3	10.1	11.4	20.6	9.0	19.7	14.2	11.2	12.9	22.1	10.9
5	15.1	12.4	10.2	13.2	14.0	6.3	15.4	13.1	11.4	15.1	16.3	7.6
6	17.2	13.4	11.8	17.9	18.1	9.7	17.7	14.3	13.2	20.3	21.4	12.5
7	20.3	11.5	10.2	15.4	19.5	7.1	20.8	12.4	11.1	16.7	21.1	8.4
8	25.1	14.5	14.4	25.1	26.9	14.0	25.5	15.8	16.3	27.5	30.1	17.2
9	23.8	15.4	14.9	19.5	14.4	6.5	24.7	16.9	16.9	21.7	16.5	8.4
10	17.7	13.9	11.7	21.7	26.5	13.1	18.1	14.7	12.9	25.1	29.8	16.8
11	21.8	12.8	10.5	19.5	19.0	6.5	22.3	13.6	11.6	21.0	20.6	7.8
12	14.7	13.1	9.2	9.9	14.1	11.8	14.9	13.4	9.6	10.6	15.2	13.1
13	22.7	16.5	13.8	18.4	17.3	7.3	24.1	17.8	16.6	21.7	19.5	9.0
14	23.5	16.9	15.2	22.2	23.1	9.1	24.0	17.9	16.8	24.1	25.1	10.7
15	14.7	11.0	9.4	18.5	24.5	13.6	15.2	11.5	10.3	20.5	27.1	16.5
16	16.7	14.2	13.8	20.2	16.7	7.6	17.3	15.7	15.8	22.5	19.0	9.3
17	17.5	14.0	11.4	22.6	29.0	18.5	18.0	14.7	12.7	26.2	33.4	23.4
18	21.9	13.9	10.6	12.1	14.9	6.8	22.4	14.6	11.4	13.8	16.8	7.6
19	14.4	10.5	8.4	8.6	33.7	30.3	14.7	10.7	8.7	9.6	35.9	32.4
20	34.2	18.4	10.1	12.3	40.0	31.9	34.7	19.2	10.7	13.9	42.6	34.6
Mean	19.8	13.7	11.2	16.5	22.3	12.2	20.3	14.6	12.4	18.5	24.6	14.4

B.6 Maximum uplift forces and deformations

Table B.6.1 Maximum uplift forces of 4-storey building in E-W direction (with GWB), (kN)

No.	Drain-3D								Sapwood							
	Wall 8				Wall 4				Wall 4 - method A				Wall 4- method B			
	st1	st2	st3	st4	st1	st2	st3	st4	st1	st2	st3	st4	st1	st2	st3	st4
1	39.0	20.8	8.2	0.0	59.8	30.8	9.4	0	50.4	26.5	20.1	6.8	19.8	21.9	14.8	6.3
2	49.3	22.3	8.0	0.2	63.2	32.9	11.3	0.3	59.3	28.7	19.6	7.3	39.0	32.3	17.1	5.9
3	29.4	11.6	7.3	1.1	36.3	14.0	8.3	1.1	63.5	34.6	26.4	11.4	33.3	37.8	23.7	9.5
4	30.6	22.4	12.1	2.2	36.8	27.3	13.5	3.0	64.1	35.9	29.1	13.3	35.2	37.4	24.3	11.0
5	32.3	15.8	7.1	0.3	32.9	16.6	8.7	0.4	45.1	26.3	18.3	10.9	22.8	23.7	13.8	6.1
6	27.9	12.4	0.0	0.0	36.7	17.0	0	0	53.2	27.5	21.1	9.8	25.3	23.6	16.3	7.1
7	42.9	20.9	4.7	0.0	66.4	32.2	6.4	0	26.1	17.7	16.2	7.9	21.4	18.6	6.6	4.0
8	50.7	26.5	10.5	1.9	62.7	39.2	14.6	2.4	55.1	28.4	23.5	17.6	30.7	34.7	20.8	9.2
9	37.3	16.5	3.3	0.0	43.5	22.2	4.0	0	45.9	20.5	16.0	6.7	22.5	25.8	14.0	5.8
10	36.2	18.5	7.3	0.0	37.0	23.2	9.6	0	54.1	25.5	18.5	10.0	21.8	25.7	13.9	6.5
11	51.3	28.1	8.1	0.1	62.2	32.7	11.4	0.1	75.7	37.8	26.9	9.6	33.1	30.4	22.4	12.6
12	46.0	25.0	10.8	1.6	58.1	31.9	12.2	1.9	80.6	46.8	36.7	19.2	32.9	34.8	22.2	12.5
13	32.1	17.2	4.7	0.0	45.2	24.0	5.9	0	45.4	24.2	15.3	8.1	22.8	22.1	11.3	5.4
14	23.2	8.7	9.2	1.1	25.5	8.5	10.7	1.5	58.3	26.5	18.9	12.0	37.8	28.3	17.4	8.0
15	36.5	18.6	7.1	0.0	49.4	25.8	7.9	0	61.5	35.3	23.1	11.3	32.7	33.1	20.9	10.9
16	15.1	36.6	18.3	33.9	20.2	44.0	20.2	44.0	44.6	23.6	20.1	10.0	23.2	21.1	13.7	5.7
17	33.1	15.1	2.8	0.0	48.3	21.1	3.2	0	43.3	25.1	23.5	12.5	30.1	24.2	13.5	6.6
18	36.5	21.1	8.0	0.8	52.6	31.2	11.4	1.1	40.2	23.6	24.6	12.2	26.8	22.7	19.7	10.1
19	40.8	21.8	8.3	0.9	61.7	33.0	12.0	1.3	52.8	37.3	28.4	14.4	32.2	37.0	25.1	12.4
20	46.0	27.8	12.1	2.6	70.6	42.1	17.9	3.8	55.6	26.9	19.7	10.4	35.3	33.9	21.5	10.2
Mean	36.8	20.4	7.9	2.3	48.4	27.5	10.4	5.1	53.7	28.9	22.3	11.1	28.9	28.4	17.7	8.3

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Table B.6.2 Maximum uplift forces of 4-storey building in N-S direction (with GWB), (kN)

No.	Drain-3D								Sapwood							
	Wall 19				Wall 25				Wall 25 - method A				Wall 25 - method B			
	st1	st2	st3	st4	st1	st2	st3	st4	st1	st2	st3	st4	st1	st2	st3	st4
1	110.8	58.8	29.5	6.9	97.5	58.7	30.7	11.1	9.0	5.7	6.3	4.0	34.9	37.6	26.5	14.1
2	106.2	58.7	34.4	13.4	90.9	58.7	33.5	16.2	15.8	8.3	7.6	5.9	40.3	36.0	24.2	9.8
3	84.9	58.7	38.7	14.2	74.3	57.6	35.0	15.1	16.2	7.5	7.5	4.8	39.4	39.2	29.1	15.6
4	87.2	58.7	36.9	13.8	75.2	53.7	32.7	14.0	12.2	6.8	8.6	6.3	38.5	37.9	27.5	13.6
5	102.2	58.7	34.9	10.6	88.7	58.7	32.7	11.7	13.0	7.1	8.0	5.0	32.7	33.7	23.2	10.7
6	110.4	58.8	30.6	6.6	98.4	58.7	32.4	11.6	15.0	7.1	6.4	5.0	31.7	33.2	24.6	15.0
7	114.5	58.8	32.8	10.4	101.2	58.7	34.1	14.2	8.6	6.7	5.9	3.3	21.3	14.9	11.6	4.9
8	96.3	58.7	40.3	13.0	84.5	58.7	37.0	14.8	16.0	9.7	11.7	8.2	33.6	36.4	25.8	13.0
9	104.3	58.7	27.7	4.5	89.8	56.5	28.4	8.7	15.7	7.4	5.9	3.2	35.9	31.7	21.1	7.7
10	108.7	58.7	34.2	9.8	93.5	58.7	34.1	13.7	13.9	9.0	8.4	4.8	32.7	33.5	23.6	10.4
11	115.1	58.8	31.5	6.4	103.0	58.8	33.5	12.7	22.2	10.4	8.0	5.1	39.5	37.2	27.7	14.3
12	102.4	58.7	41.6	15.2	89.4	58.7	39.5	17.7	18.4	12.4	13.8	7.4	38.9	36.4	28.3	17.6
13	79.1	44.6	23.9	6.6	69.0	41.3	23.1	7.3	14.8	6.9	5.1	4.1	33.3	34.1	24.0	12.9
14	72.1	41.8	24.4	18.6	62.5	38.2	23.1	16.9	14.6	8.0	8.0	5.8	40.9	36.8	23.5	14.7
15	106.5	58.7	32.7	6.7	94.4	58.7	31.9	10.6	19.2	11.1	13.4	6.3	42.1	38.6	28.8	13.3
16	79.7	41.1	21.7	8.2	69.1	38.1	21.0	8.6	15.3	7.7	7.1	4.3	31.0	32.5	23.4	12.4
17	91.2	53.1	22.3	5.6	79.8	49.3	22.2	6.5	20.8	11.5	10.4	5.5	32.8	36.2	24.0	13.2
18	86.6	58.7	36.6	17.2	75.7	53.6	32.7	16.7	14.2	9.4	10.8	5.5	33.5	33.6	25.6	13.6
19	89.2	58.7	46.8	19.3	78.2	58.7	42.4	20.0	15.5	8.3	8.5	5.8	31.6	34.3	26.7	15.0
20	114.9	58.8	36.6	13.9	99.0	58.7	36.9	17.9	17.3	10.0	9.2	7.2	38.6	37.3	26.5	14.4
Mean	98.1	56.0	32.9	11.0	85.7	54.7	31.8	13.3	15.4	8.5	8.5	5.4	35.2	34.5	24.8	12.8

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Table B.6.3 Maximum uplift deformation of 4-storey building in E-W direction (with GWB), (mm)

No.	Drain-3D								Sapwood							
	Wall 8				Wall 4				Wall 4 - method A				Wall 4- method B			
	st1	st2	st3	st4	st1	st2	st3	st4	st1	st2	st3	st4	st1	st2	st3	st4
1	1.40	1.26	0.50	0.00	2.10	2.07	0.62	0	1.78	1.84	1.39	0.47	0.70	1.52	1.03	0.44
2	1.78	1.35	0.49	0.01	2.22	2.22	0.76	0.01	2.10	1.99	1.36	0.51	1.38	2.24	1.19	0.41
3	1.03	0.70	0.48	0.09	1.27	0.92	0.59	0.10	2.24	2.40	1.83	0.79	1.18	2.62	1.64	0.66
4	1.16	1.38	0.78	0.13	1.29	1.81	0.92	0.20	2.27	2.49	2.02	0.92	1.24	2.59	1.68	0.76
5	1.14	1.04	0.48	0.02	1.15	1.08	0.61	0.03	1.60	1.82	1.27	0.76	0.81	1.65	0.96	0.42
6	1.06	0.76	0.00	0.00	1.28	1.12	0	0	1.88	1.91	1.46	0.68	0.89	1.64	1.13	0.49
7	1.53	1.29	0.30	0.00	2.35	2.22	0.44	0	0.92	1.22	1.12	0.55	0.76	1.29	0.46	0.27
8	1.79	1.55	0.64	0.11	2.20	2.63	0.97	0.14	1.95	1.97	1.63	1.22	1.09	2.40	1.44	0.64
9	1.30	1.07	0.21	0.00	1.52	1.48	0.27	0	1.62	1.42	1.11	0.46	0.80	1.79	0.97	0.40
10	1.24	1.12	0.47	0.00	1.28	1.51	0.65	0	1.91	1.76	1.28	0.69	0.77	1.78	0.97	0.45
11	1.71	1.77	0.50	0.00	2.19	2.21	0.77	0	2.68	2.62	1.86	0.66	1.17	2.11	1.55	0.87
12	1.61	1.49	0.69	0.10	2.03	2.13	0.83	0.13	2.85	3.24	2.55	1.33	1.16	2.41	1.54	0.87
13	1.12	1.04	0.29	0.00	1.59	1.62	0.38	0	1.60	1.68	1.06	0.56	0.81	1.53	0.79	0.37
14	0.06	0.52	0.63	0.08	0.07	0.51	0.74	0.11	2.06	1.84	1.31	0.83	1.34	1.96	1.21	0.55
15	1.27	1.14	0.47	0.00	1.73	1.70	0.56	0	2.17	2.44	1.60	0.78	1.16	2.30	1.45	0.76
16	1.00	0.98	0.16	0.00	1.32	1.22	0.19	0	1.58	1.64	1.40	0.69	0.82	1.46	0.95	0.40
17	1.17	0.95	0.17	0.00	1.69	1.40	0.21	0	1.53	1.74	1.63	0.86	1.06	1.67	0.94	0.46
18	1.28	1.28	0.50	0.05	1.84	2.09	0.76	0.07	1.42	1.64	1.71	0.84	0.95	1.57	1.37	0.70
19	1.50	1.47	0.51	0.05	2.15	2.21	0.80	0.07	1.87	2.58	1.97	0.99	1.14	2.56	1.74	0.86
20	1.63	1.64	0.74	0.15	2.48	2.84	1.21	0.25	1.97	1.86	1.36	0.72	1.25	2.35	1.49	0.71
Mean	1.29	1.19	0.45	0.04	1.69	1.75	0.65	0.11	1.90	2.01	1.55	0.77	1.02	1.97	1.22	0.57

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Table B.6.4 Maximum uplift deformation of 4-storey building in N-S direction (with GWB), (mm)

No.	Drain-3D								Sapwood							
	Wall 19				Wall 25				Wall 25 - method A				Wall 25 - method B			
	st1	st2	st3	st4	st1	st2	st3	st4	st1	st2	st3	st4	st1	st2	st3	st4
1	3.93	8.27	2.05	0.48	3.46	5.53	2.13	0.77	0.32	0.39	0.44	0.28	1.23	2.61	1.84	0.98
2	3.77	6.91	2.39	0.93	3.22	4.67	2.33	1.13	0.56	0.57	0.53	0.41	1.42	2.50	1.68	0.68
3	3.01	4.94	2.69	0.98	2.64	4.00	2.44	1.05	0.57	0.52	0.52	0.33	1.39	2.72	2.02	1.08
4	3.09	4.58	2.57	0.96	2.67	3.73	2.27	0.97	0.43	0.47	0.59	0.44	1.36	2.63	1.90	0.94
5	3.62	5.88	2.43	0.74	3.15	4.31	2.27	0.81	0.46	0.49	0.55	0.35	1.15	2.33	1.61	0.74
6	3.91	8.88	2.12	0.46	3.49	5.81	2.25	0.81	0.53	0.49	0.44	0.34	1.12	2.30	1.70	1.04
7	4.06	10.29	2.28	0.72	3.59	7.32	2.37	0.99	0.31	0.47	0.41	0.23	0.75	1.03	0.81	0.34
8	3.42	6.55	2.80	0.91	3.00	5.13	2.57	1.03	0.57	0.67	0.81	0.57	1.19	2.52	1.79	0.90
9	3.70	5.51	1.93	0.31	3.18	3.92	1.97	0.60	0.56	0.51	0.41	0.22	1.27	2.20	1.46	0.54
10	3.85	7.23	2.37	0.68	3.32	4.53	2.37	0.95	0.49	0.62	0.58	0.33	1.16	2.32	1.64	0.72
11	4.39	10.78	2.19	0.44	3.65	7.54	2.33	0.88	0.79	0.72	0.55	0.36	1.40	2.58	1.92	0.99
12	3.63	7.46	2.89	1.06	3.17	5.36	2.75	1.23	0.65	0.86	0.96	0.51	1.38	2.53	1.96	1.22
13	2.81	3.10	1.66	0.46	2.45	2.87	1.60	0.50	0.52	0.48	0.36	0.28	1.18	2.36	1.66	0.90
14	2.56	2.90	1.69	1.29	2.22	2.65	1.61	1.17	0.51	0.55	0.56	0.40	1.45	2.55	1.63	1.02
15	3.77	7.33	2.27	0.47	3.35	5.12	2.22	0.74	0.68	0.77	0.93	0.44	1.49	2.68	1.99	0.92
16	2.82	2.86	1.51	0.57	2.45	2.65	1.46	0.60	0.54	0.54	0.49	0.30	1.10	2.25	1.62	0.86
17	3.23	3.69	1.55	0.39	2.83	3.43	1.54	0.45	0.74	0.80	0.72	0.38	1.16	2.51	1.67	0.92
18	3.07	4.29	2.55	1.19	2.68	3.73	2.27	1.16	0.50	0.65	0.75	0.38	1.18	2.33	1.78	0.94
19	3.16	5.84	3.25	1.34	2.77	4.53	2.94	1.39	0.55	0.58	0.59	0.40	1.12	2.38	1.85	1.04
20	4.07	9.64	2.54	0.97	3.51	6.59	2.56	1.25	0.61	0.69	0.64	0.50	1.36	2.58	1.83	0.99
Mean	3.49	6.35	2.29	0.77	3.04	4.67	2.21	0.92	0.54	0.59	0.59	0.37	1.24	2.39	1.72	0.89

Table B.6.5 Maximum uplift forces of 6-storey building in E-W direction (with GWB), (kN)

No.	Drain-3D												Sapwood											
	Wall 8						Wall 4						Wall 4 - method A						Wall 4- method B					
	st1	st2	st3	st4	st5	st6	st1	st2	st3	st4	st5	st6	st1	st2	st3	st4	st5	st6	st1	st2	st3	st4	st5	st6
1	77.1	53.8	46.9	22.3	8.7	1.3	134.0	94.2	57.5	29.4	11.3	1.6	94.7	56.0	55.4	37.9	25.6	12.6	37.2	40.8	35.6	32.4	18.2	8.3
2	103.5	59.2	42.5	22.0	9.9	2.2	114.1	87.1	62.9	35.2	14.8	3.0	77.8	50.0	45.8	23.9	16.1	8.9	46.0	46.6	38.0	31.3	17.2	5.6
3	72.9	49.2	40.9	25.4	10.0	4.2	84.2	67.3	49.3	31.8	14.6	2.2	137.3	82.0	77.0	46.0	28.4	10.2	44.8	41.9	35.1	34.5	21.7	8.4
4	78.6	58.3	41.8	24.6	9.3	0.3	104.8	69.4	50.5	30.6	11.4	0.4	97.8	55.9	62.4	42.2	29.7	14.3	40.5	43.5	33.2	32.6	18.9	8.6
5	96.0	60.1	32.2	13.7	4.5	0.0	108.3	71.6	38.1	16.5	4.9	0	84.7	51.5	51.0	35.6	22.9	9.7	33.5	35.3	28.4	22.1	14.8	7.3
6	88.7	56.8	44.5	22.7	8.9	0.0	126.4	91.3	57.6	32.1	11.1	0.1	112.2	66.5	66.4	37.2	24.2	11.9	34.0	34.1	28.1	22.7	15.7	7.0
7	130.8	63.6	44.4	22.2	7.4	0.0	140.7	102.4	65.1	34.2	11.1	0.0	46.0	26.4	25.2	17.7	13.5	6.7	30.9	32.0	21.5	15.5	8.2	3.8
8	50.2	62.0	47.1	26.2	11.1	2.3	113.3	92.7	68.6	41.4	17.8	3.5	89.9	58.9	55.0	35.3	31.3	15.1	31.7	35.5	28.0	29.5	17.1	7.0
9	109.4	73.0	45.9	24.0	6.6	0.0	126.0	92.6	57.1	30.4	8.5	0	122.7	70.9	65.2	40.7	26.5	10.2	37.5	35.3	27.5	22.0	12.9	5.7
10	106.3	66.8	36.4	20.8	5.0	0.0	121.2	86.3	53.5	28.4	6.9	0	92.0	52.6	48.8	29.2	17.8	8.8	33.0	28.4	21.6	17.7	9.4	5.6
11	122.8	73.7	46.2	23.2	8.9	0.6	137.2	101.5	67.9	36.6	13.1	0.8	111.4	67.0	69.0	43.4	26.4	10.6	38.8	38.5	29.6	25.3	13.7	5.6
12	69.7	52.8	39.2	23.4	8.9	0.4	80.0	64.5	48.6	29.0	12.3	0.5	92.1	57.1	55.8	39.6	33.1	16.4	42.8	44.3	33.6	29.7	20.1	9.6
13	80.2	51.7	35.4	18.0	4.6	0.0	88.3	60.7	40.4	21.6	5.6	0	126.5	77.4	72.7	42.1	25.2	13.5	33.0	31.0	24.9	22.2	16.6	8.5
14	73.9	46.6	30.1	12.5	7.5	0.3	86.2	57.6	35.3	14.7	8.5	0.4	112.9	71.7	69.3	45.2	26.6	14.4	52.9	44.9	34.5	23.6	15.8	8.2
15	90.1	55.3	42.1	22.0	8.2	0.4	134.3	97.2	61.5	35.0	12.7	0.5	107.5	65.4	65.3	45.6	27.0	14.2	45.1	46.9	35.0	26.9	21.1	9.4
16	89.3	58.2	41.5	21.7	8.5	0.0	101.3	74.4	48.1	27.2	10.7	0.1	78.4	44.1	46.1	30.0	26.5	12.1	29.9	32.1	26.5	20.1	12.7	7.4
17	80.0	40.8	27.1	12.5	1.7	0.0	90.1	54.9	33.6	16.3	2.1	0	104.6	62.4	61.5	36.6	21.9	12.0	31.5	31.4	24.1	22.1	12.1	6.5
18	70.8	63.9	41.2	20.3	12.3	1.5	108.9	80.9	51.6	27.1	14.1	1.9	62.4	40.1	45.3	30.1	23.0	11.9	29.2	31.9	27.1	24.8	14.8	6.9
19	75.0	54.1	49.6	26.3	13.1	3.7	87.2	67.0	58.4	40.3	20.3	5.7	81.0	60.3	63.3	39.9	30.9	20.1	30.8	37.9	32.3	32.1	20.2	8.2
20	97.3	67.3	47.3	24.7	8.1	1.5	132.9	100.9	71.4	40.2	14.7	2.5	68.6	45.6	48.6	30.7	23.4	11.9	37.8	39.1	35.1	30.1	20.2	9.1
Mean	88.1	58.3	41.1	21.4	8.2	0.9	111.0	80.7	53.8	29.9	11.3	1.5	95.0	58.1	57.5	36.4	25.0	12.3	37.1	37.6	30.0	25.9	16.1	7.3

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Table B.6.6 Maximum uplift forces of 6-storey building in N-S direction (with GWB), (kN)

No.	Drain-3D												Sapwood											
	Wall 19						Wall 25						Wall 25 - method A						Wall 25 - method B					
	st1	st2	st3	st4	st5	st6	st1	st2	st3	st4	st5	st6	st1	st2	st3	st4	st5	st6	st1	st2	st3	st4	st5	st6
1	190.3	126.1	74.9	49.4	26.2	8.3	177.4	119	72.4	48.3	26.3	9.6	19.6	18.5	13.3	9.8	7.2	5.0	35.1	40.6	48.0	41.5	26.0	9.3
2	99.9	94.4	82.2	58.7	35.9	9.6	92.0	88.2	76.7	58.7	33.3	10.5	37.9	35.5	22.9	12.9	7.8	4.2	52.0	54.2	50.6	40.5	25.2	9.4
3	125.5	83.6	71.8	55.8	33.6	6.0	109.7	78.5	67.5	52.3	30.9	8.2	29.9	24.3	15.2	9.0	7.3	4.3	62.0	56.4	50.0	40.0	31.0	18.[illegible]
4	182.9	122.0	92.7	58.8	47.1	19.0	162.1	113.9	89.2	58.7	42.0	19.1	29.3	23.4	13.7	9.8	9.0	4.2	52.4	51.4	47.7	38.0	27.9	14.[illegible]
5	190.3	152.9	114.4	58.8	32.1	3.5	190.3	152.5	113.2	58.8	36.0	12.0	31.0	29.7	18.6	12.9	8.7	4.4	41.0	47.6	42.0	29.9	24.4	12.[illegible]
6	190.3	154.5	99.5	58.6	22.8	1.7	190.3	151.8	101.9	58.7	28.7	6.5	29.3	26.5	14.0	9.1	6.7	3.7	51.3	49.8	40.9	35.1	25.9	15.[illegible]
7	158.9	111.6	82.8	58.7	37.1	9.5	140.9	105.5	80.0	58.7	34.2	11.2	16.5	17.0	11.2	7.6	5.3	2.9	37.6	33.4	29.2	20.1	13.2	4.7
8	156.4	110.8	83.0	58.7	37.9	10.6	137.1	103.4	78.4	58.7	34.8	11.3	30.0	31.9	21.3	14.0	10.8	5.5	48.6	44.0	40.2	35.1	26.5	12.[illegible]
9	190.3	136.5	74.2	39.1	15.4	0.1	190.3	135.0	79.4	40.6	16.8	2.4	29.2	22.5	13.1	9.8	7.9	4.2	54.4	51.8	41.4	35.6	25.7	13.[illegible]
10	190.2	145.4	104.6	58.7	27.9	6.0	175.0	134.5	98.0	58.7	29.7	9.8	25.5	21.8	12.9	9.8	7.7	3.4	42.8	41.7	35.5	25.8	18.3	8.3
11	162.5	122.7	93.7	58.7	35.0	6.5	145.4	114.3	88.4	58.7	33.2	9.7	40.6	40.2	27.0	17.0	11.9	5.4	47.5	50.9	40.5	32.8	25.7	13.[illegible]
12	110.5	71.2	58.4	45.6	33.5	14.8	97.3	64.9	54.4	43.2	30.3	13.3	24.6	23.1	14.6	12.0	9.9	5.0	54.7	52.7	44.9	37.3	26.1	16.[illegible]
13	190.3	159.7	100.8	57.3	19.2	0.2	190.3	158.3	103.6	58.7	27.3	5.2	33.4	30.1	19.7	11.8	7.5	3.6	53.4	51.6	45.2	36.8	28.2	16.[illegible]
14	158.9	115.4	78.7	52.6	39.5	16.1	143.1	107.9	72.8	47.1	36.3	17.1	27.3	23.4	14.9	10.4	6.6	5.1	65.9	55.4	47.4	38.1	23.7	14.[illegible]
15	177.6	116.6	77.4	45.3	18.5	1.3	157.6	110.0	74.7	45.1	19.1	4.4	31.7	29.6	19.4	14.3	9.5	4.8	56.8	51.2	50.3	40.2	29.2	15.[illegible]
16	190.3	151.6	104.5	58.7	29.7	2.7	190.3	153.2	105.2	58.7	32.8	10.1	24.5	22.1	14.0	9.7	8.1	4.8	47.1	46.6	45.8	36.4	25.4	14.[illegible]
17	190.3	145.6	107.3	58.8	31.4	7.8	179.7	137.8	102.4	58.8	34.2	13.1	37.6	33.5	20.4	11.5	7.0	3.8	51.8	50.4	43.7	38.3	25.0	15.[illegible]
18	190.3	149.9	107.4	58.7	29.9	9.5	183.3	142.7	103.1	58.7	32.1	12.3	29.7	26.7	17.6	13.1	9.6	5.3	40.3	39.3	35.9	29.5	24.1	12.[illegible]
19	47.8	59.5	65.8	58.7	46.7	19.0	42.8	55.4	60.7	55.8	41.4	19.0	22.8	23.0	14.1	11.2	8.4	6.7	50.5	46.9	42.0	37.0	26.7	14.[illegible]
20	89.5	98.0	94.0	58.8	45.0	15.5	83.3	91.5	87.7	58.8	41.9	16.0	27.9	29.3	17.7	11.3	8.1	4.5	60.0	52.3	49.8	40.0	28.1	17.[illegible]
Mean	159.1	121.4	88.4	55.4	32.2	8.4	148.9	115.7	85.5	54.8	32.1	11.0	28.9	26.6	16.8	11.4	8.2	4.5	50.3	48.4	43.6	35.4	25.3	13.[illegible]

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Table B.6.7 Maximum uplift deformation of 6-storey building in E-W direction (with GWB), (mm)

No.	Drain-3D												Sapwood											
	Wall 8						Wall 4						Wall 4 - method A						Wall 4- method B					
	st1	st2	st3	st4	st5	st6	st1	st2	st3	st4	st5	st6	st1	st2	st3	st4	st5	st6	st1	st2	st3	st4	st5	st6
1	1.65	1.91	1.66	1.55	0.61	0.09	2.87	3.34	2.04	2.04	0.78	0.11	2.03	1.98	1.96	2.62	1.78	0.87	0.80	1.44	1.26	2.25	1.26	0.58
2	2.22	2.10	1.51	1.53	0.69	0.15	2.45	3.09	2.23	2.45	1.03	0.21	1.67	1.77	1.62	1.66	1.12	0.62	0.98	1.65	1.34	2.17	1.19	0.39
3	1.56	1.75	1.45	1.77	0.70	0.29	1.81	2.39	1.75	2.21	1.01	0.16	2.94	2.90	2.72	3.19	1.97	0.71	0.96	1.48	1.24	2.39	1.51	0.58
4	1.69	2.07	1.48	1.71	0.64	0.02	2.25	2.46	1.79	2.12	0.79	0.02	2.09	1.98	2.21	2.93	2.06	0.99	0.87	1.54	1.18	2.26	1.31	0.60
5	2.06	2.13	1.14	0.95	0.31	0.00	2.32	2.54	1.35	1.15	0.34	0	1.81	1.82	1.80	2.47	1.59	0.67	0.72	1.25	1.01	1.53	1.03	0.51
6	1.90	2.01	1.58	1.58	0.62	0.00	2.71	3.24	2.04	2.23	0.77	0.00	2.40	2.35	2.35	2.58	1.68	0.82	0.73	1.21	0.99	1.57	1.09	0.49
7	2.81	2.25	1.58	1.54	0.51	0.00	3.02	3.63	2.31	2.38	0.77	0.00	0.98	0.93	0.89	1.23	0.94	0.46	0.66	1.13	0.76	1.07	0.57	0.27
8	1.08	2.20	1.67	1.82	0.77	0.16	2.43	3.29	2.43	2.88	1.23	0.24	1.92	2.08	1.95	2.45	2.17	1.05	0.68	1.25	0.99	2.05	1.19	0.49
9	2.35	2.59	1.63	1.67	0.46	0.00	2.70	3.28	2.02	2.11	0.59	0	2.62	2.51	2.31	2.82	1.84	0.71	0.80	1.25	0.97	1.52	0.89	0.39
10	2.28	2.37	1.29	1.45	0.35	0.00	2.60	3.06	1.90	1.98	0.48	0	1.97	1.86	1.72	2.02	1.23	0.61	0.71	1.00	0.76	1.23	0.65	0.39
11	2.63	2.61	1.64	1.61	0.62	0.04	2.94	3.60	2.41	2.55	0.91	0.06	2.38	2.37	2.44	3.00	1.83	0.74	0.83	1.36	1.05	1.76	0.95	0.39
12	1.50	1.87	1.39	1.63	0.62	0.02	1.72	2.29	1.72	2.02	0.86	0.03	1.97	2.02	1.97	2.75	2.30	1.14	0.92	1.57	1.19	2.06	1.39	0.67
13	1.72	1.83	1.26	1.25	0.32	0.00	1.89	2.15	1.43	1.50	0.39	0	2.71	2.74	2.57	2.92	1.75	0.94	0.71	1.10	0.88	1.54	1.15	0.59
14	1.59	1.65	1.07	0.87	0.52	0.02	1.85	2.04	1.25	1.02	0.59	0.03	2.41	2.53	2.45	3.13	1.85	1.00	1.13	1.59	1.22	1.64	1.10	0.57
15	1.93	1.96	1.49	1.53	0.57	0.02	2.88	3.45	2.18	2.43	0.88	0.04	2.30	2.31	2.31	3.16	1.87	0.99	0.96	1.66	1.24	1.86	1.46	0.65
16	1.92	2.06	1.47	1.51	0.59	0.00	2.17	2.64	1.71	1.89	0.74	0.00	1.68	1.56	1.63	2.08	1.84	0.84	0.64	1.13	0.94	1.40	0.88	0.51
17	1.72	1.45	0.96	0.87	0.12	0.00	1.93	1.94	1.19	1.13	0.14	0	2.24	2.21	2.18	2.54	1.52	0.83	0.67	1.11	0.85	1.53	0.84	0.45
18	1.52	2.26	1.46	1.41	0.86	0.11	2.34	2.87	1.83	1.88	0.98	0.13	1.33	1.42	1.60	2.08	1.59	0.83	0.62	1.13	0.96	1.72	1.03	0.48
19	1.61	1.92	1.76	1.83	0.91	0.26	1.87	2.38	2.07	2.80	1.41	0.39	1.73	2.13	2.24	2.76	2.14	1.40	0.66	1.34	1.14	2.22	1.40	0.57
20	2.09	2.39	1.68	1.72	0.56	0.10	2.85	3.58	2.53	2.79	1.02	0.18	1.47	1.61	1.72	2.13	1.62	0.83	0.81	1.38	1.24	2.09	1.40	0.63
Mean	1.89	2.07	1.46	1.49	0.57	0.06	2.38	2.86	1.91	2.08	0.79	0.11	2.03	2.05	2.03	2.53	1.73	0.85	0.79	1.33	1.06	1.79	1.11	0.51

Table B.6.8 Maximum uplift deformation of 6-storey building in N-S direction (with GWB), (mm)

No.	Drain-3D												Sapwood											
	Wall 19						Wall 25						Wall 25 - method A						Wall 25 - method B					
	st1	st2	st3	st4	st5	st6	st1	st2	st3	st4	st5	st6	st1	st2	st3	st4	st5	st6	st1	st2	st3	st4	st5	st6
1	4.70	2.70	2.66	3.44	1.82	0.58	3.80	2.55	2.57	3.35	1.83	0.66	0.42	0.39	0.47	0.68	0.50	0.34	0.75	0.87	1.70	2.88	1.80	0.64
2	2.14	2.02	2.91	5.01	2.50	0.67	1.97	1.89	2.72	4.29	2.31	0.73	0.81	0.76	0.81	0.89	0.54	0.29	1.11	1.16	1.79	2.81	1.74	0.65
3	2.69	1.79	2.55	3.88	2.34	0.42	2.35	1.68	2.39	3.63	2.15	0.57	0.64	0.52	0.54	0.62	0.50	0.30	1.33	1.21	1.77	2.77	2.15	1.25
4	3.92	2.62	3.29	7.53	3.27	1.32	3.48	2.44	3.16	6.41	2.92	1.33	0.63	0.50	0.48	0.68	0.63	0.29	1.12	1.10	1.69	2.63	1.93	1.02
5	7.23	3.28	4.06	11.81	2.23	0.24	5.17	3.27	4.01	9.83	2.50	0.83	0.66	0.64	0.66	0.90	0.60	0.30	0.88	1.02	1.48	2.07	1.69	0.87
6	10.15	3.31	3.53	4.08	1.58	0.12	7.07	3.26	3.61	4.16	1.99	0.45	0.63	0.57	0.50	0.63	0.46	0.26	1.10	1.06	1.45	2.43	1.79	1.08
7	3.41	2.39	2.93	4.67	2.58	0.66	3.02	2.26	2.83	4.09	2.37	0.78	0.35	0.36	0.40	0.53	0.37	0.20	0.80	0.71	1.03	1.39	0.92	0.32
8	3.35	2.38	2.94	5.76	2.63	0.74	2.94	2.22	2.78	4.88	2.42	0.78	0.64	0.68	0.75	0.97	0.75	0.38	1.04	0.94	1.42	2.44	1.84	0.89
9	7.57	2.93	2.63	2.72	1.07	0.01	4.78	2.89	2.82	2.82	1.16	0.16	0.63	0.48	0.46	0.68	0.55	0.29	1.16	1.11	1.46	2.46	1.78	0.94
10	4.23	3.12	3.71	6.85	1.94	0.42	3.75	2.88	3.47	5.18	2.07	0.68	0.54	0.47	0.46	0.68	0.53	0.23	0.91	0.89	1.26	1.79	1.27	0.57
11	3.48	2.63	3.32	6.29	2.43	0.45	3.12	2.45	3.14	5.45	2.30	0.68	0.87	0.86	0.95	1.18	0.83	0.38	1.02	1.09	1.43	2.27	1.78	0.93
12	2.37	1.53	2.07	3.17	2.33	1.02	2.09	1.39	1.93	3.00	2.10	0.93	0.53	0.49	0.52	0.83	0.69	0.34	1.17	1.13	1.59	2.58	1.81	1.13
13	13.17	3.42	3.57	3.98	1.34	0.01	9.75	3.39	3.67	4.25	1.90	0.36	0.71	0.64	0.70	0.82	0.52	0.25	1.14	1.10	1.60	2.55	1.95	1.17
14	3.41	2.48	2.79	3.65	2.75	1.12	3.07	2.31	2.58	3.27	2.52	1.19	0.58	0.50	0.53	0.72	0.46	0.35	1.41	1.19	1.67	2.64	1.65	0.99
15	3.81	2.50	2.74	3.15	1.28	0.09	3.38	2.36	2.65	3.13	1.33	0.31	0.68	0.63	0.69	0.99	0.66	0.33	1.22	1.09	1.78	2.79	2.02	1.06
16	9.93	3.25	3.70	6.98	2.06	0.19	7.27	3.29	3.73	6.14	2.28	0.70	0.52	0.47	0.50	0.67	0.56	0.34	1.01	1.00	1.62	2.53	1.76	1.01
17	4.74	3.12	3.81	10.72	2.18	0.54	3.85	2.95	3.63	8.53	2.37	0.91	0.80	0.72	0.72	0.80	0.49	0.26	1.11	1.08	1.55	2.65	1.74	1.09
18	5.18	3.21	3.81	7.28	2.08	0.66	3.93	3.06	3.66	5.71	2.23	0.85	0.64	0.57	0.62	0.91	0.67	0.37	0.86	0.84	1.27	2.05	1.67	0.84
19	1.02	1.28	2.33	4.36	3.24	1.32	0.92	1.19	2.15	3.88	2.88	1.32	0.49	0.49	0.50	0.78	0.58	0.47	1.08	1.00	1.48	2.57	1.85	1.03
20	1.92	2.10	3.33	9.51	3.13	1.08	1.79	1.96	3.11	7.82	2.91	1.11	0.60	0.63	0.63	0.78	0.56	0.31	1.28	1.12	1.76	2.77	1.95	1.20
Mean	4.92	2.60	3.13	5.74	2.24	0.58	3.88	2.49	3.03	4.99	2.23	0.77	0.62	0.57	0.59	0.79	0.57	0.31	1.08	1.04	1.54	2.45	1.75	0.93

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Table B.6.9 Maximum uplift forces of 4-storey building in E-W direction (without GWB), (kN)

No.	Drain-3D								Sapwood							
	Wall 8				Wall 4				Wall 4 - method A				Wall 4- method B			
	st1	st2	st3	st4	st1	st2	st3	st4	st1	st2	st3	st4	st1	st2	st3	st4
1	7.3	0.0	0.0	0.0	8.8	0	0	0	50.4	26.5	20.1	6.8	25.5	39.1	27.6	19.0
2	10.6	1.5	0.0	0.0	12.5	1.8	0	0	59.3	28.7	19.6	7.3	36.5	37.6	25.0	14.5
3	7.0	0.0	0.0	0.0	8.1	0	0	0	63.5	34.6	26.4	11.4	37.4	39.2	28.4	23.7
4	3.1	0.0	0.0	0.0	3.2	0	0	0	64.1	35.9	29.1	13.3	37.0	37.9	27.4	23.7
5	6.5	0.1	0.0	0.0	6.0	0.1	0	0	45.1	26.3	18.3	10.9	31.1	34.0	24.9	20.5
6	1.5	0.0	0.0	0.0	1.5	0	0	0	53.2	27.5	21.1	9.8	32.4	34.9	25.8	20.0
7	9.8	0.0	0.0	0.0	8.4	0	0	0	26.1	17.7	16.2	7.9	21.8	20.1	10.2	5.1
8	2.3	3.0	0.1	0.0	2.5	3.0	0.1	0	55.1	28.4	23.5	17.6	30.8	36.2	27.8	19.9
9	8.3	0.2	0.0	0.0	7.7	0.1	0	0	45.9	20.5	16.0	6.7	32.8	31.9	22.1	14.1
10	5.3	0.0	0.0	0.0	6.4	0	0	0	54.1	25.5	18.5	10.0	33.3	33.2	23.0	18.1
11	8.9	0.0	0.0	0.0	10.9	0	0	0	75.7	37.8	26.9	9.6	39.2	36.3	26.1	22.5
12	1.7	2.4	1.4	0.3	1.5	2.1	1.5	0.3	80.6	46.8	36.7	19.2	37.5	39.4	26.7	20.9
13	10.1	1.2	0.0	0.0	8.1	1.0	0	0	45.4	24.2	15.3	8.1	31.9	35.9	25.5	18.3
14	0.0	0.0	0.0	0.0	0	0	0	0	58.3	26.5	18.9	12.0	38.4	37.8	27.0	19.5
15	10.7	3.9	0.0	0.0	9.3	3.5	0	0	61.5	35.3	23.1	11.3	37.2	38.0	27.9	18.3
16	2.6	0.0	0.0	0.0	2.5	0	0	0	44.6	23.6	20.1	10.0	31.8	30.6	24.1	18.5
17	4.4	0.0	0.0	0.0	5.6	0	0	0	43.3	25.1	23.5	12.5	32.6	37.9	24.7	16.4
18	0.5	0.0	0.0	1.1	0.6	0	0	1.3	40.2	23.6	24.6	12.2	30.6	35.3	25.0	19.3
19	1.3	1.8	0.1	0.2	1.4	1.9	0.1	0.3	52.8	37.3	28.4	14.4	31.9	38.7	28.4	22.6
20	12.3	3.1	0.0	0.0	15.6	3.9	0	0	55.6	26.9	19.7	10.4	38.3	38.2	27.9	19.2
Mean	5.7	0.8	0.1	0.1	6.4	1.9	0.6	0.7	53.7	28.9	22.3	11.1	33.4	35.6	25.3	18.7

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Table B.6.10 Maximum uplift forces of 4-storey building in N-S direction (without GWB), (kN)

No.	Drain-3D								Sapwood							
	Wall 19				Wall 25				Wall 25 - method A				Wall 25 - method B			
	st1	st2	st3	st4	st1	st2	st3	st4	st1	st2	st3	st4	st1	st2	st3	st4
1	93.5	58.7	28.5	10.3	78.0	50.8	25.6	11.5	9.0	5.7	6.3	4.0	37.1	40.0	28.7	17.0
2	94.2	58.7	37.5	19.7	78.7	56.8	33.1	16.9	15.8	8.3	7.6	5.9	38.2	37.7	27.3	13.4
3	72.5	52.5	30.0	11.3	60.8	44.6	26.9	12.1	16.2	7.5	7.5	4.8	43.2	40.7	30.1	21.9
4	80.8	46.8	30.2	15.4	67.9	39.3	26.6	15.2	12.2	6.8	8.6	6.3	38.8	39.3	28.9	21.7
5	92.4	58.7	32.6	14.3	78.2	53.8	29.6	15.5	13.0	7.1	8.0	5.0	34.6	36.4	27.4	18.8
6	97.6	58.7	33.5	13.8	83.6	55.3	30.4	15.2	15.0	7.1	6.4	5.0	36.1	37.3	27.8	18.3
7	96.5	58.7	30.9	15.8	82.4	55.5	29.5	16.1	8.6	6.7	5.9	3.3	26.0	19.6	15.8	9.0
8	90.2	58.7	37.9	16.8	75.2	58.3	34.1	16.6	16.0	9.7	11.7	8.2	37.9	39.4	28.0	18.1
9	96.3	58.7	34.6	15.0	81.1	57.7	32.2	16.3	15.7	7.4	5.9	3.2	38.2	36.8	26.4	15.5
10	99.0	58.7	40.5	20.0	83.7	58.4	34.2	17.1	13.9	9.0	8.4	4.8	37.3	31.5	25.3	17.0
11	102.1	58.7	36.4	15.5	88.0	58.7	33.8	16.6	22.2	10.4	8.0	5.1	42.2	40.1	28.3	19.1
12	72.2	52.3	35.3	20.1	62.2	45.6	30.4	16.7	18.4	12.4	13.8	7.4	40.5	34.5	29.3	22.9
13	73.1	40.6	18.6	6.6	63.1	37.3	17.8	6.9	14.8	6.9	5.1	4.1	42.2	39.8	27.8	20.5
14	84.3	54.0	27.7	12.5	69.6	45.6	24.7	12.6	14.6	8.0	8.0	5.8	43.1	38.0	25.5	19.3
15	90.2	57.0	26.1	7.1	75.0	48.4	23.8	8.8	19.2	11.1	13.4	6.3	40.6	39.9	29.2	19.5
16	91.5	58.7	40.9	20.5	77.7	56.6	34.4	17.3	15.3	7.7	7.1	4.3	34.2	36.8	26.6	18.3
17	75.3	43.2	22.1	7.6	64.0	38.5	19.1	7.3	20.8	11.5	10.4	5.5	33.5	37.2	27.7	18.9
18	83.8	58.7	37.6	19.1	69.3	52.9	32.5	16.5	14.2	9.4	10.8	5.5	34.0	35.4	26.8	18.5
19	79.1	57.6	39.6	27.5	68.6	49.8	32.3	22.5	15.5	8.3	8.5	5.8	37.9	37.0	28.1	18.2
20	100.9	58.7	36.9	17.4	85.1	58.7	34.5	16.7	17.3	10.0	9.2	7.2	42.1	38.0	28.7	15.3
Mean	88.3	55.4	32.9	15.3	74.6	51.1	29.3	14.7	15.4	8.5	8.5	5.4	37.9	36.8	27.2	18.1

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Table B.6.11 Maximum uplift deformation of 4-storey building in E-W direction (without GWB), (mm)

No.	Drain-3D								Sapwood							
	Wall 8				Wall 4				Wall 4 - method A				Wall 4- method B			
	st1	st2	st3	st4	st1	st2	st3	st4	st1	st2	st3	st4	st1	st2	st3	st4
1	0.26	0.00	0.00	0.00	0.31	0	0	0	1.78	1.84	1.39	0.47	0.90	2.71	1.91	1.32
2	0.38	0.10	0.00	0.00	0.44	0.13	0	0	2.10	1.99	1.36	0.51	1.29	2.61	1.73	1.00
3	0.25	0.00	0.00	0.00	0.29	0	0	0	2.24	2.40	1.83	0.79	1.32	2.71	1.97	1.64
4	0.11	0.00	0.00	0.00	0.11	0	0	0	2.27	2.49	2.02	0.92	1.31	2.63	1.90	1.65
5	0.23	0.01	0.00	0.00	0.21	0.01	0	0	1.60	1.82	1.27	0.76	1.10	2.36	1.72	1.42
6	0.05	0.00	0.00	0.00	0.05	0	0	0	1.88	1.91	1.46	0.68	1.15	2.42	1.79	1.39
7	0.35	0.00	0.00	0.00	0.30	0	0	0	0.92	1.22	1.12	0.55	0.77	1.39	0.71	0.35
8	0.08	0.21	0.01	0.00	0.09	0.21	0.01	0	1.95	1.97	1.63	1.22	1.09	2.51	1.92	1.38
9	0.29	0.01	0.00	0.00	0.27	0.01	0	0	1.62	1.42	1.11	0.46	1.16	2.21	1.53	0.98
10	0.19	0.00	0.00	0.00	0.23	0	0	0	1.91	1.76	1.28	0.69	1.18	2.30	1.60	1.25
11	0.32	0.00	0.00	0.00	0.39	0	0	0	2.68	2.62	1.86	0.66	1.39	2.52	1.81	1.56
12	0.06	0.16	0.09	0.02	0.05	0.15	0.11	0.02	2.85	3.24	2.55	1.33	1.33	2.73	1.85	1.45
13	0.36	0.08	0.00	0.00	0.29	0.07	0	0	1.60	1.68	1.06	0.56	1.13	2.49	1.77	1.27
14	0.00	0.00	0.00	0.00	0	0	0	0	2.06	1.84	1.31	0.83	1.36	2.62	1.87	1.35
15	0.38	0.27	0.00	0.00	0.33	0.24	0	0	2.17	2.44	1.60	0.78	1.31	2.63	1.93	1.27
16	0.09	0.00	0.00	0.00	0.09	0	0	0	1.58	1.64	1.40	0.69	1.12	2.12	1.67	1.28
17	0.16	0.00	0.00	0.00	0.20	0	0	0	1.53	1.74	1.63	0.86	1.15	2.62	1.71	1.13
18	0.02	0.00	0.00	0.08	0.02	0	0	0.09	1.42	1.64	1.71	0.84	1.08	2.45	1.73	1.34
19	0.04	0.12	0.01	0.01	0.05	0.13	0.01	0.02	1.87	2.58	1.97	0.99	1.13	2.68	1.97	1.57
20	0.44	0.22	0.00	0.00	0.55	0.27	0	0	1.97	1.86	1.36	0.72	1.35	2.65	1.93	1.33
Mean	0.20	0.06	0.01	0.01	0.23	0.14	0.04	0.05	1.90	2.01	1.55	0.77	1.18	2.47	1.75	1.30

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Table B.6.12 Maximum uplift deformation of 4-storey building in N-S direction (without GWB), (mm)

No.	Drain-3D								Sapwood							
	Wall 19				Wall 25				Wall 25 - method A				Wall 25 - method B			
	st1	st2	st3	st4	st1	st2	st3	st4	st1	st2	st3	st4	st1	st2	st3	st4
1	3.32	4.20	1.98	0.72	2.77	3.53	1.78	0.80	0.32	0.39	0.44	0.28	1.31	2.77	1.99	1.18
2	3.34	5.74	2.61	1.37	2.79	3.95	2.30	1.18	0.56	0.57	0.53	0.41	1.35	2.61	1.89	0.93
3	2.57	3.65	2.09	0.78	2.16	3.10	1.87	0.84	0.57	0.52	0.52	0.33	1.53	2.82	2.09	1.52
4	2.86	3.25	2.10	1.07	2.41	2.73	1.85	1.06	0.43	0.47	0.59	0.44	1.37	2.72	2.00	1.51
5	3.27	4.73	2.27	1.00	2.77	3.74	2.05	1.07	0.46	0.49	0.55	0.35	1.22	2.52	1.90	1.31
6	3.46	5.57	2.33	0.96	2.96	3.84	2.11	1.06	0.53	0.49	0.44	0.34	1.28	2.58	1.92	1.27
7	3.42	5.46	2.15	1.10	2.92	3.86	2.05	1.12	0.31	0.47	0.41	0.23	0.92	1.36	1.10	0.62
8	3.20	6.02	2.64	1.17	2.67	4.05	2.37	1.16	0.57	0.67	0.81	0.57	1.34	2.73	1.94	1.25
9	3.41	5.65	2.40	1.04	2.88	4.01	2.24	1.13	0.56	0.51	0.41	0.22	1.35	2.55	1.83	1.07
10	3.51	6.77	2.82	1.39	2.97	4.06	2.37	1.19	0.49	0.62	0.58	0.33	1.32	2.18	1.76	1.18
11	3.62	7.25	2.53	1.08	3.12	4.54	2.35	1.15	0.79	0.72	0.55	0.36	1.49	2.78	1.96	1.32
12	2.56	3.63	2.45	1.40	2.21	3.17	2.11	1.16	0.65	0.86	0.96	0.51	1.43	2.39	2.03	1.58
13	2.59	2.82	1.29	0.46	2.24	2.59	1.24	0.48	0.52	0.48	0.36	0.28	1.49	2.76	1.92	1.42
14	2.99	3.75	1.92	0.87	2.47	3.17	1.71	0.88	0.51	0.55	0.56	0.40	1.53	2.63	1.77	1.33
15	3.20	3.96	1.81	0.49	2.66	3.37	1.66	0.61	0.68	0.77	0.93	0.44	1.44	2.76	2.03	1.35
16	3.24	6.64	2.84	1.42	2.75	3.93	2.39	1.20	0.54	0.54	0.49	0.30	1.21	2.55	1.84	1.27
17	2.67	3.00	1.54	0.53	2.27	2.67	1.33	0.51	0.74	0.80	0.72	0.38	1.19	2.58	1.92	1.31
18	2.97	4.75	2.61	1.33	2.46	3.68	2.26	1.15	0.50	0.65	0.75	0.38	1.20	2.46	1.86	1.28
19	2.80	4.00	2.75	1.91	2.43	3.46	2.24	1.56	0.55	0.58	0.59	0.40	1.34	2.57	1.95	1.26
20	3.58	7.47	2.56	1.21	3.02	4.52	2.40	1.16	0.61	0.69	0.64	0.50	1.49	2.64	1.99	1.06
Mean	3.13	4.91	2.28	1.06	2.65	3.60	2.03	1.02	0.54	0.59	0.59	0.37	1.34	2.55	1.88	1.25

Table B.6.13 Maximum uplift forces of 6-storey building in E-W direction (without GWB), (kN)

No.	Drain-3D												Sapwood											
	Wall 8						Wall 4						Wall 4 - method A						Wall 4- method B					
	st1	st2	st3	st4	st5	st6	st1	st2	st3	st4	st5	st6	st1	st2	st3	st4	st5	st6	st1	st2	st3	st4	st5	st6
1	52.9	27.3	16.5	6.0	0.0	0.0	62.0	37.2	17.7	6.3	0	0	94.7	56.0	55.4	37.9	25.6	12.6	35.6	31.5	39.2	38.3	25.5	12.4
2	50.8	26.0	18.5	6.8	0.0	0.0	37.7	31.2	22.5	8.9	0	0	77.8	50.0	45.8	23.9	16.1	8.9	42.4	46.4	41.5	38.4	25.2	14.1
3	30.3	26.8	29.6	10.8	2.3	0.5	31.6	26.6	22.7	11.9	2.3	0.7	137.3	82.0	77.0	46.0	28.4	10.2	54.3	53.1	40.6	39.1	30.2	25.7
4	48.1	26.8	10.2	0.0	0.0	0.0	61.1	35.9	12.5	0	0	0	97.8	55.9	62.4	42.2	29.7	14.3	45.2	49.5	41.4	38.5	26.2	17.6
5	56.5	33.0	17.1	4.9	0.0	0.0	76.9	48.5	23.4	6.0	0	0	84.7	51.5	51.0	35.6	22.9	9.7	36.8	42.8	36.7	37.0	26.1	22.2
6	47.3	25.1	9.2	0.6	0.0	0.0	61.1	34.1	11.0	0.6	0	0	112.2	66.5	66.4	37.2	24.2	11.9	44.6	45.8	37.7	36.8	26.3	22.3
7	45.5	25.6	17.1	3.1	0.0	0.0	48.4	27.1	15.5	3.7	0	0	46.0	26.4	25.2	17.7	13.5	6.7	38.1	41.0	26.0	20.5	12.0	7.4
8	32.6	22.7	10.2	0.6	0.0	0.0	41.4	23.5	9.2	0.5	0	0	89.9	58.9	55.0	35.3	31.3	15.1	47.4	45.0	36.2	35.6	27.9	19.7
9	46.0	22.9	8.9	0.0	0.0	0.0	63.6	33.8	9.9	0	0	0	122.7	70.9	65.2	40.7	26.5	10.2	49.5	49.4	39.3	33.7	23.9	19.2
10	52.9	32.6	14.3	4.1	0.0	0.0	64.5	44.4	21.2	5.9	0	0	92.0	52.6	48.8	29.2	17.8	8.8	37.0	35.6	30.4	28.4	19.7	13.5
11	50.3	33.1	21.4	9.4	2.1	0.0	53.1	37.2	28.0	12.8	2.6	0.0	111.4	67.0	69.0	43.4	26.4	10.6	37.0	39.4	35.7	35.0	23.9	19.9
12	30.2	20.7	11.4	1.7	0.0	0.0	29.8	19.3	11.3	1.7	0	0	92.1	57.1	55.8	39.6	33.1	16.4	43.4	48.5	37.6	35.3	22.2	20.6
13	60.1	35.4	19.8	6.8	0.0	0.0	80.7	50.2	24.9	8.3	0	0	126.5	77.4	72.7	42.1	25.2	13.5	52.1	49.4	39.0	35.9	25.5	19.5
14	44.3	39.0	12.9	0.5	0.0	0.0	59.6	33.4	11.8	0.5	0	0	112.9	71.7	69.3	45.2	26.6	14.4	52.3	49.7	38.6	39.4	26.5	20.2
15	36.6	22.4	9.6	2.3	0.0	0.0	40.0	25.4	10.1	2.2	0	0	107.5	65.4	65.3	45.6	27.0	14.2	52.0	51.9	39.1	38.2	28.7	19.3
16	64.3	31.4	13.4	3.7	0.0	0.0	53.9	32.4	15.1	3.8	0	0	78.4	44.1	46.1	30.0	26.5	12.1	45.5	46.3	35.9	33.5	24.5	20.7
17	60.6	37.2	14.9	2.2	0.0	0.0	65.2	41.6	18.7	3.0	0	0	104.6	62.4	61.5	36.6	21.9	12.0	44.4	48.2	40.3	38.9	26.2	21.0
18	56.2	30.5	14.2	2.1	0.0	0.0	57.2	37.1	18.0	2.5	0	0	62.4	40.1	45.3	30.1	23.0	11.9	39.8	39.3	32.4	31.7	21.4	17.1
19	0.0	0.0	0.0	0.0	3.8	0.9	0	0	0	0	4.5	1.7	81.0	60.3	63.3	39.9	30.9	20.1	41.6	43.3	37.0	36.4	28.0	21.9
20	34.0	31.4	28.5	10.1	2.1	0.0	30.6	27.8	23.3	13.2	2.8	0	68.6	45.6	48.6	30.7	23.4	11.9	50.4	53.1	37.6	37.9	29.0	23.3
Mean	45.0	27.5	14.9	3.8	0.5	0.1	53.6	34.0	17.2	5.4	3.0	0.8	95.0	58.1	57.5	36.4	25.0	12.3	44.5	45.5	37.1	35.4	24.9	18.9

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Table B.6.14 Maximum uplift forces of 6-storey building in N-S direction (without GWB), (kN)

No.	Drain-3D												Sapwood											
	Wall 19						Wall 25						Wall 25 - method A						Wall 25 - method B					
	st1	st2	st3	st4	st5	st6	st1	st2	st3	st4	st5	st6	st1	st2	st3	st4	st5	st6	st1	st2	st3	st4	st5	st6
1	184.6	123.8	71.7	50.3	29.1	10.8	163.3	113.6	67.1	47.0	26.1	11.5	19.6	18.5	13.3	9.8	7.2	5.0	38.3	33.0	34.0	36.3	28.6	18.
2	99.3	87.4	79.6	58.7	36.5	13.9	84.2	79.7	71.1	58.5	34.4	15.6	37.9	35.5	22.9	12.9	7.8	4.2	49.5	51.9	50.0	42.8	28.7	12.
3	132.4	80.1	52.7	41.8	29.2	10.8	114.2	72.1	48.9	38.7	26.0	11.1	29.9	24.3	15.2	9.0	7.3	4.3	67.7	67.1	54.0	44.2	32.1	23.
4	188.3	129.8	85.2	56.1	40.3	17.9	167.2	119.2	78.8	48.0	35.8	17.9	29.3	23.4	13.7	9.8	9.0	4.2	52.5	54.0	49.4	42.9	30.0	21.
5	171.7	125.5	89.0	58.7	30.9	9.3	153.6	114.8	81.0	56.2	28.7	11.4	31.0	29.7	18.6	12.9	8.7	4.4	42.6	47.5	47.6	38.6	27.4	17.
6	190.2	142.7	104.6	58.8	39.7	16.3	175.2	132.8	98.0	58.8	37.6	18.7	29.3	26.5	14.0	9.1	6.7	3.7	56.8	53.0	45.7	37.3	25.3	16.
7	143.0	90.4	72.6	55.7	32.9	14.6	123.6	83.6	67.7	51.1	29.8	15.1	16.5	17.0	11.2	7.6	5.3	2.9	53.4	40.9	32.4	28.1	20.8	13.
8	139.7	103.8	84.6	58.7	38.4	14.4	122.2	94.2	77.3	58.7	36.1	16.7	30.0	31.9	21.3	14.0	10.8	5.5	55.0	56.2	48.4	42.4	29.2	17.
9	190.3	131.5	73.7	38.5	18.2	4.7	176.3	122.5	74.8	39.8	19.1	5.5	29.2	22.5	13.1	9.8	7.9	4.2	60.9	58.6	49.6	38.0	24.8	15.
10	163.2	121.7	88.3	58.7	25.6	4.9	145.7	111.1	80.2	51.6	24.2	6.9	25.5	21.8	12.9	9.8	7.7	3.4	43.4	45.9	42.8	33.0	23.3	14.
11	150.4	86.8	66.4	46.7	29.9	8.8	130.7	78.9	61.6	44.3	26.9	10.1	40.6	40.2	27.0	17.0	11.9	5.4	50.3	48.7	46.0	41.2	27.5	14.
12	100.7	64.2	52.1	43.3	34.8	17.9	89.6	59.9	48.0	39.6	30.3	15.7	24.6	23.1	14.6	12.0	9.9	5.0	48.0	51.9	44.9	35.1	28.9	21.
13	190.3	163.5	107.4	58.7	24.3	5.5	190.3	153.7	103.4	58.7	29.3	12.8	33.4	30.1	19.7	11.8	7.5	3.6	60.9	59.6	48.8	39.6	28.3	18.
14	167.7	117.1	76.3	45.8	32.8	20.2	146.8	106.3	71.8	42.7	29.2	18.0	27.3	23.4	14.9	10.4	6.6	5.1	65.3	61.0	51.3	43.4	28.2	18.
15	148.9	101.5	81.9	58.7	26.0	6.1	129.4	93.2	74.2	51.9	24.4	6.9	31.7	29.6	19.4	14.3	9.5	4.8	52.7	54.4	50.4	43.9	30.0	19.
16	190.3	150.6	104.8	58.7	27.5	10.3	184.5	140.5	98.9	57.6	28.3	14.5	24.5	22.1	14.0	9.7	8.1	4.8	48.6	48.2	46.6	34.2	24.9	15.
17	187.0	128.4	90.9	58.7	38.9	17.0	165.0	116.4	83.1	58.7	36.6	18.3	37.6	33.5	20.4	11.5	7.0	3.8	45.5	55.0	49.0	41.3	28.6	21.
18	169.5	118.8	88.5	58.7	27.0	13.4	147.4	110.2	80.5	52.7	25.1	12.6	29.7	26.7	17.6	13.1	9.6	5.3	40.8	43.0	40.2	38.3	26.1	19.
19	45.8	48.7	60.8	58.7	53.8	28.2	41.7	44.0	53.9	58.7	44.4	23.4	22.8	23.0	14.1	11.2	8.4	6.7	55.3	54.8	46.8	40.0	27.8	21.
20	87.9	89.8	86.6	58.8	48.6	22.9	80.4	82.3	77.6	58.7	40.8	19.5	27.9	29.3	17.7	11.3	8.1	4.5	60.0	60.4	48.7	38.6	30.8	21.
Mean	152.1	110.3	80.9	54.1	33.2	13.4	136.6	101.4	74.9	51.6	30.7	14.1	28.9	26.6	16.8	11.4	8.2	4.5	52.4	52.3	46.3	39.0	27.6	18.

Confidential

Table B.6.15 Maximum uplift deformation of 6-storey building in E-W direction (without GWB), (mm)

No.	Drain-3D												Sapwood											
	Wall 8						Wall 4						Wall 4 - method A						Wall 4- method B					
	st1	st2	st3	st4	st5	st6	st1	st2	st3	st4	st5	st6	st1	st2	st3	st4	st5	st6	st1	st2	st3	st4	st5	st6
1	1.14	0.97	0.59	0.42	0.00	0.00	1.33	1.32	0.63	0.44	0	0	2.03	1.98	1.96	2.62	1.78	0.87	0.76	1.11	1.39	2.65	1.77	0.86
2	1.09	0.92	0.66	0.48	0.00	0.00	0.81	1.10	0.80	0.62	0	0	1.67	1.77	1.62	1.66	1.12	0.62	0.91	1.64	1.47	2.66	1.75	0.98
3	0.65	0.95	1.05	0.75	0.16	0.04	0.68	0.94	0.80	0.82	0.16	0.05	2.94	2.90	2.72	3.19	1.97	0.71	1.16	1.88	1.44	2.71	2.09	1.78
4	1.03	0.95	0.36	0.00	0.00	0.00	1.31	1.27	0.44	0	0	0	2.09	1.98	2.21	2.93	2.06	0.99	0.97	1.75	1.46	2.67	1.81	1.22
5	1.21	1.17	0.61	0.34	0.00	0.00	1.65	1.72	0.83	0.42	0	0	1.81	1.82	1.80	2.47	1.59	0.67	0.79	1.51	1.30	2.56	1.81	1.54
6	1.01	0.89	0.33	0.04	0.00	0.00	1.31	1.21	0.39	0.04	0	0	2.40	2.35	2.35	2.58	1.68	0.82	0.95	1.62	1.33	2.55	1.82	1.55
7	0.98	0.91	0.61	0.21	0.00	0.00	1.04	0.96	0.55	0.26	0	0	0.98	0.93	0.89	1.23	0.94	0.46	0.82	1.45	0.92	1.42	0.83	0.51
8	0.70	0.80	0.36	0.04	0.00	0.00	0.89	0.83	0.33	0.03	0	0	1.92	2.08	1.95	2.45	2.17	1.05	1.01	1.59	1.28	2.47	1.94	1.37
9	0.99	0.81	0.31	0.00	0.00	0.00	1.36	1.20	0.35	0	0	0	2.62	2.51	2.31	2.82	1.84	0.71	1.06	1.75	1.39	2.34	1.66	1.33
10	1.13	1.15	0.51	0.29	0.00	0.00	1.38	1.57	0.75	0.41	0	0	1.97	1.86	1.72	2.02	1.23	0.61	0.79	1.26	1.07	1.97	1.37	0.94
11	1.08	1.17	0.76	0.66	0.15	0.00	1.14	1.32	0.99	0.89	0.18	0.00	2.38	2.37	2.44	3.00	1.83	0.74	0.79	1.39	1.26	2.43	1.66	1.38
12	0.65	0.73	0.40	0.12	0.00	0.00	0.64	0.68	0.40	0.12	0	0	1.97	2.02	1.97	2.75	2.30	1.14	0.93	1.71	1.33	2.45	1.54	1.43
13	1.29	1.25	0.70	0.47	0.00	0.00	1.73	1.78	0.88	0.57	0	0	2.71	2.74	2.57	2.92	1.75	0.94	1.11	1.75	1.38	2.49	1.77	1.35
14	0.95	1.38	0.46	0.04	0.00	0.00	1.28	1.18	0.42	0.03	0	0	2.41	2.53	2.45	3.13	1.85	1.00	1.12	1.76	1.36	2.73	1.84	1.40
15	0.78	0.79	0.34	0.16	0.00	0.00	0.86	0.90	0.36	0.15	0	0	2.30	2.31	2.31	3.16	1.87	0.99	1.11	1.84	1.38	2.65	1.99	1.34
16	1.38	1.12	0.47	0.25	0.00	0.00	1.16	1.15	0.54	0.26	0	0	1.68	1.56	1.63	2.08	1.84	0.84	0.97	1.64	1.27	2.32	1.70	1.44
17	1.30	1.32	0.53	0.15	0.00	0.00	1.40	1.47	0.66	0.21	0	0	2.24	2.21	2.18	2.54	1.52	0.83	0.95	1.70	1.43	2.70	1.81	1.46
18	1.21	1.08	0.50	0.14	0.00	0.00	1.23	1.32	0.64	0.17	0	0	1.33	1.42	1.60	2.08	1.59	0.83	0.85	1.39	1.14	2.20	1.48	1.18
19	0.00	0.00	0.00	0.00	0.26	0.07	0	0	0	0	0.31	0.12	1.73	2.13	2.24	2.76	2.14	1.40	0.89	1.53	1.31	2.52	1.94	1.52
20	0.73	1.11	1.01	0.70	0.15	0.00	0.66	0.99	0.83	0.92	0.20	0	1.47	1.61	1.72	2.13	1.62	0.83	1.08	1.88	1.33	2.63	2.01	1.62
Mean	0.96	0.97	0.53	0.26	0.04	0.01	1.15	1.21	0.61	0.37	0.21	0.06	2.03	2.05	2.03	2.53	1.73	0.85	0.95	1.61	1.31	2.46	1.73	1.31

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Table B.6.16 Maximum uplift deformation of 6-storey building in N-S direction (without GWB), mm

No.	Drain-3D												Sapwood											
	Wall 19						Wall 25						Wall 25 - method A						Wall 25 - method B					
	st1	st2	st3	st4	st5	st6	st1	st2	st3	st4	st5	st6	st1	st2	st3	st4	st5	st6	st1	st2	st3	st4	st5	st6
1	3.96	2.66	2.54	3.49	2.02	0.75	3.50	2.44	2.38	3.27	1.82	0.80	0.42	0.39	0.47	0.68	0.50	0.34	0.82	0.71	1.20	2.51	1.98	1.27
2	2.13	1.87	2.82	5.38	2.54	0.96	1.81	1.71	2.52	4.06	2.39	1.08	0.81	0.76	0.81	0.89	0.54	0.29	1.06	1.11	1.77	2.97	1.99	0.86
3	2.84	1.72	1.87	2.90	2.03	0.75	2.45	1.55	1.73	2.69	1.81	0.77	0.64	0.52	0.54	0.62	0.50	0.30	1.45	1.44	1.91	3.06	2.22	1.64
4	4.04	2.78	3.02	3.90	2.80	1.25	3.59	2.56	2.79	3.34	2.49	1.24	0.63	0.50	0.48	0.68	0.63	0.29	1.12	1.15	1.75	2.98	2.08	1.50
5	3.68	2.69	3.16	4.91	2.15	0.65	3.29	2.46	2.87	3.91	2.00	0.79	0.66	0.64	0.66	0.90	0.60	0.30	0.91	1.02	1.68	2.67	1.90	1.23
6	4.35	3.06	3.71	11.70	2.76	1.14	3.76	2.85	3.48	7.91	2.61	1.30	0.63	0.57	0.50	0.63	0.46	0.26	1.21	1.13	1.61	2.59	1.76	1.16
7	3.07	1.94	2.57	3.87	2.29	1.02	2.65	1.79	2.40	3.55	2.07	1.05	0.35	0.36	0.40	0.53	0.37	0.20	1.14	0.87	1.15	1.95	1.44	0.93
8	3.00	2.23	3.00	6.11	2.67	1.00	2.62	2.02	2.74	4.58	2.51	1.16	0.64	0.68	0.75	0.97	0.75	0.38	1.18	1.20	1.71	2.94	2.02	1.24
9	4.89	2.82	2.61	2.68	1.27	0.33	3.78	2.63	2.65	2.77	1.32	0.38	0.63	0.48	0.46	0.68	0.55	0.29	1.30	1.25	1.75	2.64	1.72	1.07
10	3.50	2.61	3.13	4.09	1.78	0.34	3.12	2.38	2.84	3.59	1.68	0.48	0.54	0.47	0.46	0.68	0.53	0.23	0.93	0.98	1.51	2.29	1.62	1.01
11	3.23	1.86	2.35	3.24	2.08	0.61	2.80	1.69	2.18	3.08	1.87	0.70	0.87	0.86	0.95	1.18	0.83	0.38	1.08	1.04	1.63	2.85	1.91	0.97
12	2.16	1.38	1.85	3.01	2.42	1.25	1.92	1.28	1.70	2.75	2.11	1.09	0.53	0.49	0.52	0.83	0.69	0.34	1.03	1.11	1.59	2.44	2.00	1.46
13	12.02	3.51	3.81	4.28	1.69	0.38	6.80	3.30	3.67	4.42	2.03	0.89	0.71	0.64	0.70	0.82	0.52	0.25	1.30	1.27	1.72	2.74	1.96	1.29
14	3.60	2.51	2.71	3.18	2.28	1.40	3.15	2.28	2.55	2.96	2.03	1.25	0.58	0.50	0.53	0.72	0.46	0.35	1.40	1.31	1.81	3.00	1.96	1.31
15	3.19	2.18	2.90	4.14	1.80	0.42	2.77	2.00	2.63	3.61	1.70	0.48	0.68	0.63	0.69	0.99	0.66	0.33	1.13	1.16	1.78	3.04	2.08	1.32
16	5.34	3.23	3.72	5.40	1.91	0.71	3.96	3.01	3.51	4.00	1.97	1.01	0.52	0.47	0.50	0.67	0.56	0.34	1.04	1.03	1.65	2.37	1.72	1.10
17	4.01	2.75	3.22	6.44	2.70	1.18	3.54	2.50	2.95	4.57	2.54	1.27	0.80	0.72	0.72	0.80	0.49	0.26	0.97	1.18	1.73	2.86	1.98	1.50
18	3.64	2.55	3.14	4.30	1.87	0.93	3.16	2.36	2.85	3.66	1.74	0.87	0.64	0.57	0.62	0.91	0.67	0.37	0.87	0.92	1.42	2.65	1.81	1.33
19	0.98	1.04	2.15	5.43	3.74	1.96	0.89	0.94	1.91	4.09	3.09	1.63	0.49	0.49	0.50	0.78	0.58	0.47	1.18	1.17	1.66	2.77	1.92	1.47
20	1.89	1.93	3.07	8.51	3.38	1.59	1.72	1.76	2.75	5.73	2.84	1.35	0.60	0.63	0.63	0.78	0.56	0.31	1.28	1.29	1.72	2.67	2.14	1.50
Mean	3.77	2.37	2.87	4.85	2.31	0.93	3.06	2.18	2.66	3.93	2.13	0.98	0.62	0.57	0.59	0.79	0.57	0.31	1.12	1.12	1.64	2.70	1.91	1.26

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Appendix C

Results of Representative Wood-Frame Buildings Designed in Accordance with NBCC 2010

C.1 Fundamental period of the Building

	4-storey building (sec)		6-storey building (sec)	
	E-W	N-S	E-W	N-S
Drain-3D	0.54	0.68	0.78	0.96
Sapwood	0.52		0.66	

C.2 Maximum base shear

No.	4-storey building (kN)				6-storey building (kN)			
	Drain-3D		Sapwood		Drain-3D		Sapwood	
	E-W	N-S	E-W	N-S	E-W	N-S	E-W	N-S
1	1411	1065	883	844	1713	1656	1066	761
2	1426	1048	785	908	1682	1644	1099	972
3	1477	1044	1179	905	1663	1527	833	957
4	1388	1028	1336	889	1687	1602	1244	943
5	1222	1077	864	784	1737	1563	887	936
6	1358	1058	814	755	1734	1590	739	893
7	1205	1098	667	583	1765	1648	1141	1006
8	1257	1024	777	1029	1642	1612	878	985
9	1468	1077	907	813	1676	1492	966	1032
10	1319	1002	822	708	1658	1652	675	679
11	1332	963	951	807	1446	1760	752	669
12	1262	1062	1225	703	1738	1708	1175	1003
13	1279	1056	686	807	1708	1603	782	847
14	1401	1005	986	1045	1340	1116	1267	1203
15	1298	1096	991	921	1722	1584	1172	931
16	1323	1033	746	705	1589	1583	641	864
17	1503	1065	539	704	1756	1517	750	800
18	1530	1120	1094	759	1621	1456	971	902
19	1194	1038	1209	1030	1607	1703	1426	1277
20	1366	1096	1298	1144	1815	1635	1278	1099
Mean	1351	1053	938	842	1665	1583	987	938

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C.3 Maximum displacement and acceleration at each storey

Table C.3.1 Maximum displacements of 4-storey building in E-W direction (with GWB), (mm)

No.	Drain-3D								Sapwood			
	Wall 8				Wall 4				Center of the storey diaphragm			
	st1	st2	st3	st4	st1	st2	st3	st4	st1	st2	st3	st4
1	33.7	58.4	72.9	79.9	35.4	56.6	71.7	78.5	23.0	36.8	48.5	51.3
2	34.9	57.7	71.4	78.9	39.3	59.2	72.6	78.8	32.6	49.5	60.5	63.2
3	32.4	57.5	70.9	77.3	34.7	56.0	69.7	76.1	18.4	43.6	58.3	64.4
4	18.2	37.0	54.2	62.4	16.4	32.0	49.7	57.7	20.8	41.1	55.9	61.7
5	24.2	37.5	46.6	53.0	25.5	37.8	45.9	49.9	9.8	19.0	25.8	28.9
6	15.8	29.0	39.8	45.3	15.0	26.6	37.3	42.7	10.9	21.8	30.1	33.6
7	41.0	70.5	84.5	91.6	42.3	68.8	82.9	90.1	33.3	50.3	61.9	64.7
8	24.2	45.1	65.2	74.0	28.5	45.8	65.4	73.1	21.7	44.9	60.0	64.6
9	18.8	32.9	45.2	51.9	21.4	33.9	45.9	52.4	11.0	20.1	28.0	30.9
10	22.1	37.2	48.5	55.6	23.3	36.2	47.7	53.5	10.0	19.2	25.9	28.9
11	37.1	56.9	73.9	83.2	38.6	57.8	71.1	79.1	16.0	30.9	45.9	52.7
12	44.0	68.3	85.5	94.0	46.6	69.7	87.8	96.7	17.7	36.2	50.4	58.3
13	15.8	29.6	41.9	48.5	17.0	29.3	41.8	48.2	11.3	19.3	25.0	27.1
14	24.4	37.1	45.8	50.6	25.6	36.9	46.2	50.9	21.5	31.8	36.3	38.1
15	32.3	54.3	68.1	75.4	31.8	49.0	61.3	67.6	16.9	32.9	46.8	51.8
16	19.1	33.8	45.9	52.5	20.2	33.0	44.0	49.7	9.9	19.0	26.3	29.0
17	26.7	41.5	52.7	59.3	27.6	40.8	51.6	58.3	13.9	25.2	35.4	39.0
18	19.5	35.0	48.3	56.9	21.5	35.9	49.5	56.7	11.4	22.2	33.9	37.8
19	29.4	53.3	71.3	80.0	31.7	51.0	68.7	76.8	15.3	31.3	49.0	52.9
20	27.8	55.8	79.6	88.5	30.0	54.3	78.1	86.6	26.6	48.4	65.9	70.6
Mean	27.1	46.4	60.6	67.9	28.6	45.5	59.4	66.2	17.6	32.2	43.5	47.5

Table C.3.2 Maximum displacements of 4-storey building in N-S direction (with GWB), (mm)

No.	Drain-3D								Sapwood			
	Wall 19				Wall 25				Center of the storey diaphragm			
	st1	st2	st3	st4	st1	st2	st3	st4	st1	st2	st3	st4
1	30.9	57.4	88.7	111.4	30.9	57.3	88.5	111.2	26.7	46.6	62.6	66.7
2	27.4	52.8	76.3	91.0	27.4	52.7	76.1	90.8	32.9	52.1	69.0	72.3
3	24.7	47.5	71.9	87.5	24.7	47.5	71.8	87.4	25.7	49.7	77.1	86.9
4	27.6	47.9	76.9	97.8	27.6	47.9	76.8	97.6	23.0	44.6	67.0	75.3
5	30.3	54.2	81.7	101.1	30.3	54.3	81.7	101	17.2	31.5	41.2	43.7
6	31.8	54.5	78.9	97.2	31.7	54.4	78.9	97.2	18.1	34.9	54.6	62.4
7	31.2	62.1	92.3	111.0	31.1	62.0	92.2	110.9	33.2	55.0	68.6	70.9
8	15.6	33.4	57.1	76.8	15.6	33.3	57.2	76.9	16.4	35.7	52.2	57.2
9	30.2	55.6	81.1	97.2	30.2	55.4	80.9	96.9	23.9	41.3	56.5	59.1
10	31.3	56.3	78.4	93.3	31.3	56.3	78.4	93.4	21.0	36.3	48.7	51.3
11	33.7	62.9	90.1	108.0	33.6	62.8	90.0	107.9	25.2	42.3	61.2	67.4
12	43.1	75.1	102.8	120.3	43.1	75.0	102.6	119.9	24.2	44.4	69.7	78.7
13	25.3	41.8	59.6	73.2	25.3	41.8	59.5	72.9	16.5	31.4	47.0	52.9
14	29.9	47.2	63.5	74.5	29.9	47.1	63.4	74.4	30.7	48.1	62.1	65.0
15	27.6	50.6	75.6	92.7	27.6	50.6	75.6	92.7	26.1	48.8	74.5	81.4
16	23.3	41.5	60.9	75.4	23.3	41.5	60.9	75.3	15.3	26.9	40.7	47.4
17	21.9	38.3	57.2	70.4	21.9	38.2	57.1	70.3	16.9	34.0	49.2	53.9
18	27.2	46.8	64.7	78.2	27.2	46.8	64.7	78.1	18.3	34.3	49.3	53.8
19	18.1	37.9	61.6	78.3	18.1	37.8	61.5	78.1	18.2	28.9	45.4	48.7
20	30.1	55.8	84.2	103.4	30.1	55.8	84.3	103.5	26.1	50.4	68.5	75.0
Mean	28.1	51.0	75.2	91.9	28.0	50.9	75.1	91.3	22.8	40.9	58.3	63.5

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Table C.3.3 Maximum displacements of 6-storey building in E-W direction (with GWB), (mm)

No.	Drain-3D												Sapwood					
	Wall 8						Wall 4						Center of the storey diaphragm					
	st1	st2	st3	st4	st5	st6	st1	st2	st3	st4	st5	st6	st1	st2	st3	st4	st5	st6
1	20.6	41.4	62.7	87.1	109.9	122.0	18.8	36.6	67.4	91.1	112.9	124.8	18.1	32.2	45.3	64.6	77.7	81.5
2	17.0	33.9	52.3	69.7	86.3	96.7	17.6	33.4	54.4	69.1	85.9	96.7	14.6	32.4	46.5	60.5	73.2	76.0
3	18.4	36.5	56.5	74.3	89.7	99.2	17.7	34.8	60.7	77.7	92.7	102.3	25.4	43.8	62.3	81.7	111.8	121.7
4	20.7	40.3	67.7	93.3	115.9	127.3	20.5	36.9	70.9	95.0	116.7	128.0	22.2	38.4	50.4	61.2	81.1	87.8
5	21.8	43.0	64.1	82.5	98.0	107.9	22.3	39.6	63.0	79.5	94.2	103.8	13.7	25.1	35.5	46.1	57.8	61.3
6	23.5	45.7	65.9	83.4	97.7	106.9	22.3	40.2	61.6	77.8	92.4	102.0	17.0	33.4	45.4	58.4	74.1	79.9
7	18.0	37.7	63.6	86.8	106.8	118.1	17.2	35.0	65.0	84.7	102.3	114.0	23.1	42.8	57.9	69.4	77.4	79.4
8	12.3	26.3	44.9	65.9	87.7	100.2	12.8	27.1	45.8	64.8	86.1	98.8	17.0	31.0	46.1	59.3	66.1	66.8
9	21.2	43.4	69.0	90.6	107.5	117.6	20.8	40.5	72.0	93.1	112.0	123.1	22.2	37.2	52.0	65.5	75.8	78.2
10	18.7	36.7	56.7	74.0	88.7	98.4	20.2	37.0	57.3	72.8	87.4	97.4	15.3	27.8	40.3	49.5	55.8	57.6
11	22.3	45.4	70.3	92.4	110.8	122.0	24.2	43.6	73.3	90.1	105.1	117.1	14.0	30.1	44.9	60.5	73.2	76.1
12	21.4	44.2	68.2	87.7	103.9	114.0	21.7	42.3	71	89.0	105.2	116.0	18.5	33.8	47.3	56.7	71.8	77.7
13	16.8	32.7	50.2	65.5	79.1	87.5	14.8	29.5	46.1	60.2	73.2	81.6	18.0	32.2	44.9	60.5	77.5	83.7
14	24.7	42.3	58.5	71.5	80.9	87.4	23.9	40.6	57.4	69.8	79.6	86.8	26.5	41.5	52.2	62.4	69.9	73.1
15	19.3	38.3	58.1	77.0	94.8	105.6	16.7	33.1	56.4	74.0	92.0	103.6	22.2	40.4	56.7	75.9	93.4	98.8
16	17.0	35.0	57.3	77.7	94.9	104.9	16.5	32.8	58.6	77.6	94.9	105.3	15.1	28.1	41.5	52.5	62.2	64.2
17	17.2	32.6	48.5	61.3	71.8	79.4	16.2	30.5	44.9	56.4	66.0	72.4	15.4	30.9	44.3	58.5	72.4	78.1
18	18.1	35.5	53.4	71.8	89.9	101.2	18.7	35.8	56.5	71.9	86.3	96.0	12.6	22.9	33.0	41.8	54.6	57.0
19	11.9	24.8	37.9	51.9	68.4	77.9	12.2	25.4	39.3	52.4	70.6	80.7	16.4	28.9	35.7	43.0	49.9	52.3
20	16.1	34.9	58.1	79.5	98.4	109.8	16.5	34.7	60.0	80.3	99.7	111.7	25.4	43.6	55.1	54.9	68.3	72.8
Mean	18.8	37.5	58.2	77.2	94.1	104.2	18.6	35.5	58.5	76.4	92.8	103.1	18.6	33.8	46.9	59.1	72.2	76.2

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Table C.3.4 Maximum displacements of 6-storey building in N-S direction (with GWB), (mm)

No.	Drain-3D												Sapwood					
	Wall 19						Wall 25						Center of the storey diaphragm					
	st1	st2	st3	st4	st5	st6	st1	st2	st3	st4	st5	st6	st1	st2	st3	st4	st5	st6
1	25.7	49.1	71.9	93.0	114.0	129.1	25.7	49.0	71.9	93.0	114.0	129.1	14.2	29.1	43.2	56.7	66.4	70.8
2	16.8	31.3	45.2	64.2	97.1	122.6	16.7	31.2	45.0	63.9	96.7	122.0	15.7	32.0	47.1	56.9	65.5	69.5
3	26.7	43.8	61.8	87.6	123.0	147.9	26.7	43.8	61.6	87.4	122.7	147.4	16.4	28.9	45.6	63.6	78.3	84.3
4	20.7	41.4	62.0	83.4	118.0	146.8	20.7	41.4	62.0	83.4	118.0	146.8	14.1	27.2	41.6	54.8	66.3	71.5
5	22.4	45.0	76.9	119.5	164.7	199.0	22.4	45.0	76.8	119.4	164.6	198.9	12.4	23.0	33.4	40.8	46.9	50.1
6	28.2	55.3	86.0	120.4	149.5	171.9	28.1	55.1	85.8	120.1	149.2	171.5	11.5	22.5	32.6	41.5	51.1	56.0
7	21.7	38.9	55.6	76.5	104.1	125.6	21.6	38.8	55.6	76.5	104.2	125.8	17.6	32.8	48.8	61.3	70.2	74.8
8	19.8	41.9	67.3	96.8	127.0	150.5	19.8	41.8	67.2	96.7	126.9	150.4	10.8	22.6	35.0	46.1	54.6	59.1
9	31.2	57.6	88.5	125.4	157.1	181.0	31.1	57.5	88.1	124.9	156.5	180.2	14.7	27.9	40.7	49.7	55.9	59.4
10	19.5	39.0	66.5	103.0	146.6	178	19.5	38.8	66.4	102.8	146.3	177.6	12.4	22.6	32.3	39.7	44.3	47.0
11	20.7	38.2	61.3	92.0	123.7	145.5	20.6	38.0	61.3	91.9	123.6	145.3	17.2	30.3	45.3	56.3	63.9	67.0
12	15.1	29.0	41.8	59.5	80.5	97.1	15.1	28.9	41.7	59.4	80.4	96.9	17.3	32.6	47.1	59.0	69.2	73.8
13	31.4	61.5	96.1	135.1	169.6	197.1	31.3	61.4	96.0	134.9	169.4	196.9	11.2	21.3	31.9	41.1	48.7	52.8
14	27.9	50.5	71.8	95.4	127	147.7	27.8	50.5	71.7	95.1	126.6	147.2	19.9	32.9	43.5	51.1	56.3	59.4
15	23.5	46.6	73.8	108.1	144.0	169.5	23.4	46.5	73.7	107.8	143.6	168.9	14.0	29.8	45.1	58.2	72.5	78.2
16	24.2	47.2	73.3	115.7	165.5	204.4	24.1	47.2	73.2	115.5	165.4	204.2	10.4	20.1	29.7	38.1	45.0	47.6
17	31.2	57.6	88.5	125.4	157.1	181.0	31.1	57.5	88.1	124.9	156.5	180.2	10.8	22.2	31.7	38.7	45.8	49.2
18	19.8	41.9	67.3	96.8	127.0	150.5	19.8	41.8	67.2	96.7	126.9	150.4	10.0	19.8	29.8	37.5	43.9	46.1
19	12.2	20.8	26.8	38.5	56.5	77.0	12.2	20.7	26.7	38.4	56.7	77.2	10.3	19.3	29.4	38.7	48.5	50.8
20	29.6	46.4	59.3	75.0	103.5	132.3	29.6	46.4	59.2	74.8	103.2	131.8	15.2	30.5	46.0	58.9	68.7	72.9
Mean	23.4	44.1	67.1	95.6	127.8	151.4	23.4	44.1	67.0	95.4	127.6	152.4	13.8	26.4	39.0	49.4	58.1	62.0

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Table C.3.5 Maximum accelerations of 4-storey building (with GWB), (g)

No.	Sapwood							
	E-W				N-S			
	st1	st2	st3	st4	st1	st2	st3	st4
1	0.32	0.31	0.39	0.41	0.34	0.35	0.28	0.35
2	0.28	0.39	0.36	0.38	0.34	0.27	0.29	0.31
3	0.39	0.41	0.43	0.50	0.36	0.43	0.34	0.46
4	0.44	0.39	0.39	0.43	0.32	0.35	0.30	0.39
5	0.30	0.26	0.25	0.28	0.33	0.30	0.25	0.28
6	0.28	0.29	0.28	0.32	0.34	0.34	0.30	0.36
7	0.28	0.34	0.39	0.40	0.19	0.27	0.27	0.27
8	0.31	0.34	0.42	0.46	0.33	0.28	0.28	0.33
9	0.30	0.30	0.26	0.29	0.33	0.29	0.26	0.26
10	0.27	0.24	0.28	0.30	0.28	0.25	0.23	0.26
11	0.28	0.39	0.38	0.50	0.30	0.34	0.31	0.41
12	0.40	0.32	0.39	0.44	0.24	0.37	0.32	0.38
13	0.22	0.24	0.24	0.28	0.35	0.32	0.27	0.35
14	0.37	0.35	0.28	0.40	0.40	0.30	0.25	0.28
15	0.38	0.37	0.39	0.46	0.42	0.43	0.31	0.39
16	0.21	0.25	0.23	0.26	0.29	0.26	0.27	0.31
17	0.23	0.26	0.32	0.37	0.29	0.28	0.29	0.31
18	0.35	0.30	0.31	0.39	0.33	0.30	0.29	0.37
19	0.44	0.40	0.41	0.48	0.42	0.32	0.32	0.33
20	0.44	0.39	0.42	0.50	0.46	0.33	0.31	0.40
Mean	0.32	0.33	0.34	0.39	0.33	0.32	0.29	0.34

Note:
The acceleration is the moving average acceleration over 0.1 sec relative to stationary reference coordinates. The reason the moving average is used is that sudden spikes in acceleration over a very short time will not have significant impact on the contents or residents in the building, while the moving average value is felt to be more correlated with content damage and human comfort.

Table C.3.6 Maximum accelerations of 6-storey building (with GWB), (g)

No.	Sapwood											
	E-W						N-S					
	st1	st2	st3	st4	st5	st6	st1	st2	st3	st4	st5	st6
1	0.32	0.29	0.38	0.33	0.33	0.38	0.22	0.28	0.22	0.31	0.26	0.32
2	0.30	0.28	0.25	0.28	0.34	0.38	0.27	0.21	0.20	0.24	0.27	0.30
3	0.30	0.35	0.38	0.41	0.39	0.45	0.32	0.35	0.33	0.40	0.37	0.49
4	0.40	0.34	0.33	0.30	0.31	0.35	0.33	0.31	0.25	0.30	0.26	0.34
5	0.24	0.26	0.29	0.25	0.23	0.31	0.30	0.22	0.23	0.28	0.26	0.31
6	0.24	0.29	0.31	0.29	0.27	0.36	0.29	0.25	0.28	0.34	0.30	0.37
7	0.31	0.25	0.30	0.34	0.33	0.40	0.27	0.21	0.23	0.26	0.25	0.26
8	0.32	0.27	0.22	0.26	0.33	0.36	0.37	0.32	0.26	0.29	0.23	0.30
9	0.29	0.24	0.20	0.25	0.28	0.31	0.36	0.26	0.25	0.33	0.28	0.37
10	0.16	0.19	0.19	0.21	0.23	0.24	0.18	0.15	0.17	0.19	0.18	0.22
11	0.23	0.22	0.29	0.28	0.29	0.33	0.23	0.18	0.21	0.29	0.28	0.38
12	0.29	0.28	0.28	0.33	0.31	0.36	0.30	0.27	0.24	0.28	0.27	0.37
13	0.24	0.26	0.30	0.30	0.28	0.36	0.26	0.24	0.28	0.37	0.33	0.40
14	0.41	0.46	0.36	0.28	0.25	0.30	0.35	0.32	0.31	0.29	0.24	0.26
15	0.35	0.38	0.38	0.35	0.38	0.45	0.33	0.34	0.41	0.41	0.32	0.40
16	0.21	0.23	0.22	0.24	0.25	0.27	0.31	0.26	0.33	0.32	0.25	0.29
17	0.24	0.24	0.24	0.22	0.23	0.25	0.30	0.29	0.25	0.32	0.28	0.34
18	0.27	0.28	0.32	0.28	0.26	0.35	0.29	0.25	0.22	0.26	0.24	0.30
19	0.41	0.37	0.26	0.23	0.32	0.35	0.37	0.37	0.29	0.29	0.26	0.37
20	0.52	0.42	0.30	0.33	0.36	0.41	0.44	0.54	0.54	0.33	0.30	0.38
Mean	0.30	0.30	0.29	0.29	0.30	0.35	0.30	0.28	0.28	0.31	0.27	0.34

Note:
The acceleration is the moving average acceleration over 0.1 sec relative to stationary reference coordinates. The reason the moving average is used is that sudden spikes in acceleration over a very short time will not have significant impact on the contents or residents in the building, while the moving average value is felt to be more correlated with content damage and human comfort.

C.4 Maximum inter-storey drift

Table C.4.1 Inter-storey drift of 4-storey building in E-W direction (with GWB), (%)

No.	Drain-3D								Sapwood			
	Wall 8				Wall 4				Center of the storey diaphragm			
	st1	st2	st3	st4	st1	st2	st3	st4	st1	st2	st3	st4
1	1.23	0.90	0.67	0.31	1.29	0.77	0.69	0.32	0.84	0.51	0.43	0.15
2	1.27	0.87	0.61	0.30	1.43	0.75	0.62	0.30	1.19	0.63	0.41	0.14
3	1.18	0.91	0.51	0.25	1.26	0.78	0.52	0.26	0.67	0.92	0.56	0.23
4	0.66	0.69	0.67	0.32	0.60	0.57	0.71	0.33	0.76	0.85	0.64	0.24
5	0.88	0.52	0.46	0.27	0.93	0.47	0.44	0.26	0.36	0.40	0.32	0.12
6	0.58	0.48	0.41	0.22	0.54	0.44	0.41	0.22	0.40	0.41	0.37	0.15
7	1.49	1.09	0.52	0.27	1.54	0.97	0.52	0.26	1.21	0.62	0.44	0.12
8	0.88	0.99	0.75	0.34	1.04	0.85	0.72	0.34	0.79	0.86	0.63	0.17
9	0.68	0.53	0.45	0.25	0.78	0.46	0.44	0.24	0.40	0.41	0.32	0.12
10	0.80	0.55	0.51	0.30	0.85	0.51	0.49	0.28	0.36	0.37	0.31	0.12
11	1.35	0.80	0.63	0.34	1.40	0.72	0.61	0.29	0.58	0.60	0.56	0.28
12	1.60	0.95	0.63	0.33	1.70	0.89	0.66	0.34	0.64	0.68	0.55	0.31
13	0.57	0.50	0.45	0.24	0.62	0.46	0.47	0.23	0.41	0.34	0.24	0.10
14	0.89	0.46	0.47	0.29	0.93	0.42	0.46	0.27	0.78	0.43	0.44	0.23
15	1.18	0.83	0.57	0.30	1.16	0.64	0.58	0.29	0.61	0.61	0.59	0.20
16	0.70	0.54	0.46	0.24	0.73	0.48	0.47	0.23	0.36	0.36	0.31	0.12
17	0.97	0.54	0.41	0.24	1.00	0.48	0.41	0.25	0.51	0.43	0.37	0.16
18	0.71	0.59	0.54	0.31	0.78	0.55	0.58	0.30	0.41	0.41	0.46	0.21
19	1.07	0.87	0.66	0.31	1.15	0.73	0.67	0.31	0.56	0.71	0.77	0.32
20	1.01	1.05	0.87	0.38	1.09	0.90	0.87	0.37	0.97	0.80	0.67	0.21
Mean	0.98	0.73	0.56	0.29	1.04	0.64	0.57	0.28	0.64	0.57	0.47	0.18

Note:
Storey height = 2750 mm

Table C.4.2 Inter-storey drift of 4-storey building in N-S direction (with GWB), (%)

No.	Drain-3D								Sapwood			
	Wall 19				Wall 25				Center of the storey diaphragm			
	st1	st2	st3	st4	st1	st2	st3	st4	st1	st2	st3	st4
1	1.12	1.03	1.22	0.83	1.12	1.03	1.22	0.83	0.97	0.81	0.79	0.27
2	1.00	0.94	0.96	0.60	1.00	0.94	0.96	0.60	1.20	0.76	0.68	0.18
3	0.90	0.88	0.91	0.65	0.90	0.88	0.91	0.65	0.93	0.89	1.12	0.37
4	1.00	0.83	1.12	0.76	1.00	0.83	1.12	0.76	0.84	0.83	0.92	0.30
5	1.10	0.89	1.04	0.73	1.10	0.89	1.04	0.73	0.63	0.68	0.58	0.24
6	1.16	0.88	0.93	0.68	1.15	0.87	0.93	0.68	0.66	0.72	0.76	0.29
7	1.13	1.15	1.10	0.70	1.13	1.14	1.10	0.70	1.21	0.80	0.52	0.11
8	0.57	0.68	1.01	0.72	0.57	0.68	1.01	0.72	0.60	0.70	0.82	0.24
9	1.10	0.93	0.93	0.59	1.10	0.93	0.93	0.58	0.87	0.65	0.57	0.13
10	1.14	0.92	0.91	0.66	1.14	0.92	0.91	0.66	0.76	0.59	0.55	0.21
11	1.22	1.07	1.01	0.66	1.22	1.07	1.00	0.66	0.92	0.78	0.87	0.31
12	1.57	1.19	1.05	0.77	1.57	1.19	1.05	0.77	0.88	0.76	0.98	0.37
13	0.92	0.63	0.67	0.49	0.92	0.62	0.67	0.49	0.60	0.67	0.63	0.23
14	1.09	0.70	0.65	0.52	1.09	0.70	0.65	0.52	1.12	0.73	0.68	0.29
15	1.00	0.85	0.91	0.62	1.00	0.85	0.91	0.62	0.95	0.86	1.16	0.25
16	0.85	0.67	0.75	0.54	0.85	0.67	0.75	0.54	0.56	0.57	0.59	0.27
17	0.80	0.62	0.69	0.48	0.80	0.62	0.69	0.48	0.61	0.69	0.57	0.27
18	0.99	0.72	0.71	0.60	0.99	0.72	0.71	0.60	0.67	0.64	0.77	0.27
19	0.66	0.74	1.09	0.72	0.66	0.74	1.10	0.72	0.66	0.65	0.83	0.29
20	1.10	0.98	1.12	0.71	1.10	0.98	1.12	0.71	0.95	0.93	0.80	0.29
Mean	1.02	0.86	0.94	0.65	1.02	0.86	0.94	0.65	0.83	0.74	0.76	0.26

Note:
Storey height = 2750 mm

Table C.4.3 Inter-storey drift of 6-storey building in E-W direction (with GWB), (%)

No.	Drain-3D												Sapwood					
	Wall 8						Wall 4						Center of the storey diaphragm					
	st1	st2	st3	st4	st5	st6	st1	st2	st3	st4	st5	st6	st1	st2	st3	st4	st5	st6
1	0.75	0.77	0.98	0.91	0.83	0.46	0.68	0.66	1.26	0.87	0.79	0.45	0.52	0.56	0.61	0.52	0.47	0.19
2	0.62	0.62	0.79	0.75	0.65	0.39	0.64	0.60	0.89	0.68	0.64	0.39	0.57	0.61	0.63	0.44	0.32	0.16
3	0.67	0.67	0.75	0.68	0.70	0.43	0.64	0.63	0.95	0.64	0.65	0.42	0.60	0.49	0.62	0.72	0.59	0.22
4	0.75	0.80	1.00	0.93	0.85	0.46	0.74	0.70	1.24	0.88	0.83	0.47	0.51	0.57	0.59	0.52	0.43	0.19
5	0.79	0.78	0.77	0.67	0.57	0.37	0.81	0.64	0.87	0.61	0.54	0.35	0.45	0.43	0.42	0.34	0.32	0.17
6	0.86	0.81	0.75	0.68	0.65	0.41	0.81	0.65	0.79	0.62	0.66	0.41	0.42	0.43	0.43	0.38	0.39	0.20
7	0.65	0.73	0.96	0.84	0.73	0.42	0.63	0.68	1.09	0.72	0.65	0.42	0.64	0.62	0.73	0.47	0.37	0.17
8	0.45	0.54	0.74	0.83	0.84	0.46	0.47	0.55	0.79	0.75	0.82	0.47	0.39	0.44	0.49	0.56	0.37	0.18
9	0.77	0.84	0.94	0.79	0.64	0.39	0.76	0.73	1.19	0.77	0.70	0.44	0.53	0.49	0.47	0.33	0.23	0.13
10	0.68	0.68	0.73	0.66	0.56	0.35	0.73	0.61	0.81	0.59	0.55	0.37	0.45	0.38	0.35	0.27	0.21	0.12
11	0.81	0.88	0.98	0.83	0.67	0.41	0.88	0.79	1.12	0.73	0.68	0.44	0.63	0.60	0.55	0.45	0.31	0.14
12	0.78	0.85	0.89	0.72	0.69	0.43	0.79	0.75	1.08	0.68	0.62	0.39	0.63	0.57	0.54	0.47	0.41	0.20
13	0.61	0.59	0.66	0.58	0.50	0.32	0.54	0.54	0.66	0.52	0.50	0.33	0.41	0.41	0.43	0.38	0.40	0.16
14	0.90	0.68	0.68	0.55	0.49	0.32	0.87	0.63	0.73	0.51	0.50	0.30	0.72	0.56	0.55	0.36	0.32	0.17
15	0.70	0.69	0.76	0.73	0.68	0.42	0.61	0.61	0.86	0.67	0.67	0.43	0.51	0.61	0.61	0.51	0.60	0.21
16	0.62	0.66	0.81	0.74	0.64	0.38	0.60	0.60	0.97	0.69	0.65	0.40	0.38	0.38	0.37	0.32	0.28	0.15
17	0.63	0.58	0.59	0.53	0.47	0.31	0.59	0.53	0.56	0.48	0.46	0.30	0.39	0.42	0.38	0.32	0.27	0.14
18	0.66	0.65	0.70	0.69	0.66	0.41	0.68	0.62	0.82	0.57	0.61	0.38	0.36	0.39	0.41	0.37	0.33	0.16
19	0.43	0.50	0.52	0.62	0.76	0.44	0.44	0.51	0.56	0.61	0.78	0.46	0.37	0.44	0.50	0.43	0.43	0.17
20	0.59	0.71	0.94	0.87	0.73	0.41	0.60	0.67	1.09	0.81	0.74	0.43	0.55	0.59	0.66	0.50	0.45	0.19
Mean	0.69	0.70	0.80	0.73	0.66	0.40	0.68	0.63	0.92	0.67	0.65	0.40	0.50	0.50	0.52	0.43	0.38	0.17

Note:
Storey height = 2750 mm

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Table C.4.4 Inter-storey drift of 6-storey building in N-S direction (with GWB), (%)

No.	Drain-3D												Sapwood					
	Wall 19						Wall 25						Center of the storey diaphragm					
	st1	st2	st3	st4	st5	st6	st1	st2	st3	st4	st5	st6	st1	st2	st3	st4	st5	st6
1	0.94	0.85	0.84	0.93	1.06	0.77	0.94	0.85	0.84	0.93	1.05	0.77	0.66	0.55	0.66	0.83	0.60	0.14
2	0.61	0.55	0.64	0.85	1.46	1.02	0.61	0.55	0.64	0.85	1.46	1.01	0.53	0.69	0.61	0.64	0.59	0.14
3	0.97	0.69	0.80	1.18	1.46	0.92	0.97	0.68	0.80	1.18	1.45	0.92	0.90	0.73	0.67	0.75	1.31	0.36
4	0.75	0.75	0.83	1.04	1.45	1.08	0.75	0.75	0.83	1.04	1.45	1.08	0.81	0.63	0.61	0.65	0.77	0.25
5	0.81	0.91	1.27	1.62	1.67	1.25	0.81	0.91	1.27	1.62	1.67	1.25	0.49	0.53	0.46	0.48	0.58	0.20
6	1.02	1.00	1.15	1.26	1.15	0.87	1.02	1.00	1.14	1.26	1.15	0.87	0.56	0.58	0.54	0.64	0.64	0.29
7	0.79	0.68	0.75	0.91	1.16	0.86	0.79	0.68	0.75	0.90	1.16	0.86	0.84	0.73	0.61	0.59	0.41	0.10
8	1.25	2.07	2.74	3.66	4.64	5.47	1.25	2.06	2.73	3.65	4.62	5.45	0.63	0.60	0.58	0.67	0.59	0.21
9	1.13	1.04	1.20	1.37	1.21	0.92	1.13	1.03	1.19	1.36	1.20	0.92	0.85	0.65	0.58	0.56	0.62	0.19
10	0.71	0.76	1.11	1.35	1.68	1.23	0.71	0.76	1.10	1.34	1.68	1.22	0.59	0.47	0.46	0.37	0.32	0.13
11	0.75	0.73	0.93	1.11	1.34	0.98	0.75	0.73	0.93	1.11	1.34	0.98	0.53	0.56	0.58	0.55	0.66	0.22
12	0.55	0.54	0.61	0.70	0.83	0.69	0.55	0.54	0.61	0.70	0.84	0.69	0.65	0.67	0.52	0.55	0.71	0.30
13	1.14	1.11	1.28	1.42	1.27	1.01	1.14	1.11	1.28	1.42	1.27	1.01	0.63	0.65	0.52	0.60	0.80	0.33
14	1.01	0.86	0.93	1.20	1.15	0.89	1.01	0.86	0.93	1.19	1.15	0.89	0.95	0.63	0.58	0.62	0.53	0.23
15	0.85	0.88	1.07	1.41	1.41	1.05	0.85	0.88	1.06	1.41	1.41	1.05	0.79	0.69	0.69	0.70	1.01	0.24
16	0.88	0.84	1.28	1.64	1.86	1.41	0.88	0.84	1.28	1.64	1.86	1.41	0.57	0.57	0.57	0.62	0.59	0.24
17	0.97	0.79	1.14	1.52	1.65	1.25	0.97	1.70	2.63	4.10	5.73	6.97	0.57	0.61	0.56	0.56	0.56	0.28
18	0.72	0.82	0.98	1.18	1.24	0.97	0.72	0.82	0.98	1.18	1.24	0.97	0.45	0.44	0.47	0.46	0.55	0.22
19	0.44	0.38	0.42	0.57	1.02	0.83	0.44	0.38	0.41	0.57	1.02	0.83	0.59	0.53	0.51	0.59	0.70	0.27
20	1.08	0.63	0.69	1.04	1.98	1.28	1.08	0.63	0.69	1.04	1.97	1.27	0.93	0.68	0.76	0.95	0.74	0.30
Mean	0.87	0.84	1.03	1.30	1.53	1.24	0.87	0.89	1.10	1.42	1.74	1.52	0.68	0.61	0.58	0.62	0.66	0.23

Note:
Storey height = 2750 mm

C.5 Maximum shear wall deformation at each storey

Table C.5.1 Shear wall deformation of 4-storey building in E-W direction (with GWB)

No.	Drain-3D							
	Wall 8				Wall 4			
	st1	st2	st3	st4	st1	st2	st3	st4
1	32.9	23.2	16.2	6.0	34.1	19.2	16.4	6.0
2	33.8	22.5	14.7	5.9	37.9	18.6	14.3	5.0
3	31.5	23.4	11.8	5.1	33.5	19.4	11.6	5.3
4	17.1	17.4	16.2	6.8	15.2	13.7	17.0	6.1
5	23.5	13.1	10.9	5.7	24.7	11.7	10.0	5.1
6	15.1	12.0	9.4	3.9	14.0	10.2	9.2	3.7
7	40.0	28.5	12.4	5.1	40.8	24.5	11.4	4.0
8	23.1	25.7	18.7	6.8	27.3	21.0	17.1	6.2
9	17.8	13.4	10.4	4.9	20.3	10.9	9.7	4.0
10	21.2	13.7	12.1	6.0	22.4	12.1	11.0	4.8
11	36.1	20.4	15.5	6.9	37.4	18.0	14.0	4.9
12	42.9	24.4	14.9	6.5	45.2	22.5	15.5	6.3
13	15.0	12.5	10.6	4.6	15.9	10.6	10.6	3.8
14	23.5	11.3	11.6	6.7	24.6	10.0	11.1	5.5
15	31.4	21.4	13.3	5.7	30.5	15.6	13.3	5.1
16	18.3	13.3	10.5	4.7	19.0	11.4	10.5	3.9
17	25.8	13.5	9.4	4.6	26.4	11.2	9.1	4.2
18	18.8	14.9	12.9	6.5	20.4	13.0	13.3	5.3
19	28.4	22.6	16.1	6.3	30.2	18.0	15.4	5.4
20	26.9	27.4	21.7	7.8	28.5	22.6	20.8	6.4
Mean	26.2	18.7	13.5	5.8	27.4	15.7	13.1	5.0

Table C.5.2 Shear wall deformation of 4-storey building in N-S direction (with GWB)

No.	Drain-3D							
	Wall 19				Wall 25			
	st1	st2	st3	st4	st1	st2	st3	st4
1	24.8	19.1	20.6	8.2	26.0	20.3	22.2	9.9
2	22.7	17.9	14.5	5.0	23.4	19.0	16.0	6.2
3	20.3	16.2	14.5	5.5	21.0	17.3	15.8	6.9
4	24.0	15.4	18.9	8.4	24.4	16.4	20.4	9.7
5	25.7	16.1	17.0	7.8	26.4	17.3	18.4	9.0
6	28.0	16.5	15.2	6.8	28.6	17.6	16.5	8.0
7	24.0	20.9	15.9	4.3	25.9	22.7	18.2	6.4
8	11.5	10.9	15.9	5.5	12.0	12.0	17.4	7.0
9	25.2	17.4	14.8	4.6	25.9	18.5	16.2	5.8
10	25.9	16.0	12.6	5.4	26.7	17.2	14.2	6.3
11	27.0	18.6	13.7	4.0	28.4	20.8	16.1	5.9
12	37.7	24.2	17.7	7.9	38.5	25.3	19.1	9.2
13	21.1	10.4	9.2	4.5	21.6	11.3	10.2	5.0
14	25.8	13.0	10.5	6.9	26.3	13.8	11.5	7.8
15	22.6	15.2	14.0	5.1	23.4	16.4	15.5	6.4
16	19.4	11.5	11.1	4.6	19.9	12.4	12.4	5.7
17	17.5	9.0	8.3	3.3	18.0	9.8	9.3	3.9
18	22.9	12.8	10.0	6.7	23.5	13.7	11.1	7.6
19	13.4	12.8	18.2	7.5	13.9	13.7	19.6	8.3
20	24.0	16.8	18.5	7.9	25.0	18.6	20.4	8.7
Mean	23.2	15.5	14.6	6.0	23.9	16.7	16.0	7.2

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Table C.5.3 Shear wall deformation of 6-storey building in E-W direction (with GWB)

No.	Drain-3D											
	Wall 8						Wall 4					
	st1	st2	st3	st4	st5	st6	st1	st2	st3	st4	st5	st6
1	19.5	19.1	23.1	20.6	17.6	6.9	17.0	14.6	29.9	18.1	14.9	5.0
2	15.6	14.9	18.8	17.0	14.3	6.7	16.0	13.3	19.8	13.2	12.1	5.4
3	17.0	16.3	16.8	14.4	15.0	7.3	16.1	14.3	21.7	12.0	11.9	5.2
4	19.5	19.3	23.6	20.8	17.7	6.7	18.9	16.0	29.3	18.3	15.8	5.5
5	20.3	18.8	17.4	14.0	10.7	5.0	20.6	14.4	19.4	11.3	9.2	4.0
6	22.3	20.1	17.4	14.8	12.7	5.9	20.6	14.6	17.6	11.7	11.7	4.7
7	16.6	17.9	22.7	19.0	15.2	6.6	15.7	15.1	24.8	13.3	10.6	4.3
8	11.7	12.7	17.2	19.3	19.2	8.0	11.6	11.8	17.1	14.8	16.2	5.6
9	19.6	20.2	22.3	17.2	12.2	5.2	19.0	16.4	28.3	15.5	12.5	4.8
10	17.2	16.5	17.0	14.3	10.8	5.2	18.5	13.9	17.6	11.0	8.9	3.5
11	20.8	21.6	23.7	18.9	13.7	6.3	22.5	18.3	25.6	13.9	11.7	4.6
12	19.8	20.5	20.8	15.6	14.6	7.2	19.9	17.1	25.0	13.3	11.0	4.6
13	15.4	13.8	14.8	12.2	9.3	4.6	13.3	11.9	14.3	9.7	8.5	3.6
14	23.5	16.4	15.8	11.7	10.0	5.8	22.4	14.7	16.7	10.2	9.9	4.5
15	18.2	17.2	17.5	16.0	14.1	6.7	15.2	13.4	18.9	12.1	11.5	4.5
16	15.6	15.7	18.6	16.0	12.4	5.9	14.8	13.2	22.4	13.4	11.5	4.3
17	16.0	13.8	13.3	11.2	9.1	4.4	14.8	11.9	11.9	8.9	7.8	3.3
18	17.1	15.3	16.2	15.3	13.7	6.9	17.1	13.9	18.6	11	11.7	5.1
19	10.8	11.6	11.6	13.6	17.3	7.9	10.9	11.4	12.1	11.5	16.0	6.4
20	14.8	17.0	22.6	20.5	16.5	7.5	14.7	14.7	25.2	16.7	13.9	5.3
Mean	17.6	16.9	18.6	16.1	13.8	6.3	17.0	14.2	20.8	13.1	11.9	4.7

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Table C.5.4 Shear wall deformation of 6-storey building in N-S direction (with GWB)

No.	Drain-3D											
	Wall 19						Wall 25					
	st1	st2	st3	st4	st5	st6	st1	st2	st3	st4	st5	st6
1	20.2	13.4	9.7	11.2	12.4	3.5	20.8	14.3	10.8	12.5	13.6	4.8
2	13.7	10.0	8.5	9.8	22.6	8.5	14.0	10.4	9.1	11.0	24.2	10.2
3	23.7	12.4	10.5	16.4	23.1	7.5	24.2	13.0	11.5	17.9	24.7	9.0
4	15.7	11.8	9.8	12.5	18.2	6.1	16.2	12.7	10.9	13.9	19.8	7.6
5	17.1	13.2	12.7	17.4	15.4	4.0	17.6	14.2	16.4	21.8	19.6	6.4
6	21.4	14.9	13.9	13.9	10.3	3.3	22.2	16.4	15.9	16.0	11.9	4.4
7	17.2	10.6	9.4	11.2	12.4	3.5	17.8	11.2	10.2	12.4	14.0	4.6
8	30.0	14.8	11.0	16.5	20.4	6.1	30.6	15.7	12.3	17.9	21.9	7.3
9	25.1	16.8	16.6	18.0	12.2	3.9	25.7	18.2	18.5	20.2	14.3	5.8
10	15.5	12.4	14.7	17.3	22.9	8.5	15.9	13.0	16.9	19.6	25.4	11.1
11	16.2	10.4	11.7	13.7	14.8	5.9	16.7	11.3	13.1	15.3	16.8	7.4
12	13.8	10.3	9.3	9.7	10.7	7.3	13.9	10.5	9.9	10.4	11.4	8.1
13	24.2	17.0	14.9	15.5	10.0	2.9	25.1	18.8	18.2	18.9	12.0	4.2
14	23.3	14.7	12.4	17.5	14.4	5.6	23.8	15.6	13.9	19.3	16.2	7.2
15	18.4	13.4	13.5	20.3	18.8	7.5	18.9	14.4	15.3	22.4	20.9	9.5
16	18.9	13.2	12.7	17.7	18.5	5.9	19.4	14.1	15.5	21.0	22.9	8.8
17	22.1	12.7	14.1	20.7	20.1	7.5	22.6	13.6	17.1	23.3	23.2	10.2
18	15.6	11.7	10.7	13.7	11.3	4.6	16.0	12.6	12.1	15.4	13.4	5.5
19	12.0	9.7	5.9	6.9	13.4	7.4	12.1	9.8	6.2	7.5	14.5	8.3
20	26.8	13.5	8.8	15.2	36.7	17.1	27.2	13.8	9.5	16.8	39.0	19.6
Mean	19.5	12.8	11.5	14.8	16.9	6.3	20.0	13.7	13.2	16.7	19.0	8.0

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C.6 Maximum uplift forces and deformations

Table C.6.1 Maximum uplift forces of 4-storey building in E-W direction (with GWB), (kN)

No.	Drain-3D								Sapwood							
	Wall 8				Wall 4				Wall 4 - method A				Wall 4 - method B			
	st1	st2	st3	st4	st1	st2	st3	st4	st1	st2	st3	st4	st1	st2	st3	st4
1	39.0	20.8	8.2	0.0	59.8	30.8	9.4	0	47.3	34.2	16.9	8.3	20.2	20.0	16.4	7.5
2	49.3	22.3	8.0	0.2	63.2	32.9	11.3	0.3	54.0	34.1	16.0	9.4	38.8	32.2	17.2	5.8
3	29.4	11.6	7.3	1.1	36.3	14.0	8.3	1.1	64.6	49.5	27.7	11.7	34.3	38.5	22.2	9.1
4	30.6	22.4	12.1	2.2	36.8	27.3	13.5	3.0	63.0	46.5	27.8	13.5	33.5	36.7	23.8	11.0
5	32.3	15.8	7.1	0.3	32.9	16.6	8.7	0.4	42.4	33.8	22.7	15.3	21.9	23.2	14.5	6.4
6	27.9	12.4	0.0	0.0	36.7	17.0	0	0	51.9	36.0	22.1	8.3	24.8	24.4	16.6	7.4
7	42.9	20.9	4.7	0.0	66.4	32.2	6.4	0	32.1	24.8	18.0	8.8	20.9	18.0	6.3	3.4
8	50.7	26.5	10.5	1.9	62.7	39.2	14.6	2.4	57.5	46.1	23.5	14.7	32.9	34.5	21.7	9.5
9	37.3	16.5	3.3	0.0	43.5	22.2	4.0	0	47.6	31.1	14.1	7.2	22.7	24.4	14.2	6.8
10	36.2	18.5	7.3	0.0	37.0	23.2	9.6	0	53.2	33.5	18.1	12.1	22.0	24.3	13.6	6.3
11	51.3	28.1	8.1	0.1	62.2	32.7	11.4	0.1	65.0	42.9	21.2	11.1	33.0	33.4	22.1	12.8
12	46.0	25.0	10.8	1.6	58.1	31.9	12.2	1.9	68.5	43.7	24.2	13.4	33.0	33.7	21.8	13.1
13	32.1	17.2	4.7	0.0	45.2	24.0	5.9	0	45.1	35.3	18.2	7.8	23.6	21.5	11.1	4.8
14	23.2	8.7	9.2	1.1	25.5	8.5	10.7	1.5	53.6	34.9	21.4	10.4	37.8	27.8	16.9	8.7
15	36.5	18.6	7.1	0.0	49.4	25.8	7.9	0	62.4	45.8	22.3	11.1	33.1	33.2	20.9	10.3
16	15.1	36.6	18.3	33.9	20.2	44.0	20.2	44.0	50.3	40.1	24.4	11.7	22.7	21.9	13.6	6.1
17	33.1	15.1	2.8	0.0	48.3	21.1	3.2	0	49.7	37.3	25.5	11.6	28.5	24.9	14.9	8.1
18	36.5	21.1	8.0	0.8	52.6	31.2	11.4	1.1	42.6	30.2	21.1	10.7	25.8	23.4	20.0	9.6
19	40.8	21.8	8.3	0.9	61.7	33.0	12.0	1.3	69.4	58.5	30.0	13.9	32.3	36.1	25.7	13.9
20	46.0	27.8	12.1	2.6	70.6	42.1	17.9	3.8	43.0	38.1	26.4	14.1	36.0	33.9	23.5	9.6
Mean	36.8	20.4	7.9	2.3	48.4	27.5	10.4	5.1	53.2	38.8	22.1	11.3	28.9	28.3	17.9	8.5

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Table C.6.2 Maximum uplift forces of 4-storey building in N-S direction (with GWB), (kN)

No.	Drain-3D								Sapwood							
	Wall 19				Wall 25				Wall 25 - method A				Wall 25 - method B			
	st1	st2	st3	st4	st1	st2	st3	st4	st1	st2	st3	st4	st1	st2	st3	st4
1	115.1	73.8	36.4	11.5	100.1	64.2	33.1	13.0	8.0	7.2	5.2	2.5	34.8	37.6	26.5	13.9
2	111.3	73.8	35.7	12.8	93.9	63.3	32.2	13.0	15.4	11.3	7.9	5.2	40.3	36.3	24.0	9.5
3	91.1	64.7	38.9	14.6	79.7	57.8	34.2	14.7	14.3	11.2	7.8	5.4	39.6	39.2	28.5	16.2
4	92.8	63.7	37.3	13.0	78.1	54.7	32.8	13.0	12.9	9.2	9.0	5.8	38.6	37.7	27.5	14.5
5	105.1	65.0	33.7	9.8	88.9	56.2	29.9	10.0	14.7	12.1	8.8	6.3	33.3	34.1	23.2	11.9
6	115.1	76.6	37.8	11.1	98.2	65.6	34.1	12.5	14.3	11.6	7.7	5.6	32.0	33.5	25.3	14.5
7	115.1	76.2	35.9	11.0	104.1	67.7	34.5	13.7	8.8	7.3	6.6	4.1	21.1	15.2	12.1	4.9
8	101.3	76.3	42.6	14.5	87.7	66.8	37.9	15.2	19.3	17.8	15.0	8.5	33.8	36.9	25.5	13.0
9	108.4	66.3	28.2	6.0	91.4	57.6	26.9	8.3	15.3	11.0	6.0	3.4	36.0	31.6	20.8	7.5
10	112.4	70.9	38.0	11.6	94.9	60.8	34.0	12.8	14.7	11.3	7.2	5.1	32.9	33.1	23.4	10.8
11	115.1	75.6	35.3	9.9	103.6	67.1	33.7	12.6	22.6	15.7	8.6	4.6	38.8	36.9	27.5	14.6
12	111.0	75.1	44.6	16.7	94.2	64.7	40.0	17.3	16.8	11.5	9.1	6.9	38.2	36.5	27.8	17.5
13	84.8	48.6	26.9	7.2	73.8	44.5	25.2	7.9	14.9	11.5	6.3	3.3	33.5	34.3	24.2	12.9
14	73.9	46.3	27.1	18.3	63.7	42.2	25.6	16.6	13.7	12.5	9.1	6.3	40.3	34.0	23.6	15.0
15	113.8	72.4	33.6	7.1	95.7	62.3	30.7	9.3	21.0	15.5	11.0	5.2	41.4	38.2	27.8	12.8
16	83.2	44.6	19.3	6.7	71.8	40.9	18.8	7.5	15.0	10.7	6.2	4.6	30.7	31.7	23.1	12.7
17	96.1	55.9	23.8	4.8	83.7	51.5	23.4	5.5	16.2	11.7	8.1	4.6	34.3	37.2	24.3	12.5
18	92.9	60.2	34.0	17.9	80.9	54.8	30.3	16.4	14.3	11.9	7.6	4.9	32.6	33.7	25.6	13.6
19	94.8	72.3	45.9	16.8	82.8	64.1	40.3	16.8	19.6	16.5	10.9	7.8	31.8	34.3	26.7	14.9
20	115.1	80.8	43.6	17.0	101.7	70.0	39.4	17.9	19.1	16.7	12.8	8.9	38.1	37.7	26.4	14.6
Mean	102.4	67.0	34.9	11.9	88.4	58.8	31.8	12.7	15.5	12.2	8.5	5.5	35.1	34.5	24.7	12.9

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Table C.6.3 Maximum uplift deformation of 4-storey building in E-W direction (with GWB), (mm)

No.	Drain-3D								Sapwood							
	Wall 8				Wall 4				Wall 4 - method A				Wall 4 - method B			
	st1	st2	st3	st4	st1	st2	st3	st4	st1	st2	st3	st4	st1	st2	st3	st4
1	1.38	0.74	0.57	0.00	2.12	1.09	0.65	0	1.67	1.21	1.17	0.58	0.72	0.71	1.14	0.52
2	1.75	0.79	0.55	0.02	2.24	1.16	0.78	0.02	1.91	1.21	1.11	0.65	1.37	1.14	1.19	0.40
3	1.04	0.41	0.51	0.08	1.29	0.50	0.58	0.08	2.28	1.75	1.92	0.81	1.21	1.36	1.54	0.63
4	1.09	0.80	0.84	0.15	1.31	0.97	0.94	0.21	2.23	1.64	1.93	0.93	1.18	1.30	1.65	0.76
5	1.15	0.56	0.50	0.02	1.17	0.59	0.61	0.03	1.50	1.20	1.57	1.06	0.78	0.82	1.00	0.45
6	0.99	0.44	0.00	0.00	1.30	0.60	0	0	1.83	1.27	1.53	0.57	0.88	0.86	1.15	0.51
7	1.52	0.74	0.32	0.00	2.36	1.14	0.44	0	1.13	0.88	1.25	0.61	0.74	0.64	0.43	0.24
8	1.80	0.94	0.73	0.13	2.22	1.39	1.02	0.17	2.03	1.63	1.63	1.02	1.16	1.22	1.51	0.66
9	1.32	0.58	0.23	0.00	1.54	0.79	0.28	0	1.68	1.10	0.98	0.50	0.80	0.86	0.99	0.47
10	1.28	0.66	0.51	0.00	1.31	0.82	0.66	0	1.88	1.19	1.26	0.84	0.78	0.86	0.94	0.44
11	1.82	1.00	0.57	0.01	2.21	1.16	0.79	0.01	2.30	1.52	1.47	0.77	1.17	1.18	1.53	0.89
12	1.63	0.89	0.75	0.11	2.06	1.13	0.85	0.13	2.42	1.55	1.68	0.93	1.17	1.19	1.51	0.91
13	1.14	0.61	0.33	0.00	1.60	0.85	0.41	0	1.60	1.25	1.26	0.54	0.83	0.76	0.77	0.33
14	0.06	0.31	0.64	0.08	0.06	0.30	0.74	0.10	1.89	1.24	1.49	0.72	1.34	0.98	1.17	0.61
15	1.29	0.66	0.49	0.00	1.75	0.91	0.55	0	2.21	1.62	1.55	0.77	1.17	1.17	1.45	0.72
16	1.01	0.54	0.17	0.00	1.35	0.65	0.19	0	1.78	1.42	1.69	0.81	0.80	0.78	0.95	0.43
17	1.18	0.54	0.19	0.00	1.71	0.75	0.22	0	1.76	1.32	1.76	0.81	1.01	0.88	1.04	0.56
18	1.29	0.75	0.56	0.05	1.86	1.10	0.79	0.07	1.51	1.07	1.46	0.74	0.91	0.83	1.39	0.67
19	1.45	0.77	0.58	0.06	2.19	1.17	0.83	0.09	2.46	2.07	2.08	0.96	1.14	1.28	1.78	0.96
20	1.63	0.99	0.84	0.18	2.50	1.49	1.24	0.27	1.52	1.35	1.83	0.98	1.27	1.20	1.63	0.67
Mean	1.29	0.69	0.49	0.04	1.71	0.93	0.66	0.11	1.88	1.37	1.53	0.78	1.02	1.00	1.24	0.59

Table C.6.4 Maximum uplift deformation of 4-storey building in N-S direction (with GWB), (mm)

No.	Drain-3D								Sapwood							
	Wall 19				Wall 25				Wall 25 - method A				Wall 25 - method B			
	st1	st2	st3	st4	st1	st2	st3	st4	st1	st2	st3	st4	st1	st2	st3	st4
1	4.67	2.62	2.53	0.80	3.55	2.28	2.30	0.90	0.28	0.25	0.36	0.17	1.23	1.33	1.84	0.97
2	3.94	2.61	2.48	0.89	3.33	2.24	2.24	0.90	0.54	0.40	0.55	0.36	1.43	1.28	1.67	0.66
3	3.23	2.29	2.70	1.02	2.82	2.05	2.38	1.02	0.51	0.40	0.54	0.37	1.40	1.39	1.98	1.12
4	3.29	2.26	2.59	0.90	2.77	1.94	2.28	0.91	0.45	0.33	0.63	0.40	1.36	1.33	1.91	1.01
5	3.73	2.30	2.34	0.68	3.15	1.99	2.08	0.70	0.52	0.43	0.61	0.44	1.18	1.21	1.61	0.82
6	4.25	2.72	2.63	0.77	3.48	2.33	2.37	0.87	0.51	0.41	0.54	0.39	1.13	1.19	1.75	1.01
7	5.54	2.70	2.49	0.76	3.69	2.40	2.40	0.96	0.31	0.26	0.46	0.29	0.75	0.54	0.84	0.34
8	3.59	2.71	2.96	1.01	3.11	2.37	2.63	1.05	0.68	0.63	1.04	0.59	1.20	1.31	1.76	0.90
9	3.84	2.35	1.96	0.42	3.24	2.04	1.87	0.57	0.54	0.39	0.42	0.24	1.27	1.12	1.44	0.52
10	3.99	2.51	2.64	0.81	3.36	2.15	2.36	0.89	0.52	0.40	0.50	0.35	1.16	1.17	1.62	0.75
11	5.32	2.68	2.45	0.69	3.67	2.38	2.34	0.87	0.80	0.56	0.60	0.32	1.37	1.31	1.91	1.01
12	3.94	2.66	3.10	1.16	3.34	2.29	2.78	1.20	0.59	0.41	0.63	0.48	1.35	1.29	1.93	1.21
13	3.01	1.72	1.87	0.50	2.61	1.58	1.75	0.55	0.53	0.41	0.44	0.23	1.19	1.21	1.68	0.89
14	2.62	1.64	1.88	1.27	2.26	1.50	1.78	1.15	0.48	0.44	0.63	0.44	1.43	1.20	1.64	1.04
15	4.04	2.57	2.34	0.49	3.39	2.21	2.14	0.65	0.74	0.55	0.76	0.36	1.46	1.35	1.92	0.89
16	2.95	1.58	1.34	0.47	2.54	1.45	1.30	0.52	0.53	0.38	0.43	0.32	1.09	1.12	1.60	0.88
17	3.41	1.98	1.66	0.33	2.97	1.82	1.62	0.38	0.57	0.41	0.56	0.32	1.21	1.32	1.68	0.87
18	3.29	2.13	2.36	1.24	2.87	1.94	2.11	1.14	0.50	0.42	0.53	0.34	1.15	1.19	1.78	0.95
19	3.36	2.56	3.19	1.17	2.94	2.27	2.80	1.17	0.69	0.58	0.76	0.54	1.12	1.21	1.85	1.03
20	4.68	2.87	3.03	1.18	3.61	2.48	2.74	1.24	0.68	0.59	0.88	0.62	1.35	1.33	1.83	1.02
Mean	3.83	2.37	2.43	0.83	3.14	2.09	2.21	0.88	0.55	0.43	0.59	0.38	1.24	1.22	1.71	0.89

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Table C.6.5 Maximum uplift forces of 6-storey building in E-W direction (with GWB), (kN)

No.	Drain-3D												Sapwood											
	Wall 8						Wall 4						Wall 4 - method A						Wall 4 - method B					
	st1	st2	st3	st4	st5	st6	st1	st2	st3	st4	st5	st6	st1	st2	st3	st4	st5	st6	st1	st2	st3	st4	st5	st6
1	76.7	54.2	46.1	21.9	8.5	1.1	133.7	94.0	57.3	29.2	11.1	1.5	102.8	61.9	62.5	33.1	35.7	15.5	37.3	39.7	34.4	32.1	18.6	9.2
2	103.4	59.1	42.5	21.8	9.8	2.1	114.1	87.1	62.8	34.9	14.6	2.9	72.4	48.0	43.3	17.1	16.3	7.8	45.7	47.1	37.3	31.2	17.2	5.7
3	72.5	48.9	40.8	25.0	9.9	1.5	84.2	67.2	49.0	31.2	14.4	2.1	143.6	85.0	78.5	32.7	26.7	9.7	44.8	41.1	35.4	34.0	21.4	8.8
4	78.5	57.2	41.1	24.2	9.4	0.4	104.7	69.4	50.5	30.4	11.6	0.4	95.8	57.8	67.8	31.8	30.0	14.0	38.4	45.6	34.0	31.8	17.7	8.6
5	96.0	59.8	31.9	13.3	4.3	0.0	108.1	71.4	37.7	16.2	4.8	0	81.5	48.8	48.8	23.5	17.5	7.8	33.4	34.8	27.4	22.1	14.9	6.7
6	88.1	56.4	44.0	22.1	8.8	0.0	126.3	91.0	57.4	31.9	10.9	0.0	116.4	70.9	63.9	28.3	24.1	9.8	34.1	34.2	27.7	22.6	16.1	8.4
7	130.2	62.5	44.2	21.8	7.2	0.0	140.4	102.1	64.8	33.8	10.8	0	42.6	24.2	27.6	13.5	13.4	8.5	31.2	31.6	22.3	15.7	8.4	3.7
8	50.3	62.0	46.8	26.0	10.9	2.2	113.3	92.6	68.4	41.1	17.6	3.3	85.4	52.0	59.8	34.6	36.9	15.4	32.1	34.5	26.7	29.7	16.4	7.4
9	109.4	72.4	45.4	23.7	6.5	0.0	125.9	92.5	56.9	30.1	8.4	0	120.3	67.7	64.4	29.6	25.1	9.8	37.4	35.8	27.6	22.3	12.2	5.5
10	106.4	66.8	36.3	21.1	4.9	0.0	121.5	86.5	53.6	28.3	6.8	0	95.4	52.6	48.1	20.9	17.9	8.6	32.9	29.2	21.8	17.3	9.4	5.9
11	122.3	73.3	45.2	22.8	8.7	0.4	137.1	101.0	67.6	36.1	12.8	0.6	97.7	58.4	57.8	25.6	23.8	11.4	40.0	37.8	29.9	25.2	13.5	5.5
12	69.7	52.7	39.0	22.9	8.8	0.3	80.0	64.5	48.5	28.6	12.2	0.4	96.8	61.5	57.8	32.3	33.7	15.0	43.0	44.0	33.2	30.6	19.6	8.0
13	80.1	51.5	35.3	17.8	4.4	0.0	88.3	60.6	40.3	21.4	5.5	0	124.2	70.9	67.6	27.7	22.4	10.1	34.0	32.0	25.9	22.3	17.5	9.2
14	73.8	46.5	29.9	12.3	7.5	0.3	86.1	57.5	35.1	14.4	8.5	0.4	112.2	70.1	69.9	31.8	24.3	13.6	52.5	44.7	33.9	23.4	16.0	7.7
15	90.3	55.3	42.5	21.8	8.1	0.3	134.3	97.1	61.5	34.8	12.5	0.4	107.7	62.1	67.3	30.3	28.8	15.2	44.6	46.3	34.5	26.3	21.5	8.6
16	87.4	56.5	40.9	21.2	8.3	0.0	101.1	74.1	47.7	26.7	10.5	0	78.5	44.2	42.0	21.0	20.1	10.7	30.7	31.3	26.5	20.0	12.0	6.8
17	79.9	40.5	27.1	12.4	1.6	0.0	90.0	54.8	33.5	16.1	1.9	0	97.9	59.5	58.7	24.7	21.8	10.4	31.9	31.3	24.6	21.6	11.9	6.4
18	66.3	63.5	40.8	20.4	12.4	1.5	108.7	80.6	51.3	26.7	14.1	1.9	67.1	38.9	40.7	21.3	18.1	9.0	29.0	31.2	28.8	24.9	16.2	6.8
19	75.0	54.2	49.6	26.0	13.0	3.6	87.1	67.0	58.4	39.8	20.1	5.4	79.7	50.8	52.7	24.8	25.8	16.8	29.8	35.1	33.6	29.7	20.9	7.3
20	97.0	67.1	46.9	24.4	7.8	1.4	132.8	100.8	71.2	39.8	14.4	2.3	75.7	44.0	52.2	23.1	24.2	13.4	37.9	39.7	34.2	28.8	21.7	9.5
Mean	87.7	58.0	40.8	21.1	8.0	0.7	110.9	80.6	53.7	29.6	11.2	1.7	94.7	56.5	56.6	26.4	24.3	11.6	37.0	37.4	30.0	25.6	16.2	7.3

Table C.6.6 Maximum uplift forces of 6-storey building in N-S direction (with GWB), (kN)

No.	Drain-3D												Sapwood											
	Wall 19						Wall 25						Wall 25 - method A						Wall 25 - method B					
	st1	st2	st3	st4	st5	st6	st1	st2	st3	st4	st5	st6	st1	st2	st3	st4	st5	st6	st1	st2	st3	st4	st5	st6
1	201.1	128.1	76.0	50.8	25.3	5.3	178.6	118.8	73.1	49.1	25.6	7.0	18.7	18.8	13.9	13.9	8.3	5.2	35.3	41.1	48.8	41.6	25.8	8.8
2	120.6	103.0	86.1	69.9	36.8	11.8	110.0	94.5	79.8	63.9	33.6	12.3	37.0	34.7	21.3	16.9	7.3	4.1	52.0	54.1	50.8	40.5	25.1	9.6
3	125.0	87.8	75.9	61.1	34.7	6.3	108.6	82.0	71.0	56.6	31.7	8.2	32.0	27.8	16.4	15.4	7.1	3.1	61.6	56.0	49.3	39.9	31.2	18.1
4	183.7	130.4	108.3	81.6	47.2	17.9	163.3	121.0	100.5	74.7	41.4	18.2	29.1	23.9	14.1	14.5	9.5	4.6	52.3	51.6	47.5	38.5	27.7	14.4
5	246.5	190.2	115.2	82.8	37.7	7.3	220.1	175.7	115.1	79.8	41.3	15.5	26.6	25.8	15.4	12.6	6.6	2.9	40.2	46.3	39.5	30.8	23.6	11.5
6	252.4	182.6	115.1	63.9	23.8	2.1	218.8	160.3	105.0	60.3	27.3	6.4	28.3	24.9	13.5	12.1	6.5	3.4	50.9	46.4	42.2	35.9	26.1	16.1
7	190.3	126.1	74.9	49.4	26.2	8.3	177.4	119	72.4	48.3	26.3	9.6	18.1	17.9	11.0	9.2	4.4	3.0	37.4	33.8	27.1	19.7	13.3	4.8
8	162.1	115.3	85.3	72.2	40.1	10.8	142.7	104.4	80.6	66.8	36.1	11.9	29.7	31.6	20.6	19.4	10.2	5.3	48.0	44.9	39.6	34.9	26.2	12.3
9	224.5	148.0	79.1	40.5	15.8	0.3	197.2	134.5	77.7	41.2	17.1	2.7	27.1	21.9	12.9	11.7	7.0	3.9	54.9	53.9	41.3	33.6	25.7	13.1
10	203.4	156.5	115.1	80.0	45.3	16.9	182.9	142.7	108.5	72.1	42.3	18.9	24.8	22.3	14.2	12.8	7.7	3.7	44.3	41.6	35.3	25.1	16.8	7.9
11	174.5	134.5	108.0	80.3	39.9	9.5	156.7	123.5	98.7	70.8	37.3	12.4	37.1	33.5	20.7	21.1	11.3	4.8	49.0	47.7	41.1	33.4	26.0	13.6
12	111.1	72.4	61.6	49.8	34.6	15.0	97.8	66.0	57.2	46.6	31.5	13.5	20.1	20.1	14.6	19.1	9.9	5.1	53.6	52.6	44.9	35.9	26.3	16.8
13	268.3	190.3	115.1	65.3	24.2	0.3	232.3	175.1	115.1	67.5	30.6	8.5	33.3	29.9	18.0	15.1	6.1	2.8	52.3	53.0	45.8	36.2	27.4	16.7
14	164.5	121.2	82.8	61.3	40.6	16.0	148.2	112.6	76.4	57.3	37.2	17.0	27.6	26.1	17.4	17.1	6.5	5.1	66.0	55.5	47.8	38.0	24.1	13.3
15	185.0	123	78.4	44.6	19.3	2.1	164.3	114.4	75.4	44.2	19.6	4.1	28.5	28.2	18.2	17.2	9.0	6.4	56.3	51.3	50.7	40.1	29.1	14.8
16	236.3	180.9	115.2	90.8	46.1	14.5	214.0	171.4	115.1	86.9	48.7	21.9	25.2	22.1	13.4	14.9	9.1	4.1	48.1	46.5	45.2	37.4	24.5	14.1
17	224.4	169.9	115.1	84.4	43.2	14.7	202.6	158.5	115.1	75.7	42.9	19.3	35.5	32.1	18.3	15.1	6.9	4.0	51.3	50.9	44.2	36.2	24.5	14.9
18	212.0	159.5	113.8	74.6	36.2	10.4	189.3	147.4	105.8	66.4	34.5	11.3	30.3	26.5	15.7	14.2	7.2	3.9	37.0	38.0	36.8	28.7	24.0	11.7
19	49.9	62.3	67.3	62.2	46.6	19.1	44.6	57.9	61.8	56.1	41.2	18.9	20.4	18.7	12.6	12.5	9.4	6.5	50.6	48.3	42.1	37.7	27.3	15.8
20	104.9	103.3	102.1	95.1	58.7	28.2	90.9	95.5	92.2	79.3	49.5	23.8	25.7	27.9	16.8	16.2	7.9	4.8	59.8	51.9	48.7	41.5	28.1	17.3
Mean	182.0	134.9	94.5	68.0	36.1	10.8	162.0	124.0	89.8	63.2	34.8	13.1	27.8	25.7	15.9	15.1	7.9	4.3	50.0	48.3	43.4	35.3	25.1	13.3

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Table C.6.7 Maximum uplift deformation of 6-storey building in E-W direction (with GWB), (mm)

No.	Drain-3D												Sapwood											
	Wall 8						Wall 4						Wall 4 - method A						Wall 4 - method B					
	st1	st2	st3	st4	st5	st6	st1	st2	st3	st4	st5	st6	st1	st2	st3	st4	st5	st6	st1	st2	st3	st4	st5	st6
1	1.65	1.92	1.64	1.52	0.59	0.08	2.87	3.33	2.03	2.03	0.77	0.10	2.20	2.19	2.21	2.29	2.47	1.07	0.80	1.41	1.22	2.22	1.29	0.64
2	2.22	2.10	1.51	1.52	0.68	0.15	2.45	3.09	2.23	2.43	1.02	0.20	1.55	1.70	1.53	1.18	1.13	0.54	0.98	1.66	1.32	2.16	1.19	0.40
3	1.56	1.73	1.45	1.74	0.69	0.10	1.81	2.38	1.74	2.17	1.00	0.14	3.07	3.00	2.78	2.27	1.85	0.67	0.96	1.45	1.25	2.35	1.48	0.61
4	1.68	2.03	1.46	1.68	0.65	0.03	2.25	2.46	1.79	2.11	0.81	0.03	2.05	2.04	2.40	2.20	2.08	0.97	0.82	1.61	1.20	2.20	1.22	0.60
5	2.06	2.12	1.13	0.93	0.30	0.00	2.32	2.53	1.34	1.12	0.33	0	1.74	1.72	1.73	1.63	1.21	0.54	0.71	1.23	0.97	1.53	1.04	0.47
6	1.89	2.00	1.56	1.54	0.61	0.00	2.71	3.23	2.03	2.21	0.76	0.00	2.49	2.51	2.26	1.96	1.67	0.68	0.73	1.21	0.98	1.56	1.12	0.59
7	2.79	2.22	1.57	1.52	0.50	0.00	3.01	3.62	2.30	2.35	0.75	0	0.91	0.86	0.98	0.94	0.93	0.59	0.67	1.12	0.79	1.09	0.59	0.26
8	1.08	2.20	1.66	1.80	0.76	0.15	2.43	3.28	2.42	2.86	1.22	0.23	1.83	1.84	2.11	2.40	2.56	1.07	0.69	1.22	0.94	2.06	1.14	0.51
9	2.35	2.57	1.61	1.64	0.45	0.00	2.70	3.28	2.02	2.09	0.58	0	2.57	2.40	2.28	2.05	1.74	0.68	0.80	1.26	0.98	1.55	0.85	0.38
10	2.28	2.37	1.29	1.47	0.34	0.00	2.60	3.07	1.90	1.96	0.47	0	2.04	1.86	1.70	1.45	1.24	0.59	0.70	1.03	0.77	1.20	0.65	0.41
11	2.62	2.60	1.60	1.59	0.60	0.03	2.94	3.58	2.40	2.51	0.89	0.04	2.09	2.06	2.04	1.78	1.65	0.79	0.85	1.34	1.06	1.75	0.94	0.38
12	1.50	1.87	1.38	1.59	0.61	0.02	1.72	2.29	1.72	1.99	0.85	0.03	2.07	2.18	2.05	2.24	2.34	1.04	0.92	1.56	1.18	2.12	1.36	0.55
13	1.72	1.83	1.25	1.24	0.31	0.00	1.89	2.15	1.43	1.49	0.38	0	2.66	2.51	2.39	1.92	1.55	0.70	0.73	1.13	0.92	1.55	1.21	0.63
14	1.58	1.65	1.06	0.85	0.52	0.02	1.85	2.04	1.24	1.00	0.59	0.03	2.40	2.48	2.47	2.20	1.69	0.94	1.12	1.58	1.20	1.62	1.11	0.53
15	1.94	1.96	1.51	1.52	0.56	0.02	2.88	3.44	2.18	2.42	0.87	0.03	2.30	2.20	2.38	2.10	1.99	1.05	0.95	1.64	1.22	1.83	1.49	0.60
16	1.87	2.00	1.45	1.47	0.58	0.00	2.17	2.63	1.69	1.85	0.73	0	1.68	1.56	1.49	1.45	1.39	0.74	0.66	1.11	0.94	1.39	0.83	0.47
17	1.71	1.44	0.96	0.86	0.11	0.00	1.93	1.94	1.19	1.12	0.13	0	2.09	2.10	2.08	1.71	1.51	0.72	0.68	1.11	0.87	1.50	0.82	0.44
18	1.42	2.25	1.45	1.42	0.86	0.10	2.33	2.86	1.82	1.85	0.98	0.13	1.44	1.38	1.44	1.48	1.25	0.62	0.62	1.10	1.02	1.73	1.12	0.47
19	1.61	1.92	1.76	1.81	0.90	0.25	1.87	2.37	2.07	2.77	1.39	0.38	1.71	1.79	1.86	1.72	1.79	1.17	0.64	1.24	1.19	2.06	1.45	0.51
20	2.08	2.38	1.66	1.69	0.54	0.10	2.85	3.57	2.52	2.76	1.00	0.16	1.62	1.56	1.85	1.60	1.68	0.93	0.81	1.40	1.21	2.00	1.50	0.66
Mean	1.88	2.06	1.45	1.47	0.56	0.05	2.38	2.86	1.90	2.05	0.78	0.11	2.03	2.00	2.00	1.83	1.69	0.81	0.79	1.32	1.06	1.77	1.12	0.51

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Table C.6.8 Maximum uplift deformation of 6-storey building in N-S direction (with GWB), mm

No.	Drain-3D												Sapwood											
	Wall 19						Wall 25						Wall 25 - method A						Wall 25 - method B					
	st1	st2	st3	st4	st5	st6	st1	st2	st3	st4	st5	st6	st1	st2	st3	st4	st5	st6	st1	st2	st3	st4	st5	st6
1	4.31	2.75	2.70	1.80	1.76	0.37	3.83	2.55	2.59	1.74	1.78	0.49	0.40	0.40	0.49	0.49	0.58	0.36	0.75	0.88	1.72	1.47	1.79	0.61
2	2.59	2.21	3.05	2.48	2.56	0.82	2.36	2.03	2.83	2.27	2.33	0.86	0.79	0.74	0.75	0.60	0.51	0.28	1.11	1.16	1.80	1.43	1.74	0.67
3	2.68	1.88	2.69	2.16	2.41	0.44	2.33	1.76	2.52	2.00	2.20	0.57	0.68	0.59	0.58	0.54	0.49	0.21	1.32	1.20	1.74	1.41	2.16	1.25
4	3.94	2.80	3.84	2.89	3.28	1.24	3.50	2.60	3.56	2.65	2.87	1.27	0.62	0.51	0.50	0.51	0.66	0.32	1.12	1.10	1.68	1.36	1.92	1.00
5	5.29	4.27	11.00	2.93	2.62	0.50	4.72	3.77	7.27	2.83	2.87	1.08	0.57	0.55	0.55	0.45	0.46	0.20	0.86	0.99	1.40	1.09	1.64	0.80
6	5.42	3.92	4.11	2.27	1.65	0.15	4.69	3.44	3.72	2.14	1.90	0.44	0.61	0.53	0.48	0.43	0.45	0.24	1.09	0.99	1.49	1.27	1.81	1.12
7	4.70	2.70	2.66	3.44	1.82	0.58	3.80	2.55	2.57	3.35	1.83	0.66	0.39	0.38	0.39	0.32	0.30	0.21	0.80	0.72	0.96	0.70	0.92	0.33
8	3.48	2.47	3.02	2.56	2.78	0.75	3.06	2.24	2.86	2.37	2.51	0.83	0.64	0.68	0.73	0.68	0.71	0.37	1.03	0.96	1.40	1.23	1.81	0.85
9	4.82	3.17	2.80	1.44	1.10	0.02	4.23	2.88	2.76	1.46	1.19	0.19	0.58	0.47	0.46	0.42	0.48	0.27	1.18	1.15	1.46	1.19	1.78	0.91
10	4.36	3.36	4.48	2.84	3.15	1.17	3.93	3.06	3.84	2.56	2.94	1.31	0.53	0.48	0.50	0.45	0.53	0.26	0.95	0.89	1.25	0.89	1.17	0.55
11	3.74	2.88	3.83	2.85	2.77	0.66	3.36	2.65	3.50	2.51	2.59	0.86	0.79	0.72	0.73	0.75	0.78	0.33	1.05	1.02	1.46	1.18	1.81	0.94
12	2.38	1.55	2.18	1.77	2.41	1.04	2.10	1.42	2.03	1.65	2.19	0.94	0.43	0.43	0.52	0.68	0.69	0.35	1.15	1.13	1.59	1.27	1.83	1.16
13	5.76	4.66	6.40	2.32	1.69	0.02	4.98	3.76	4.35	2.39	2.13	0.59	0.71	0.64	0.64	0.54	0.42	0.19	1.12	1.13	1.62	1.28	1.90	1.16
14	3.53	2.60	2.93	2.17	2.82	1.11	3.18	2.42	2.71	2.03	2.58	1.18	0.59	0.56	0.62	0.61	0.45	0.35	1.41	1.19	1.69	1.34	1.67	0.92
15	3.97	2.64	2.78	1.58	1.34	0.14	3.53	2.45	2.67	1.57	1.36	0.28	0.61	0.60	0.64	0.61	0.62	0.44	1.21	1.10	1.79	1.42	2.02	1.02
16	5.07	3.88	13.35	3.22	3.20	1.01	4.59	3.68	9.17	3.08	3.39	1.52	0.54	0.47	0.47	0.53	0.63	0.28	1.03	0.99	1.60	1.32	1.70	0.98
17	4.82	3.64	7.29	2.99	3.00	1.02	4.35	3.40	5.19	2.68	2.98	1.34	0.76	0.69	0.65	0.53	0.48	0.28	1.10	1.09	1.56	1.28	1.70	1.03
18	4.55	3.42	4.03	2.64	2.52	0.72	4.06	3.16	3.75	2.36	2.40	0.78	0.65	0.57	0.56	0.50	0.50	0.27	0.79	0.81	1.30	1.02	1.67	0.81
19	1.07	1.34	2.38	2.21	3.24	1.33	0.96	1.24	2.19	1.99	2.86	1.31	0.44	0.40	0.44	0.44	0.65	0.45	1.08	1.03	1.49	1.33	1.89	1.10
20	1.97	2.21	3.62	3.17	3.43	1.53	1.83	2.05	0.00	2.77	3.12	1.44	0.55	0.60	0.59	0.57	0.55	0.33	1.28	1.11	1.72	1.47	1.95	1.20
Mean	3.92	2.92	4.46	2.49	2.48	0.73	3.47	2.65	3.50	2.32	2.40	0.90	0.59	0.55	0.56	0.53	0.55	0.30	1.07	1.03	1.54	1.25	1.74	0.92

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Appendix D

Results of NEESWood Wood-Frame Building Designed in Accordance with NBCC 2010

Appendix E

Selected time history responses and hysteresis loops of selected shear walls

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Figures B.1 and B.2 show some examples of displacement time history responses (relative to the ground) resulting from the analyses with SAPWood:

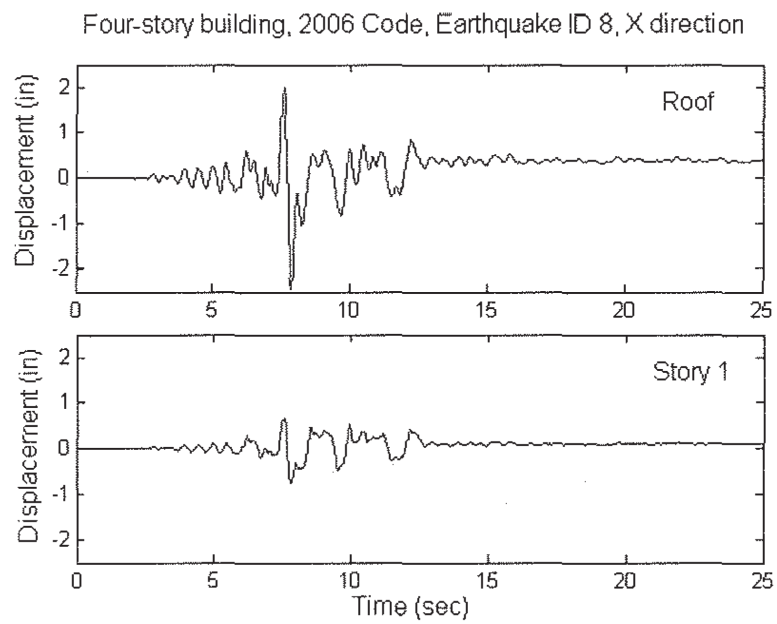

Figure B.1. Displacement time history for the roof level and first storey of the four-story structure

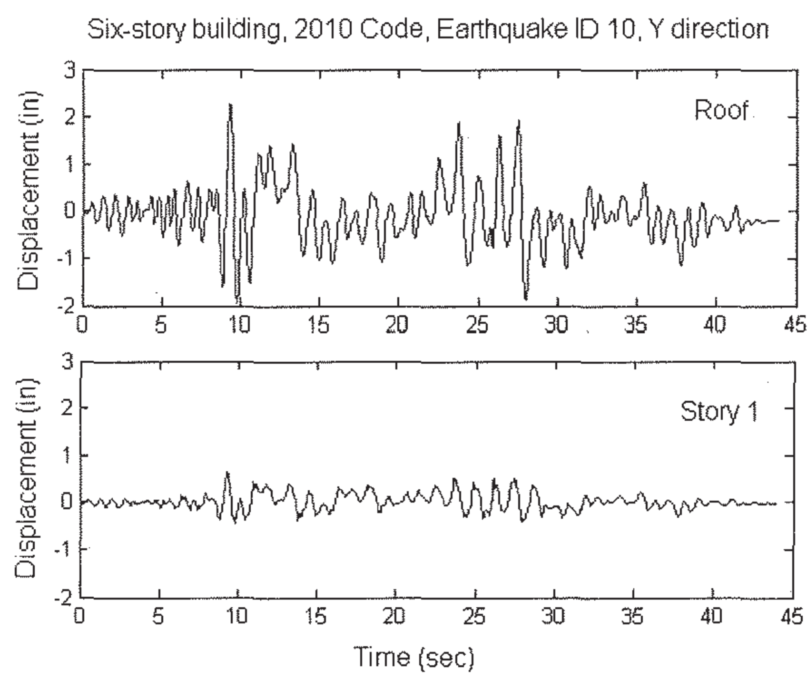

Figure B.2. Displacement time history for the roof level and first storey of the six-story structure

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Jensen, Jun'ichi MEM:EX

From: Rodney McPhee [RMcPhee@cwc.ca]
Sent: Monday, February 23, 2009 6:25 PM
To: Lam, Roger SG:EX
Cc: Rotgans, Trudy SG:EX; Helen Griffin
Subject: RE: Technical Support for 1 hour Wood Frame Floor Assemblies
Attachments: CWC BCBC change form FRR_STC_Tables.pdf; CWC Proposed BCBC Code Wording Re FRR-STC Tables Sentence 3.1.7.1.(2)(Feb 23-09).pdf; CWC Proposed BCBC Part 3 FRR-STC Table-Walls (Feb 23-09).pdf; CWC Commentary (Rationale)-CWC Proposed BCBC Part 3 FRR-STC Table-Walls (Feb 23-09).pdf; CWC Proposed BCBC Part 3 FRR-STC Table-Floors (Feb 23-09).pdf; CWC Commentary (Rationale)-CWC Proposed BCBC Part 3 FRR-STC TAble-Floors (Feb 23-09).pdf; image001.jpg

Roger:

I have taken your code change form and filled in the information to be used as a basis for a code change proposal regarding the fire resistance and sound transmission tables for wood frame walls and floors.

I've attached the 'proposal form' along with attachments that provide the meat of the proposal as well as the commentary/rationale for the change.

I will speak to Helen tomorrow regarding any discussions she may have had with Trudy in Halifax and also follow-up with you, as appropriate, on this information and certainly before we finalize our letter to Glenn Gibson.

Best regards.

Rodney A. McPhee, CET, CIP, ASFPE
Director, Codes and Standards
Canadian Wood Council
email: rmcphee@cwc.ca
Ph: 613-747-1801

Non-Responsive

From: Rodney McPhee [mailto:RMcPhee@cwc.ca]
Sent: Tuesday, February 17, 2009 6:08 PM
To: Lam, Roger HSD:EX
Cc: Helen Griffin
Subject: RE: Technical Support for 1 hour Wood Frame Floor Assemblies

Roger:

We are finalizing our response to Glenn Gibson's letter, but before doing so, Helen Griffin and I would like to talk to you to discuss how we might assist you and develop appropriate language and rationale for addressing this issue.

Can you advise on when might be a good time for us to call you to discuss the issue?

Currently, with our schedule, we're looking at sometime Friday morning, starting anytime between 8:30 and 10:00 a.m. your time (11:30-1:00 EST our time).

If Friday is not a good time, then perhaps we could look at sometime Thursday morning, starting anytime between 10:30 and 12:00 your time (1:30-3:00 EST our time).

Best regards,

Rodney A. McPhee, CET, CIP, ASFPE
Director, Codes and Standards
Canadian Wood Council
email: rmcphee@cwc.ca
Ph: 613-747-1801

Non-Responsive

From: Rodney McPhee [mailto:RMcPhee@cwc.ca]
Sent: Tuesday, February 3, 2009 1:46 PM
To: Andrew Harmsworth (GHL); Lam, Roger HSD:EX; John Nicol (Business Fax)
Cc: Helen Griffin; Etienne Lalonde; Mary Tracey
Subject: RE: Technical Support for 1 hour Wood Frame Floor Assemblies

Andrew:

Thanks for the heads-up.

I am currently working with Helen Griffin of our office in preparing a response to Glenn Gibson's letter, which we received yesterday.

Just one point of clarification regarding your email comments below.

The issue of the hose stream test is not, in any way, implicated when it comes to floor assemblies.

Under the ULC S-101 standard, the hose stream test is only conducted on wall assemblies.

As part of our response, among others, we will be referencing the materials I had prepared last fall for the BC code regarding the revised Fire and Acoustic tables.

Regards.

Rodney A. McPhee, CET, CIP, ASFPE
Director, Codes and Standards
Canadian Wood Council
email: rmcphee@cwc.ca
Ph: 613-747-1801

From: Andrew Harmsworth (GHL) [mailto:ah@ghl.ca]
Sent: Tuesday, February 03, 2009 3:21 PM
To: Lam, Roger HSD:EX; John Nicol (Business Fax)
Cc: Rodney McPhee
Subject: FW: Technical Support for 1 hour Wood Frame Floor Assemblies

Roger

Please see the attached letter from the CP Committee to CWC. I had hoped to include recommendations in our Code Change recommendations, but information from CWC unfortunately arrived too late.

I attach information provided by CWC to answer this question - and the full data is readily available, however it is not 'direct conformance' in that they are not designs tested at an accredited laboratory, as NRC is not an 'accredited testing agency', being a govenrnment agency.

In my opionion these should be acceptable as a 'alterate solution, however some municipalities are not accepting alternative solutions for floor assemblies. Surrey in particular has told our staff they will not accept these as an alternative solution, no matter what level of proof is provided.

I understand that these tests were performed in full conformance with ULC S101, with the sole exception that no hose stream test was performed.

Rod, could you please supply a letter stating that these tests were performed at NRC, and in full conformance with the requirements of ULC S101, including furnace details, fire size and loading and justification for not performing the hose stream test.

Whether we are submitting these designs for inclusion in the Code, or as an alternate solution, we need that documentation.

Thanks.

Andrew Harmsworth, M Eng, P Eng, CP
GHL CONSULTANTS LTD
Building Codes & Fire Science
950 - 409 Granville Street
Vancouver, BC V6C 1T2

T 604 689 4449 ext 107
F 604 689 4419
E ah@ghl.ca

From: Dave Graham (GHL)
Sent: Tuesday, February 3, 2009 8:21 AM
To: Andrew Harmsworth (GHL); Teddy Lai (GHL)
Cc: Khash Vorell (GHL)
Subject: FW: Technical Support for 1 hour Wood Frame Floor Assemblies

FYI - from the CP committee

David W Graham, P Eng, CP

GHL CONSULTANTS LTD

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T 604 689 4449 Ext 105
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A member company of
Saffire Safety Consultants Inc
www.saffire.ca

From: Glenn Gibson [mailto:ggibson@lmdg.com]
Sent: February 2, 2009 3:14 PM
To: 'hgriffin@cwc.ca'
Cc: 'bob.bowen@NRC-CNRC.gc.ca'; 'bob.thompson@gov.bc.ca'; 'eholt@aibc.ca'; 'lbowser@apeg.bc.ca'; 'Mitchell, Jeff'; 'Mitchell, Jeff'; 'Agren, Soren'; s.22 [redacted] Dave Graham (GHL); 'ggibson@lmdg.com'; 'mbruckner@ibigroup.com'; 'Mehran Nazeman \(MRNazeman@city.surrey.bc.ca\)'; s.22 [redacted] 'patrick.shek@burnaby.ca'; s.22 [redacted]
Subject: Technical Support for 1 hour Wood Frame Floor Assemblies

Helen
Please refer to the attached letter regarding the lack of technical information available to support the use of standard wood frame floor assemblies to achieve a 1 hour fire-resistance rating. We believe that it is essential to make available to the building industry typical wood frame floor assemblies that will comply with the 1 hour fire-resistance rating requirements of the building code.

Please let us know your comments and if there is any way we can assist you in this matter.

Glenn A. Gibson, M.Eng., P.Eng., CP
LMDG Building Code Consultants Ltd.
Tel: 604-682-7146
Fax: 604-682-7149

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Office of Housing and Construction Standards

Building and Safety Policy Branch

Proposed Change to the BC Building Code

For staff use only:
Date Received ______________
Review Committee ______________
PCF# ______________

Instructions:

- Submit no more than one proposed change on this form. Submit separate forms for any additional changes.
- Provide summary information on this form and attach detailed information.

Email completed form to: building.safety@gov.bc.ca

Name Rodney A McPhee Company Canadian Wood Council

Phone # (613) 747-1801 Fax # (613) 747-6264 Email rmcphee@cwc.ca

Address 400-99 Bank Street, Ottawa, ON, K1P 6B4

1. Identify the Code objectives that your proposed change will address:

- ☐ Health
- ■ Safety
- ☐ Accessibility
- ■ Fire and structural protection of buildings in British Columbia
- ☐ Protection of the building or facility from water and sewer damage
- ■ 'Green building' objectives, such as energy conservation, water conservation, reduction of greenhouse gas emissions, use of non-reactive building materials, and resource or site sustainability.

2. Describe the problem. Identify the gap or problem that needs to be addressed. Please provide specific evidence of the problem. How, specifically, are Code objectives not being met? Who is affected by the problem?

In multi-storey multi-unit residential occupancies of wood frame construction, the walls and floors separating dwelling units from other dwelling units or the remainder of the building must be designed to provide 45, 60, 90 or 120 minute fire resistance ratings (FRRs) and sound transmission classification (STC) ratings of either 50 or 55.

There is limited technical information available in the marketplace regarding the different FRRs ratings of wood frame walls and floor assemblies. Currently, only proprietary testing information (i.e., ULC or Intertek listings) can be used by designers/engineers to specify such wood frame assemblies. Recently, ULC has published design load restrictions on wood frame floors that are listed in their published test information, which further limits the use of that information and the types of floor assemblies involved. Information on STC ratings for such assemblies is much more limited.

Designers/engineers in BC (CP Professional group) have recently confirmed with CWC that there is limited, to no, information available on the FRR and STC for commonly used wood frame floor assemblies or for wood frame assemblies constructed using engineered wood products, such as wood I-joists and wood trusses. (cont'd ...)

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Without a broad set of information on wood frame construction for designers/builders to choose from, more expensive types of construction must be used. Also, where non-wood types of construction are used, the potential is greater for increased environmental impacts, i.e. climate change due to greenhouse gas emissions.

3. Describe your proposed solution to the problem. How will the change you propose solve the problem you have identified? How, specifically, will the change better meet Code objectives?

The proposed change will introduce a list of wood frame wall and floor assemblies described in two Code Tables with generic sets of fire resistance and sound transmission classification ratings. The descriptions in the tables will provide dozens of different wood frame wall and floor assembly designs for architects/engineers/builders to choose from when specifying a building design for multi-family residential construction.

This information will also be useful for other non-residential occupancy building types, where clients/designers are looking to specifying the use of fire-rated or acoustically rated wood frame construction, i.e. to reduce environmental impacts (through the use of wood) and improve indoor environmental quality (relative to noise).

4. Draft wording for the proposed change. Identify the specific Code section(s) (e.g., Article, Sentence, Appendix, etc.) that would change. Please provide draft wording of how the provision might appear in the Code. The format and wording of the provision should be objective- or performance-based, rather than prescriptive.

See attached files.

5. Views of Code stakeholders. Does your proposal have the support of other stakeholders? What steps have you taken to consult with stakeholders? How will your proposal affect them? What are their views? How will your proposal affect stakeholders in different regions of the province?

As noted earlier, designers/architects have sought help from CWC to identify readily available sources of information to meet their needs in specifying code-conforming wood frame construction assemblies. With such generic information published in the Code, design professional/builders will not have to rely on limited proprietary information or direct references to research reports.

This proposal is consistent with a much broader proposal recently submitted to change Part 9 of the National Building Code of Canada on the FRRs and STC for light frame construction (wood and steel frame), which had the support of a number of industry stakeholders (i.e., gypsum, insulation, homebuilders, steel industry, etc.) as well as the National Research Council.

This information will be available for use by all professionals in the Province.

This information has the potential for increasing the use of wood frame construction, which will benefit the wood product manufacturers in the Province.

6. Summarize the science behind your proposal. Provide specific evidence (e.g., reports by recognized standards organizations, test results, etc.) that demonstrates how this change will meet Code objectives and standards and solve the problem you have identified. Is the change applicable and appropriate for all climactic or geophysical areas of the province?

See attached files.

7. Greenhouse Gas Emissions – Will the change you propose reduce greenhouse gas emissions related to construction or operation of the building? Please provide specific information (e.g., the percentage of greenhouse gas reduction) compared to common construction practice for this building type. Please provide information for different regions of the province, if the impacts will vary for different climactic or geophysical zones.

The use of wood products has been shown to have a lower environmental impacts in a number of impact categories relative to other types of construction materials (i.e., steel and concrete). See publications from www.wood-works.org and www.cwc.ca.

8. Energy Consumption – Will the change you propose reduce the consumption of hydroelectric or fossil fuel energy? Please provide specific information (e.g., the percentage by which consumption will be reduced) compared to common construction practice for this building type. Please provide information for different regions of the province, if the impacts will vary for different climactic or geophysical zones.

The assemblies affected are not typically designed as part of the environmental separations (exterior walls and roof) in a building. The design of most of these code-conforming assemblies require the use of absorptive insulation materials, but only in the interior walls and floor assemblies. This could have some minimal impact on the overall energy consumption of the building users, based on different persons needs for thermal comfort levels in their individual dwelling units.

9. Interior Environment Health – Will the change you propose result in more healthful interior environments? Will air quality be improved? Will it result in less off-gassing from materials? Please provide specific information (e.g., test results) compared to common construction practice for this building type.

WHO studies have shown that the level of noise from a neighbouring space/suite can have an impact on the health of the person living in adjacent spaces.

(Source: World Health Organization LARES Final Report, "Noise effects morbidity," Dr. Hildegard Niemann and Dr. Christian Masche, Interdisciplinary Research Network "Noise and Health" EUR/04/504777, 2004.)

10. Is the proposal cost effective? Identify the costs and benefits that will accrue to all key stakeholder groups. What are the baseline costs of current common construction practices (rather than minimum Code standards)? What will the costs be if this proposed change is implemented? Will building costs, design costs, rent costs, etc., increase? Will any costs decrease? Do the net benefits (to life safety, energy conservation, health, etc.) outweigh the net costs? Will costs vary in different areas of the province?

Specific cost-benefit analyses have not been conducted at this point. This change will not add more restrictive requirements for building designs as the code already requires residential structures to be designed to meet minimum fire resistance and sound transmission performance requirements.

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With the multiple choices of different wall and floor/ceiling design options, the use of different materials/components will provide greater number of options for designers/builders, which should result in more economical choices.

11. Enforcement Implications - Can compliance with the proposed provision be monitored during local inspection processes? Can the provision be enforced with existing resources in all areas of the province or would new or additional resources be required? Have you discussed your proposal with local authorities?

This enforcement and confirmation of performance specification for various wall and floor assemblies is already carried out by local inspectors.

The information as described in this proposal will result in simple generic design solutions being described directly in the building code. Having such generic information directly published in the Code will simplify the needs of building inspectors, as well as specifiers, in recognizing and confirming the required minimum details of construction and materials used in the different construction assemblies.

Since all the materials are described in a generic manner, this avoids the need for confirming proprietary information on various products/components, since the majority of the components are required to conform to general product specifications that are already specified in the Code.

12. Is the Code the best vehicle for addressing the problem? – Can the problem be addressed without a Code change? Can it be addressed through education, product testing, or other non-regulatory means? Why is a Code change the best approach?

Currently, similar fire resistance and sound transmission information is provided on wood frame walls and floors for builders/designers/inspectors to use in residential buildings designed and constructed in conformance with Part 9 of the BCBC. (See Appendix Tables A-9.10.3.1.A and B)

Providing such Tables of information on wood frame construction assemblies for use in Part 3 buildings will provide the information in a simple manner and be consistent with the generic fire performance informaiton already included in Appendix A and Appendix D of the BCBC.

Having such information published in the BCBC also provides a strong and clear indication to the end-users that the information has been compiled and provided as consistent with the Objectives, Functional Statements and Intent of the Code, especially as it relates to the Code requirements for standardized testing for fire resistance and sound transmission ratings. Such confidence is not always readily present when dealing with information from other sources.

13. Best Practices Worldwide – How does this proposed change compare to industry leaders and best practices elsewhere in North America and Europe? Does your proposal exist as a Code provision in any other jurisdiction?

There are similar sets of generic information/design tools recognized by the building codes in the US, China, South Korea and countries in Europe, where sets of generic information on the fire performance of light frame assemblies is used in the marketplace by designers/builders.

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Building and Safety Policy Branch

Recent best practice published by CMHC make specific reference to the research information used as a basis for the proposed Table submitted as part of this submission for changes to the BCBC. This information has also been recently used by industry in China for comparison to fire testing and research in China on similar light wood frame walls and floors as a basis for confirming generic ratings for publishing in the China Fire (Building) Code (GB50016).

14. Other Comments:

NONE

15. Please list the supporting material that you are attaching to this form:

The following electronic files were attached to the email used to submit this proposal:

CWC Proposed BCBC Code Wording Re FRR-STC Tables Sentence 3.1.7.1.(2) (Feb 23-09).pdf

CWC Proposed BCBC Part 3 FRR-STC Table-Walls (Feb 23-09).pdf

CWC Commentary (Rationale)-CWC Proposed BCBC Part 3 FRR-STC Table-Walls (Feb 23-09).pdf

CWC Proposed BCBC Part 3 FRR-STC Table-Floors (Feb 23-09).pdf

CWC Commentary (Rationale)-CWC Proposed BCBC Part 3 FRR-STC Table-Floors (Feb 23-09).pdf

Email completed form to: building.safety@gov.bc.ca

Please leave this space blank

CWC SUGGESTED CHANGES FOR BCBC FIRE RESISTANCE AND SOUND TRANSMISSION RATING TABLES for WOOD FRAME CONSTRUCTION

ITEM A

CODE REFERENCE:
Sentence 3.1.7.1.(2)

EXISTING WORDING:
3.1.7.1. Determination of Ratings
2) A material, assembly of materials or a structural member is permitted to be assigned a *fire-resistance rating* on the basis of Appendix D.

PROPOSED CHANGE
3.1.7.1. Determination of Ratings
2) A material, assembly of materials or a structural member is permitted to be assigned a *fire-resistance rating* on the basis of A-3.1.7.1 in Appendix A or Appendix D. (See Appendix)

ITEM B

CODE REFERENCE:
Appendix A-3.1.7.1.(2); Table A-3.1.7.1.(A) & Table A-3.1.7.1.(B) [New]

EXISTING WORDING:
NONE

PROPOSED CHANGE:
A-3.1.7.1. Fire and Sound Resistance of Building Assemblies
The following tables may be used to select building assemblies for compliance with Sentence 3.1.7.1.(1) and Subsection 9.11.2. Tables A-3.1.7.1.A. and A-3.1.7.1.B. have been developed from information gathered from tests. A much more extensive set of listings are described in Tables A-9.10.3.1.A and A-9.10.3.1.B for use in buildings designed to Part 9. While most of the assemblies listed were actually tested, the fire-resistance and acoustical ratings for some were assigned on the basis of extrapolation of information from tests of similar assemblies. Where there was enough confidence relative to the fire performance of an assembly, the fire-resistance ratings were assigned relative to the commonly used minimum ratings of 1 h and 1.5 hours.

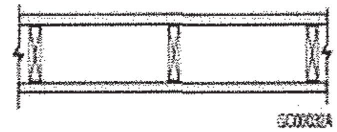
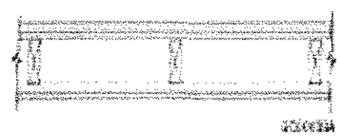
These tables are provided only for the convenience of Code users and do not limit the number of assemblies permitted to those in the tables. Assemblies not listed in these tables are equally acceptable provided their fire and sound resistance can be demonstrated to meet the above-noted requirements either on the basis of tests referred to in Sentence 3.1.7.1.(1) and Subsection 9.11.1. or by using the data in Appendix D, Fire-Performance Ratings. It should be noted, however, that Tables A-3.1.7.1.A. and A-3.1.7.1.B. are not based on the same assumptions as those used in Appendix D. Assemblies in Tables A-3.1.7.1.A. and A-3.1.7.1.B. are described through their generic descriptions and variants and include details given in the notes to the tables. Assumptions for Appendix D include different construction details that must be followed rigorously for the calculated ratings to be expected. These are two different methods of choosing assemblies that meet required fire resistance ratings.

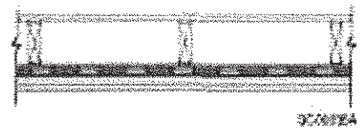
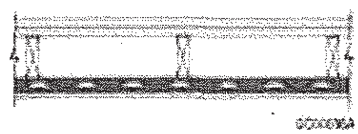
Insert TABLES A-3.1.7.1.A. AND A-3.1.7.1.B

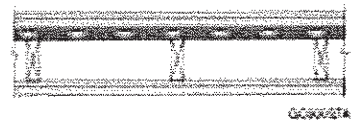
See separate 'Table' files from CWC

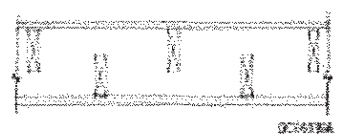
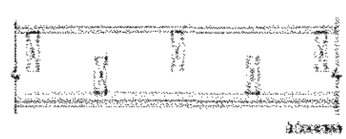
REASON FOR CHANGE (Both Items):

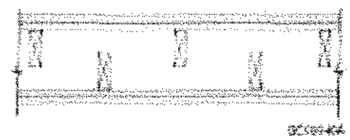
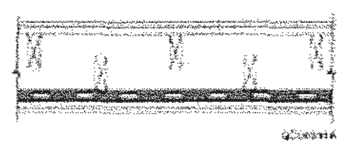
See separate 'Commentary' documents from CWC

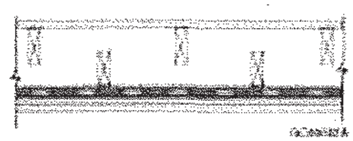
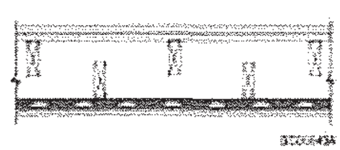
Type of Wall	Wall Number	Description	Fire resistance rating[1][6]		Typical Sound Transmission[1][2][3]
			Loadbearing	Non-loadbearing	
• Wood studs • Single row • Loadbearing or nonloadbearing	**W1**	• 38 mm x 89 mm studs spaced 400 mm or 600 mm o.c. • with or without absorptive material • 1 layer of gypsum board on each side			
	W1a	W1 with • studs spaced 400 mm o.c. • 89 mm thick absorptive material[4] • 15.9 mm Type X gypsum board[5]	1 h	1 h	36
	W1b	W1 with • studs spaced 600 mm o.c. • 89 mm thick absorptive material[4] • 15.9 mm Type X gypsum board[5]	1 h[7]	1 h	36
	W1c	W1 with • studs spaced 400 mm o.c. • 89 mm thick absorptive material[4] • 12.7 mm Type X gypsum board[5]	1 h[7]	1 h[7]	34
	W1d	W1 with • studs spaced 600 mm o.c. • 89 mm thick absorptive material[4] • 12.7 mm Type X gypsum board[5]	-	1 h[7]	34
	W1e	W1 with • studs spaced 400 mm o.c. • no absorptive material • 15.9 mm Type X gypsum board[5]	1 h	1 h	32
	W2	• 38 mm x 89 mm studs spaced 400 mm or 600 mm o.c. • with or without absorptive material • 2 layers of gypsum board on each side			
	W2a	W2 with • studs spaced 400 mm o.c. • 89 mm thick absorptive material[4] • 15.9 mm Type X gypsum board[5]	1.5 h	2 h	38
	W2b	W2 with • studs spaced 600 mm o.c. • 89 mm thick absorptive material[4] • 15.9 mm Type X gypsum board[5]	1.5 h[7]	2 h[7]	38
	W2c	W2 with • 89 mm thick absorptive material[4] • 12.7 mm Type X gypsum board[5]	1 h	1.5 h	38
	W2d	W2 with • studs spaced 400 mm o.c. • no absorptive material • 15.9 mm Type X gypsum board[5]	1.5 h	2 h	36

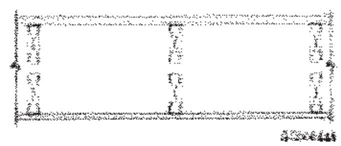
• Wood studs • Single row • Loadbearing or nonloadbearing (continued)	W2e	W2 with • no absorptive material • 12.7 mm Type X gypsum board[5]	1 h	1.5 h	35
	W2f	W2 with • no absorptive material • 12.7 mm regular gypsum board[5]	-	1 h	34
	W3	• 38 mm x 89 mm studs spaced 400 mm or 600 mm o.c. • 89 mm thick absorptive material[4] • resilient metal channels on one side spaced 400 mm or 600 mm o.c. • 2 layers of gypsum board on resilient metal channel side • 1 layer of gypsum board on other side			
	W3a	W3 with • studs spaced 400 mm o.c. • 15.9 mm Type X gypsum board[5]	1 h	1 h [1.5 h[7]]	51
	W3b	W3 with • studs spaced 600 mm o.c. • 15.9 mm Type X gypsum board[5]	1 h[7]	1 h [1.5 h[7]]	54
	W3c	W3 with • studs spaced 400 mm o.c. • 12.7 mm Type X gypsum board[5]	1 h[7]	1 h	49
	W3d	W3 with • studs spaced 600 mm o.c. • 12.7 mm Type X gypsum board[5]	-	1 h	53
	W4	• 38 mm x 89 mm studs spaced 400 mm or 600 mm o.c. • 89 mm thick absorptive material[4] • resilient metal channels on one side spaced 400 mm or 600 mm o.c. • 1 layer of gypsum board on resilient metal channel side • 2 layers of gypsum board on other side			
	W4a	W4 with • studs spaced 400 mm o.c. • 15.9 mm Type X gypsum board[5]	-	1 h	51
	W4b	W4 with • studs spaced 600 mm o.c. • 15.9 mm Type X gypsum board[5]	-	1 h	54
	W4c	W4 with • studs spaced 400 mm o.c. • 12.7 mm Type X gypsum board[5]	-	1 h	49
	W4d	W4 with • studs spaced 600 mm o.c. • 12.7 mm Type X gypsum board[5]	-	1 h	53

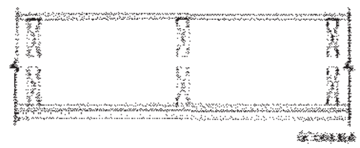
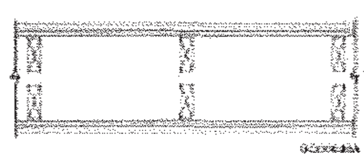
• Wood studs • Single row • Loadbearing or nonloadbearing (continued)	**W5**	• 38 mm x 89 mm studs spaced 400 mm or 600 mm o.c. • with or without absorptive material • resilient metal channels on one side • 2 layers of gypsum board on each side			
	W5a	W5 with • studs spaced 400 mm o.c. • 89 mm thick absorptive material[4] • resilient metal channels spaced 400 mm o.c. • 15.9 mm Type X gypsum board[5]	1.5 h	2 h	55
	W5b	W5 with • studs spaced 600 mm o.c. • 89 mm thick absorptive material[4] • resilient metal channels spaced 400 mm o.c. • 15.9 mm Type X gypsum board[5]	1.5 h[7]	2 h[7]	55
	W5c	W5 with • studs spaced 400 mmo.c. • 89 mm thick absorptive material[4] • resilient metal channels spaced 600 mm o.c. • 15.9 mm Type X gypsum board[5]	1.5 h	2 h	58
	W5d	W5 with • studs spaced 600 mm o.c. • 89 mm thick absorptive material[4] • resilient metal channels spaced 600 mm o.c. • 15.9 mm Type X gypsum board[5]	1.5 h[7]	2 h[7]	58
	W5e	W5 with • studs spaced 400 mm o.c. • 89 mm thick absorptive material[4] • resilient metal channels spaced 400 mm o.c. • 12.7 mm Type X gypsum board[5]	1 h	1.5 h	53
	W5f	W5 with • studs spaced 400 mm o.c. • 89 mm thick absorptive material[4] • resilient metal channels spaced 600 mm o.c. • 12.7 mm Type X gypsum board[5]	1 h	1.5 h	55
	W5g	W5 with • studs spaced 600 mm o.c. • 89 mm thick absorptive material[4] • resilient metal channels spaced 400 mm o.c. • 12.7 mm Type X gypsum board[5]	1 h	1.5 h	55

• Wood studs • Single row • Loadbearing or nonloadbearing (continued)	W5h	W5 with • studs spaced 600 mm o.c. • 89 mm thick absorptive material[4] • resilient metal channels spaced 600 mm o.c. • 12.7 mm Type X gypsum board[5]	1 h	1.5 h	58
	W5i	W5 with • studs spaced 400 mm o.c. • no absorptive material • resilient metal channels spaced 400 mm or 600 mm o.c. • 15.9 mm Type X gypsum board[5]	1.5 h	2 h	47
	W5j	W5 with • studs spaced 400 mm or 600 mm o.c. • no absorptive material • resilient metal channels spaced 400 mm or 600 mm o.c. • 12.7 mm Type X gypsum board[5]	1 h	1.5 h	46
• Wood studs • Two rows staggered on 38 mm×140 mm common plate • Loadbearing or nonloadbearing	**W6**	• two rows 38 mm x 89 mm studs each spaced 400 mm o.c. staggered on common 38 mm x 140 mm plate • 89 mm thick absorptive material on one side or 65 mm thick on each side[4] • 1 layer of gypsum board on each side			
	W6a	W6 with • studs spaced 400 mm o.c. • 15.9 mm Type X gypsum board[5]	1 h	1 h	47
	W6b	W6 with • studs spaced 600 mm o.c. • 15.9 mm Type X gypsum board[5]	1 h[7]	1 h	47
	W6c	W6 with • studs spaced 400 mm o.c. • 12.7 mm Type X gypsum board[5]	1 h[7]	1 h[7]	45
	W6d	W6 with • studs spaced 600 mm o.c. • 12.7 mm Type X gypsum board[5]	-	1 h[7]	45
	W7	• two rows 38 mm x 89 mm studs each spaced 400 mm or 600 mm o.c. staggered on common 38 mm x 140 mm plate • 89 mm thick absorptive material on one side or 65 mm thick on each side[4] • 2 layers of gypsum board on one side • 1 layer of gypsum board on other side			
	W7a	W7 with • studs spaced 400 mm o.c. • 15.9 mm Type X gypsum board[5]	1 h	1.5 h	52

• Wood studs • Two rows staggered on 38 mm×140 mm common plate • Loadbearing or nonloadbearing (continued)	W7b	W7 with • studs spaced 600 mm o.c. • 15.9 mm Type X gypsum board[5]	1 h[7]	1.5 h	52
	W7c	W7 with • 12.7 mm Type X gypsum board[5]	-	1 h	50
	W8	• two rows 38 mm x 89 mm studs each spaced 400 mm or 600 mm o.c. staggered on common 38 mm x 140 mm plate • with or without absorptive material • 2 layers of gypsum board on each side			
	W8a	W8 with • studs spaced 400 mm o.c. • 89 mm thick absorptive material on one side or 65 mm thick on each side[4] • 15.9 mm Type X gypsum board[5]	1.5 h	2 h	56
	W8b	W8 with • studs spaced 600 mm o.c. • 89 mm thick absorptive material on one side or 65 mm thick on each side[4] • 15.9 mm Type X gypsum board[5]	1.5 h[7]	2 h[7]	56
	W8c	W8 with • 89 mm thick absorptive material on one side or 65 mm thick on each side[4] • 12.7 mm Type X gypsum board[5]	1 h	1.5 h	55
	W8d	W8 with • studs spaced 400 mm o.c. • no absorptive material • 15.9 mm Type X gypsum board[5]	1.5 h	2 h	48
	W9	• two rows 38 mm x 89 mm studs each spaced 400 mm or 600 mm o.c. staggered on common 38 mm x 140 mm plate • with or without absorptive material • resilient metal channels on one side spaced 400 mm or 600 mm o.c. • 2 layers of gypsum board on each side			
	W9a	W9 with • studs spaced 400 mm o.c. • 89 mm thick absorptive material on one side or 65 mm thick on each side[4] • 15.9 mm Type X gypsum board[5]	1.5 h	2 h	62
	W9b	W8 with • studs spaced 600 mm o.c. • 89 mm thick absorptive material on one side or 65 mm thick on each side[4] • 15.9 mm Type X gypsum board[5]	1.5 h[7]	2 h[7]	62

• Wood studs • Two rows staggered on 38 mm×140 mm common plate • Loadbearing or nonloadbearing (continued)	W9c	W9 with • 89 mm thick absorptive material on one side or 65 mm thick on each side(4) • 12.7 mm Type X gypsum board(5)	1 h	1.5 h	60
	W9d	W9 with • studs spaced 400 mm o.c. • no absorptive material • 15.9 mm Type X gypsum board(5)	1.5 h	2 h	50
	W9e	W9 with • no absorptive material • 12.7 mm Type X gypsum board(5)	1 h	1.5 h	48
	W10	• two rows 38 mm x 89 mm studs each spaced 400 mm or 600 mm o.c. staggered on common 38 mm x 140 mm plate • 89 mm thick absorptive material on one side or 65 mm thick on each side(4) • resilient metal channels on one side spaced 400 mm or 600 mm o.c. • 2 layers of gypsum board on resilient channel side • 1 layer of gypsum board on other side			
	W10a	W10 with • studs spaced 400 mm o.c. • 15.9 mm Type X gypsum board(5)	1 h	1 h	56
	W10b	W10 with • studs spaced 600 mm o.c. • 15.9 mm Type X gypsum board(5)	1 h(7)	1 h	56
	W10c	W10 with • 12.7 mm Type X gypsum board(5)	1 h(7)	1 h	54
	W10d	W10 with • studs spaced 600 mm o.c. • 12.7 mm Type X gypsum board(5)	-	1 h	54
	W11	• two rows 38 mm x 89 mm studs each spaced 400 mm or 600 mm o.c. staggered on common 38 mm x 140 mm plate • 89 mm thick absorptive material on one side or 65 mm thick on each side(4) • resilient metal channels on one side spaced 400 mm or 600 mm o.c. • 1 layer of gypsum board on resilient metal channel side • 2 layers of gypsum board on other side			
	W11a	W11 with • 15.9 mm Type X gypsum board(5)	-	1 h	56

• Wood studs • Two rows staggered on 38 mm×140 mm common plate • Loadbearing or nonloadbearing (continued)	W11b	W11 with • 12.7 mm Type X gypsum board[5]	-	1 h	54
• Wood studs • Two rows on separate plates • Loadbearing or nonloadbearing	**W12**	• two rows 38 mm x 89 mm studs, each spaced 400 mm or 600 mm o.c. on separate 38 mm x 89 mm plates set 25 mm apart • with or without absorptive material • 1 layer of gypsum board on each side			
	W12a	W12 with • studs spaced 400 mm o.c. • 89 mm thick absorptive material on each side[4][8] • 15.9 mm Type X gypsum board[5]	1 h	1 h	57
	W12b	W12 with • studs spaced 600 mm o.c. • 89 mm thick absorptive material on each side[4][8] • 15.9 mm Type X gypsum board[5]	1 h[7]	1 h	57
	W12c	W12 with • studs spaced 400 mm o.c. • 89 mm thick absorptive material on each side[4][8] • 12.7 mm Type X gypsum board[5]	1 h[7]	1 h[7]	57
	W12d	W12 with • studs spaced 600 mm o.c. • 89 mm thick absorptive material on each side[4][8] • 12.7 mm Type X gypsum board[5]	-	1 h[7]	57
	W12e	W12 with • studs spaced 400 mm o.c. • 89 mm thick absorptive material on one side only[4] • 15.9 mm Type X gypsum board[5]	1 h	1 h	54
	W12f	W12 with • studs spaced 600 mm o.c. • 89 mm thick absorptive material on side with 1 layer gypsum board only[4][8] • 15.9 mm Type X gypsum board[5]	1 h[7]	1 h	54

• Wood studs • Two rows on separate plates • Loadbearing or nonloadbearing (continued)	**W13**	• two rows 38 mm x 89 mm studs, each spaced 400 mm or 600 mm o.c. on separate 38 mm x 89 mm plates set 25 mm apart • with or without absorptive material • 2 layers of gypsum board on one side • 1 layer of gypsum board on other side			
	W13a	W13 with • studs spaced 400 mm o.c. • 89 mm thick absorptive material on each side(4) • 15.9 mm Type X gypsum board(5)	1 h	1 h [1.5 h(7)]	61
	W13b	W13 with • studs spaced 600 mm o.c. • 89 mm thick absorptive material on each side(4)(8) • 15.9 mm Type X gypsum board(5)	1 h(7)	1 h [1.5 h(7)]	61
	W13c	W13 with • studs spaced 400 mm o.c. • 89 mm thick absorptive material on each side(4)(8) • 12.7 mm Type X gypsum board(5)	1 h(7)	1 h	61
	W13d	W13 with • studs spaced 600 mm o.c. • 89 mm thick absorptive material on each side(4)(8) • 12.7 mm Type X gypsum board(5)	-	1 h	61
	W13e	W13 with • studs spaced 400 mm o.c. • 89 mm thick absorptive material on one side only(4) • 15.9 mm Type X gypsum board(5)	1 h	1 h	57
	W13f	W13 with • studs spaced 600 mm o.c. • 89 mm thick absorptive material on side with 1 layer gypsum board only(4)(8) • 15.9 mm Type X gypsum board(5)	1 h(7)	1 h	57
	W13g	W13 with • 89 mm thick absorptive material on one side only(4)(8) • 12.7 mm Type X gypsum board(5)	-	1 h	57
	W14	• two rows 38 mm x 89 mm studs, each spaced 400 mm or 600 mm o.c. on separate 38 mm x 89 mm plates set 25 mm apart • with or without absorptive material • 2 layers of gypsum board on each side			

• Wood studs • Two rows on separate plates • Loadbearing or nonloadbearing (continued)	W14a	W14 with • studs spaced 400 mm o.c. • 89 mm thick absorptive material on each side[4][8] • 15.9 mm Type X gypsum board[5]	1.5 h	2 h	66
	W14b	W14 with • studs spaced 600 mm o.c. • 89 mm thick absorptive material on each side[4][8] • 15.9 mm Type X gypsum board[5]	1.5 h[7]	2 h[7]	66
	W14c	W14 with • 89 mm thick absorptive material on each side[4][8] • 12.7 mm Type X gypsum board[5]	1 h	1.5 h	65
	W14d	W14 with • studs spaced 400 mm o.c. • 89 mm thick absorptive material on one side only[4][8] • 15.9 mm Type X gypsum board[5]	1.5 h	2 h	62
	W14e	W14 with • studs spaced 600 mm o.c. • 89 mm thick absorptive material on one side only[4][8] • 15.9 mm Type X gypsum board[5]	1.5 h[7]	2 h[7]	62
	W14f	W14 with • 89 mm thick absorptive material on one side only[4][8] • 12.7 mm Type X gypsum board[5]	1 h	1.5 h	60
	W14g	W14 with • studs spaced 400 mm o.c. • no absorptive material • 15.9 mm Type X gypsum board[5]	1.5 h	2 h	56
	W14h	W14 with • no absorptive material • 12.7 mm Type X gypsum board[5]	1 h	1.5 h	55
• Exterior[9] • Wood studs • Single row • Loadbearing or nonloadbearing	**EW1**	• 38 mm x 89 mm studs spaced 400 mm or 600 mm o.c. • 89 mm thick absorptive material[7] • 1 layer of gypsum board on inside • exterior sheathing and siding			
	EW1a	EW1 with • 15.9 mm Type X gypsum board[5]	1 h	1 h	n/a
	EW1b	EW1 with • studs spaced 400 mm o.c. • 12.7 mm Type X gypsum board[5]	1 h	1 h	n/a

Notes to Table A-3.1.7.1.A.:

(1) Fire-resistance and STC ratings of wood-frame construction were evaluated only for constructions with solid-sawn 38 mm x 89 mm lumber. However, the fire-resistance and STC ratings provided for 38 mm x 89 mm wood-frame construction may be applied to wood frame construction with solid-sawn 38 mm x 140 mm lumber; in some cases the ratings may be conservative. Where 38 mm x 140 mm framing is used and absorptive material is called for, the absorptive material must be 140 mm thick. See D-1.2.1.(2) in Appendix D for the significance of fire-resistance ratings. The STC ratings may also be applied to fingerjoined lumber. The fire-resistance ratings are applicable to constructions using fingerjoined lumber that has been manufactured with a heat-resistant adhesive (HRA) in accordance with NLGA special product standard SPS-1, "Fingerjoined Structural Lumber". or SPS-3, "Fingerjoined "Vertical Stud Use Only" Lumber". (See also A-9.23.10.4.(1).). A hyphen in the Table indicates that the assigned fire resistance rating is less than 1 h.

(2) Sound ratings listed are based on the most reliable laboratory test data available for specimens conforming to installation details required by CSA A82.31–M, "Gypsum Board Application." Results of specific tests may differ slightly because of measurement precision and minor variations in construction details. These results should only be used where the actual construction details, including spacing of fasteners and supporting framing, correspond exactly to the details of the test specimens on which the ratings are based. Assemblies with sound transmission class ratings of 50 or more require acoustical sealant applied around electrical boxes and other openings, and at the junction of intersecting walls and floors, except intersection of walls constructed of concrete or solid brick.

(3) Sound ratings are only valid where there are no discernible cracks or voids in the visible surfaces.

(4) Sound absorptive material includes fibre processed from rock, slag, glass or cellulose fibre, except as otherwise noted. It must fill at least 90% of the cavity thickness for the wall to have the listed STC value. The absorptive material should not overfill the cavity to the point of producing significant outward pressure on the finishes; such an assembly will not achieve the STC rating.

(5)The complete descriptions of indicated finishes are as follows:

- 12.7 mm regular gypsum board – 12.7 mm regular gypsum board conforming to Article 9.29.5.2.
- 12.7 mm Type X gypsum board – 12.7 mm special fire-resistant Type X gypsum board conforming to Article 9.29.5.2.
- 15.9 mm Type X gypsum board – 15.9 mm special fire-resistant Type X gypsum board conforming to Article 9.29.5.2.
- Except for exterior walls (see Note 9), the outer layer of finish on both sides of the wall must have its joints taped and finished.
- Fastener types and spacing must conform to CSA A82.31–M, "Gypsum Board Application."

(6) Where bracing material, such as plywood or OSB sheathing is installed beneath the gypsum board on the outer face of the studs in single row, staggered, or double row stud walls, the fire-resistance rating is not affected. Attaching such bracing layers may increase the STC value but enough data to permit assignment of STC ratings for this situation is not available.

(7) Absorptive material required for the fire-resistance rating is mineral fibre processed from rock or slag with a mass of at least 4.8 kg/m² for 150 mm thickness, 2.8 kg/m² for 89 mm thickness and 2.0 kg/m² for 65 mm thickness and completely filling the wall cavity. For assemblies with double wood studs on separate plates, absorptive material is required in the stud cavities on both sides.

(8) Where bracing material, such as diagonal lumber or plywood, OSB, gypsum board or fibreboard sheathing is installed on the inner face of one row of studs in double stud assemblies, the STC rating will be reduced by 3 for any assemblies containing absorptive material in both rows of studs or in the row of studs opposite to that to which the bracing material is attached. Attaching such layers on both inner faces of the studs may drastically reduce the STC value but enough data to permit assignment of STC ratings for this situation is not available. The fire-resistance rating is not affected by the inclusion of such bracing.

(9) The fire resistance ratings listed in the Table for single row loadbearing or nonloadbearing wood stud wall assemblies can be used for exterior walls constructed the same as an interior wall. The finish joints must be taped and finished for the outer layer of the interior side only. The gypsum board required on the exterior side may be replaced with gypsum sheathing of the same thickness and type (regular or Type X).

Jensen, Jun'ichi MEM:EX

From: Peter Moonen [pmoonen@wood-works.ca]
Sent: Thursday, February 19, 2009 9:06 AM
To: Rotgans, Trudy SG:EX
Subject: Fwd: Meeting with Fire Protection Officers March 19

I'll call you Friday or monday s.22

Peter Moonen
Leader, Sustainable Building Coalition
Ph. 877.929.9663. Ext. 5
pmoonen@dccnet.com
Sent from my iPod

Begin forwarded message:

> **From:** Mark S <msmitton@fpoa.bc.ca>
> **Date:** February 18, 2009 23:15:29 PST
> **To:** Peter Moonen <pmoonen@wood-works.ca>
> **Subject: Meeting with Fire Protection Officers March 19**
> **Reply-To:** "msmitton@fpoa.bc.ca" <msmitton@fpoa.bc.ca>
>
> Peter
>
> I have asked around and find that a there is a lot of interest from fire inspectors to attend this session.
>
> ---
>
> **From:** Peter Moonen [mailto:pmoonen@wood-works.ca]
> **Sent:** February-13-09 4:18 PM
> **To:** gc@ghl.ca; Sukh Johal
> **Cc:** Trudy Rotgans; Mary Tracey; msmitton@fpoa.bc.ca
> **Subject:** Meeting with Fire Protection Officers March 19
>
> Hello, all.
>
> I spoke briefly with Gary Chen of GHL regarding their participation in the proposed meeting with Fire Protection Officers on March 19. Gary said he would touch base with his colleague, Andrew Hamsworth, about this meeting.
>
> s.22 I would like to ask Sukh to carry the ball next week with Gary, Andrew and two other contacts Trudy recommended to me -- Peter Senez (604.295.3420) and Keith Calder (604.295.3422)of Senez Reed Calder. Sukh, can you do that?

We are going to arrange the meeting for 10:00 a.m. somewhere in the New Westminster area to prevent FPOs from having to brave the morning commute to downtown Vancouver.

I am also including the Andrew Waugh Presentation for Gary to see, so if you have that already, my apologies.

Jensen, Jun'ichi MEM:EX

From: Helen Griffin [hgriffin@cwc.ca]
Sent: Wednesday, February 18, 2009 2:00 PM
To: Lam, Roger SG:EX; Rodney McPhee
Cc: Rotgans, Trudy SG:EX
Subject: RE: Technical Support for 1 hour Wood Frame Floor Assemblies
Attachments: image001.jpg

Hi Roger,
I will be attending the CCBFC meeting in Halifax so Trudy and I can make a point of talking about this while we are there. In the meantime, Rodney will have a look at the code change proposal form you sent. He will try, if possible, to start filling in the form with the needed information and then send you a draft to look at. This will give us something more concrete to discuss.
Thanks,
Helen.

Non-Responsive

From: Rodney McPhee [mailto:RMcPhee@cwc.ca]
Sent: Tuesday, February 17, 2009 6:08 PM
To: Lam, Roger HSD:EX
Cc: Helen Griffin
Subject: RE: Technical Support for 1 hour Wood Frame Floor Assemblies

Roger:

We are finalizing our response to Glenn Gibson's letter, but before doing so, Helen Griffin and I would like to talk to you to discuss how we might assist you and develop appropriate language and rationale for addressing this issue.

Can you advise on when might be a good time for us to call you to discuss the issue?

Currently, with our schedule, we're looking at sometime Friday morning, starting anytime between 8:30 and 10:00 a.m. your time (11:30-1:00 EST our time).

If Friday is not a good time, then perhaps we could look at sometime Thursday morning, starting anytime between 10:30 and 12:00 your time (1:30-3:00 EST our time).

Best regards.

Rodney A. McPhee, CET, CIP, ASFPE
Director, Codes and Standards
Canadian Wood Council
email: rmcphee@cwc.ca
Ph: 613-747-1801

Non-Responsive

From: Rodney McPhee [mailto:RMcPhee@cwc.ca]
Sent: Tuesday, February 3, 2009 1:46 PM
To: Andrew Harmsworth (GHL); Lam, Roger HSD:EX; John Nicol (Business Fax)
Cc: Helen Griffin; Etienne Lalonde; Mary Tracey
Subject: RE: Technical Support for 1 hour Wood Frame Floor Assemblies

Andrew:

Thanks for the heads-up.

I am currently working with Helen Griffin of our office in preparing a response to Glenn Gibson's letter, which we received yesterday.

Just one point of clarification regarding your email comments below.

The issue of the hose stream test is not, in any way, implicated when it comes to floor assemblies.

Under the ULC S-101 standard, the hose stream test is only conducted on wall assemblies.

As part of our response, among others, we will be referencing the materials I had prepared last fall for the BC code regarding the revised Fire and Acoustic tables.

Regards.

Rodney A. McPhee, CET, CIP, ASFPE
Director, Codes and Standards
Canadian Wood Council
email: rmcphee@cwc.ca
Ph: 613-747-1801

From: Andrew Harmsworth (GHL) [mailto:ah@ghl.ca]
Sent: Tuesday, February 03, 2009 3:21 PM

To: Lam, Roger HSD:EX; John Nicol (Business Fax)
Cc: Rodney McPhee
Subject: FW: Technical Support for 1 hour Wood Frame Floor Assemblies

Roger

Please see the attached letter from the CP Committee to CWC. I had hoped to include recommendations in our Code Change recommendations, but information from CWC unfortunately arrived too late.

I attach information provided by CWC to answer this question - and the full data is readily available, however it is not 'direct conformance' in that they are not designs tested at an accredited laboratory, as NRC is not an 'accredited testing agency', being a govenrnment agency.

In my opionion these should be acceptable as a 'alterate solution, however some municipalities are not accepting alternative solutions for floor assemblies. Surrey in particular has told our staff they will not accept these as an alternative solution, no matter what level of proof is provided.

I understand that these tests were performed in full conformance with ULC S101, with the sole exception that no hose stream test was performed.

Rod, could you please supply a letter stating that these tests were performed at NRC, and in full conformance with the requirements of ULC S101, including furnace details, fire size and loading and justification for not performing the hose stream test.

Whether we are submitting these designs for inclusion in the Code, or as an alternate solution, we need that documentation.

Thanks.

Andrew Harmsworth, M Eng, P Eng, CP
GHL CONSULTANTS LTD
Building Codes & Fire Science
950 - 409 Granville Street
Vancouver, BC V6C 1T2

T 604 689 4449 ext 107
F 604 689 4419
E ah@ghl.ca

From: Dave Graham (GHL)
Sent: Tuesday, February 3, 2009 8:21 AM
To: Andrew Harmsworth (GHL); Teddy Lai (GHL)
Cc: Khash Vorell (GHL)
Subject: FW: Technical Support for 1 hour Wood Frame Floor Assemblies

FYI - from the CP committee

David W Graham, P Eng, CP
GHL
CONSULTANTS LTD

Building Codes & Fire Science
950 - 409 Granville Street
Vancouver, BC V6C 1T2

T 604 689 4449 Ext 105
F 604 689 4419
E dg@ghl.ca
www.ghl.ca

A member company of
Saffire Safety Consultants Inc
www.saffire.ca

From: Glenn Gibson [mailto:ggibson@lmdg.com]
Sent: February 2, 2009 3:14 PM
To: 'hgriffin@cwc.ca'
Cc: 'bob.bowen@NRC-CNRC.gc.ca'; 'bob.thompson@gov.bc.ca'; 'eholt@aibc.ca'; 'lbowser@apeg.bc.ca'; 'Mitchell, Jeff'; 'Mitchell, Jeff'; 'Agren, Soren'; s.22 Dave Graham (GHL); 'ggibson@lmdg.com'; 'mbruckner@ibigroup.com'; 'Mehran Nazeman \(MRNazeman@city.surrey.bc.ca\)'; s.22 'patrick.shek@burnaby.ca'; s.22
Subject: Technical Support for 1 hour Wood Frame Floor Assemblies

Helen
Please refer to the attached letter regarding the lack of technical information available to support the use of standard wood frame floor assemblies to achieve a 1 hour fire-resistance rating. We believe that it is essential to make available to the building industry typical wood frame floor assemblies that will comply with the 1 hour fire-resistance rating requirements of the building code.

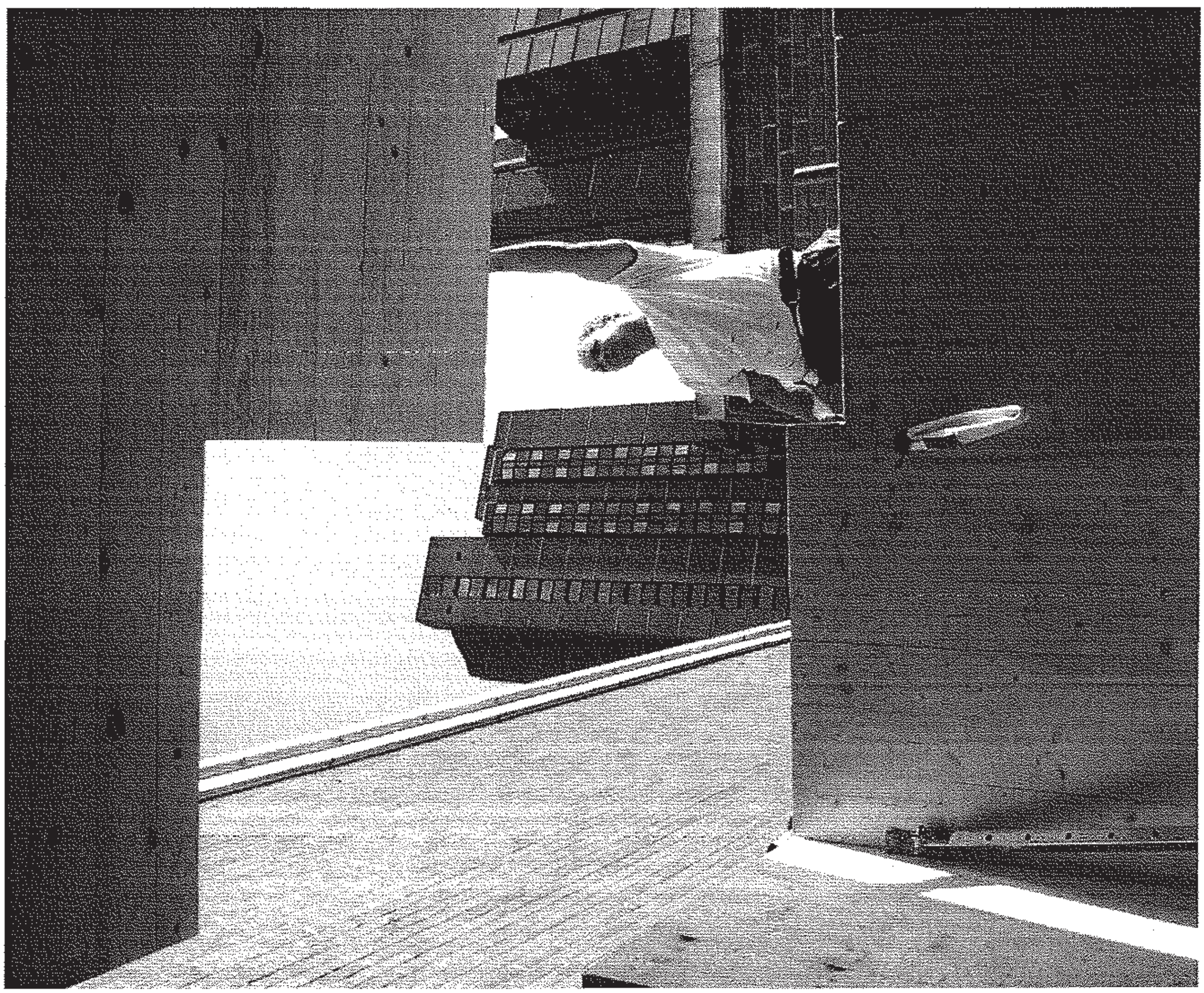
Please let us know your comments and if there is any way we can assist you in this matter.

Glenn A. Gibson, M.Eng., P.Eng., CP
LMDG Building Code Consultants Ltd.
Tel: 604-682-7146
Fax: 604-682-7149

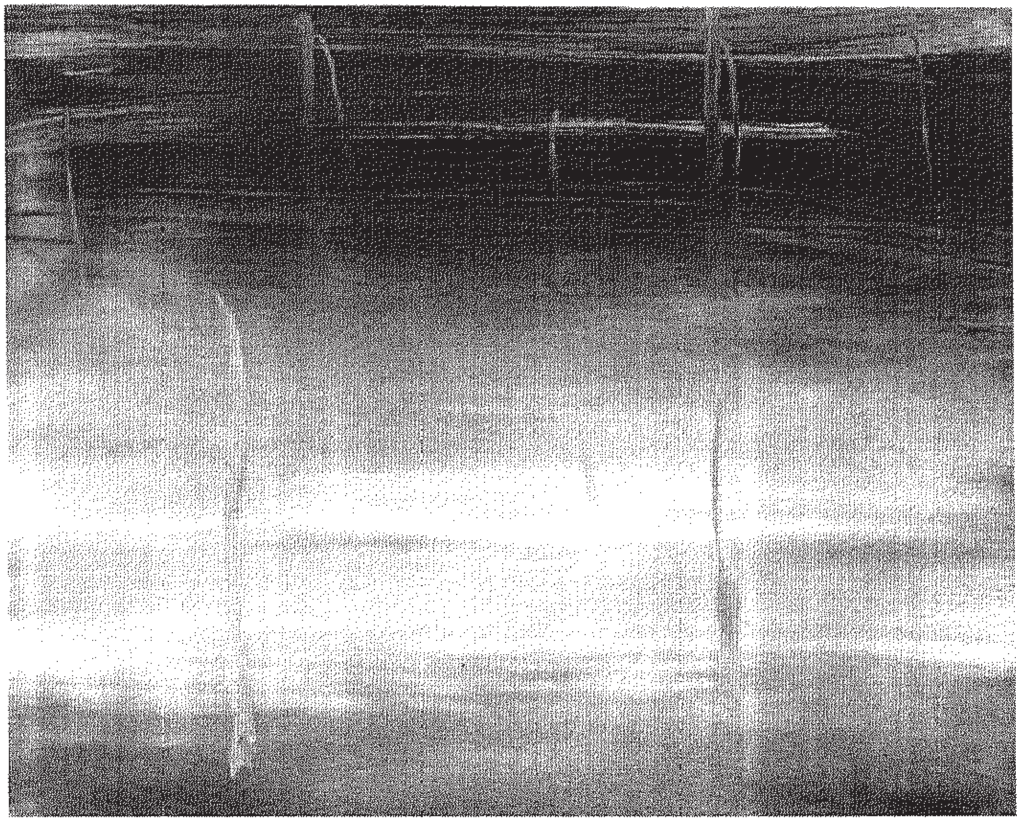
Opportunities and Constraints of Using Wood: Experiences from a large building company

By Andrew Waugh, Director
Waugh Thistleton Architects Ltd.
London, UK

Exton Street



Murray Grove



Architects:
WaughThistleton

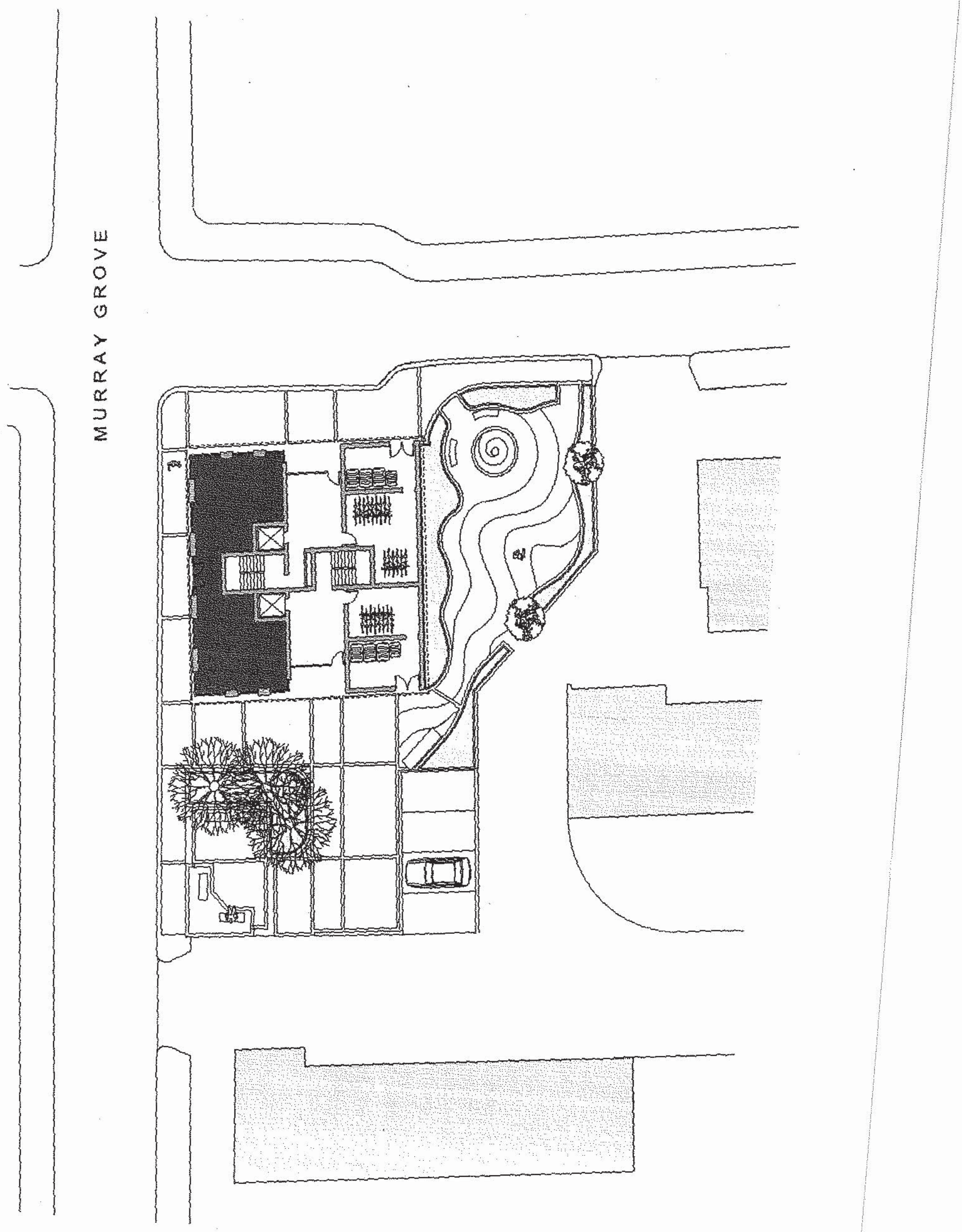
Engineers:
Techniker

Timber Supplier:
KLH

Development of 29 flats
10 affordable and 19 private

Residents office on ground floor

Clients
Telford Homes
Metropolitan Housing Association


MURRAY GROVE

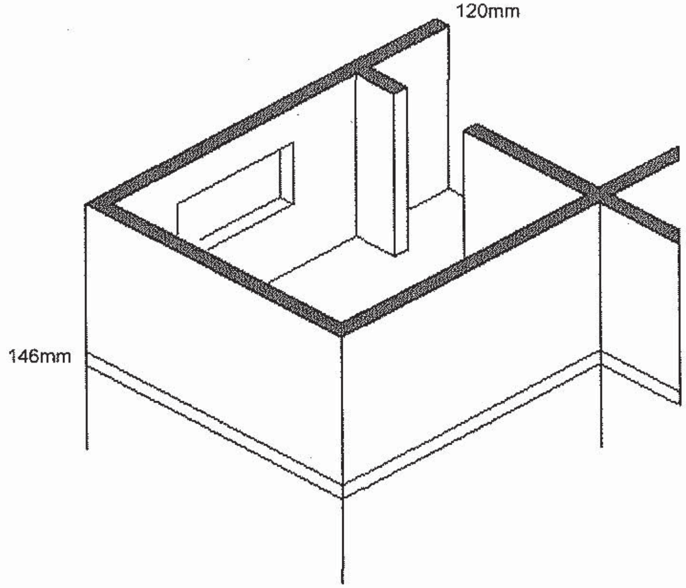
[redacted]

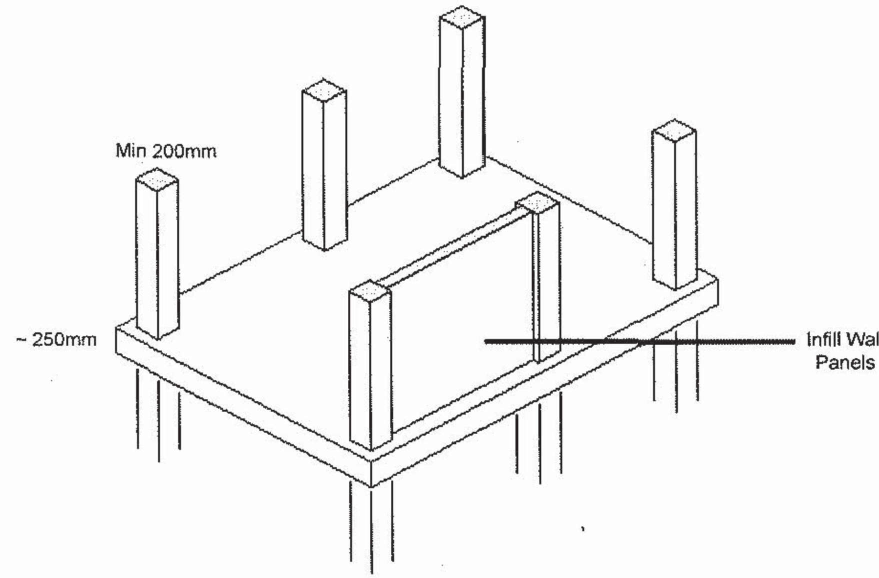
CO2 store

saves 300,000 kg of carbon

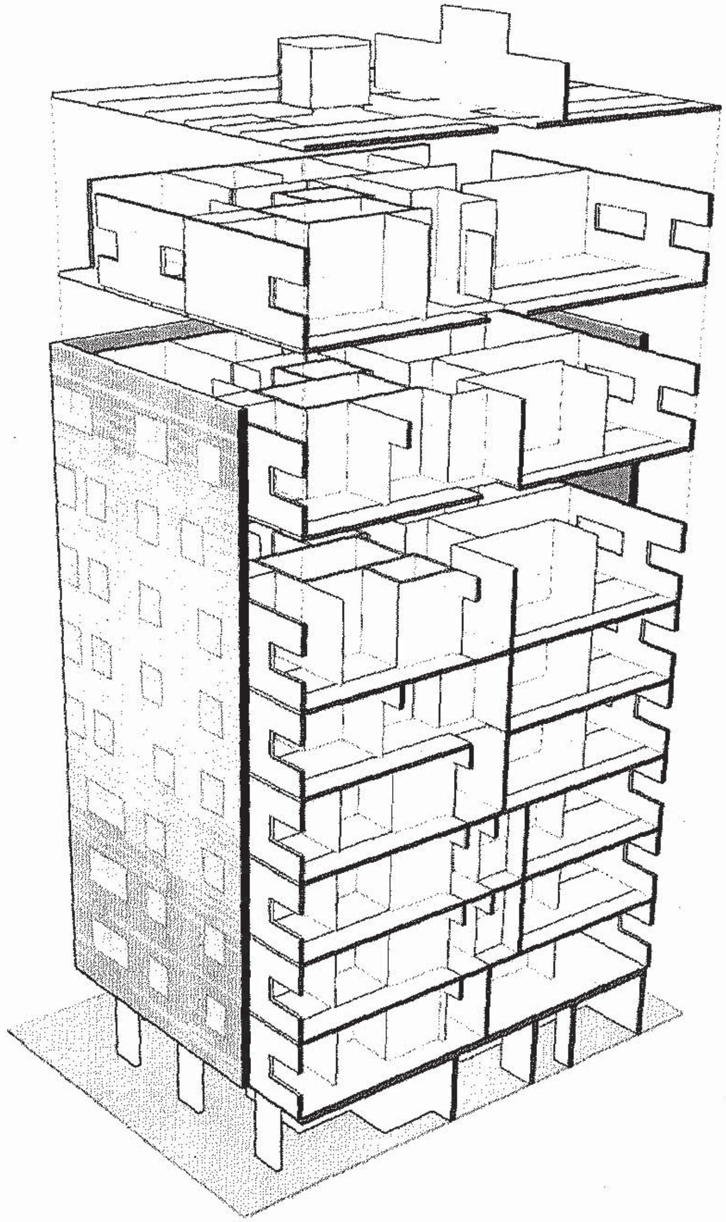
equivalent to 210 years of 10% reduction

Structural Form





Density	480kg/m3	2400kg/m3
Weight	300tonnes	1200tonnes
Programme	49 weeks	66 weeks

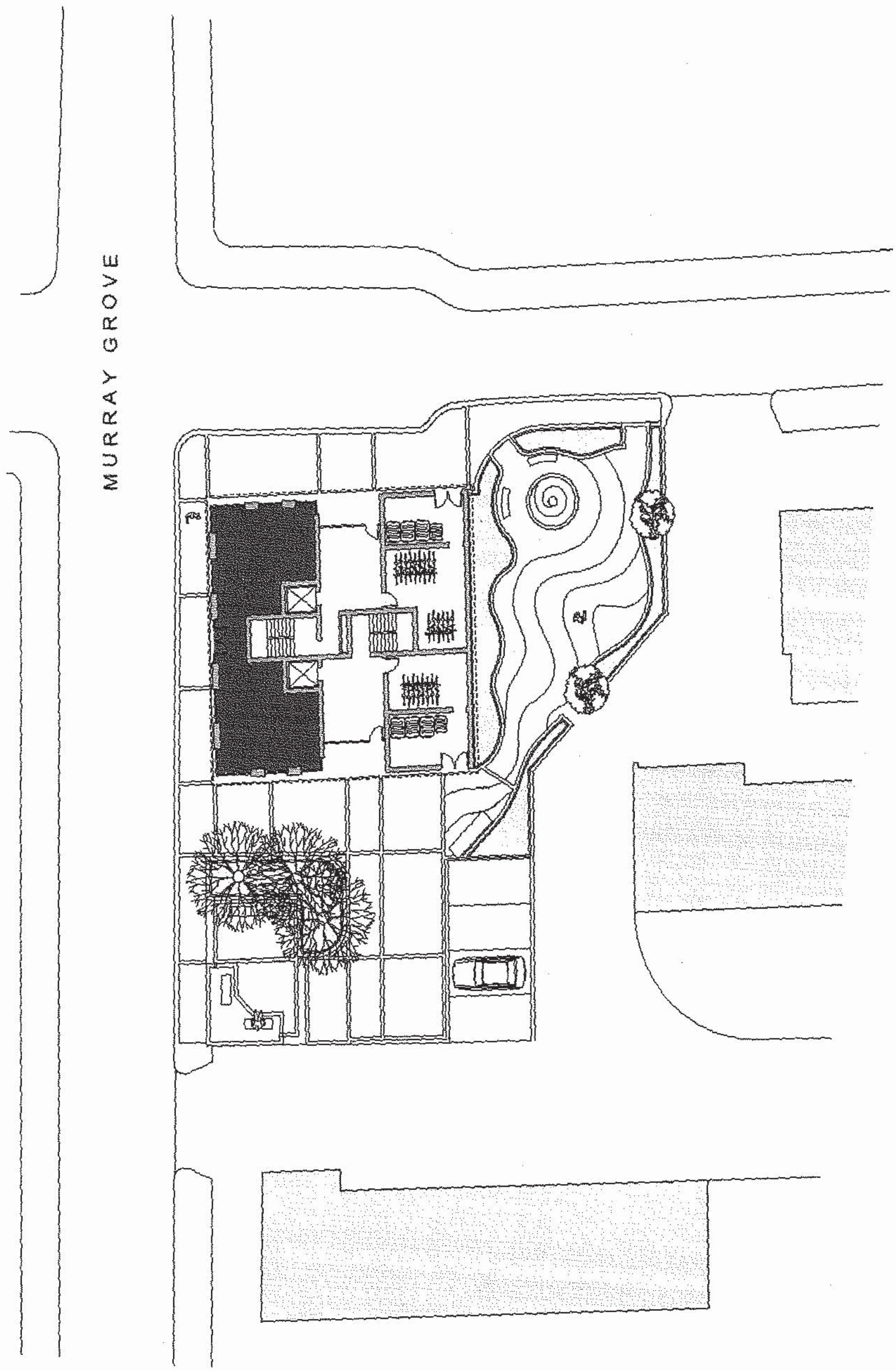


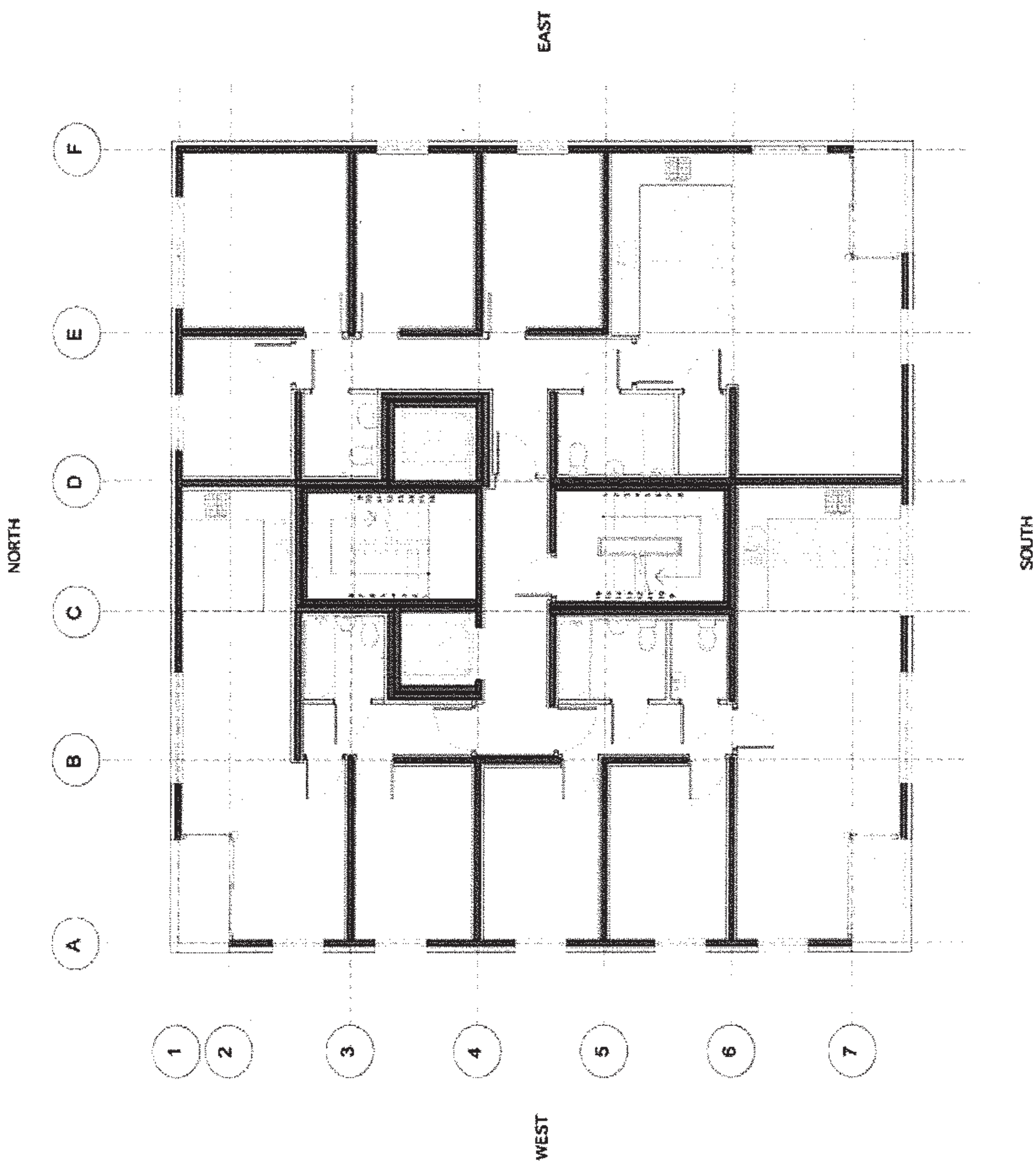
Honeycomb structure

Rotated plans

Load-bearing walls, floors and cores

Tallest timber building in the world


MURRAY GROVE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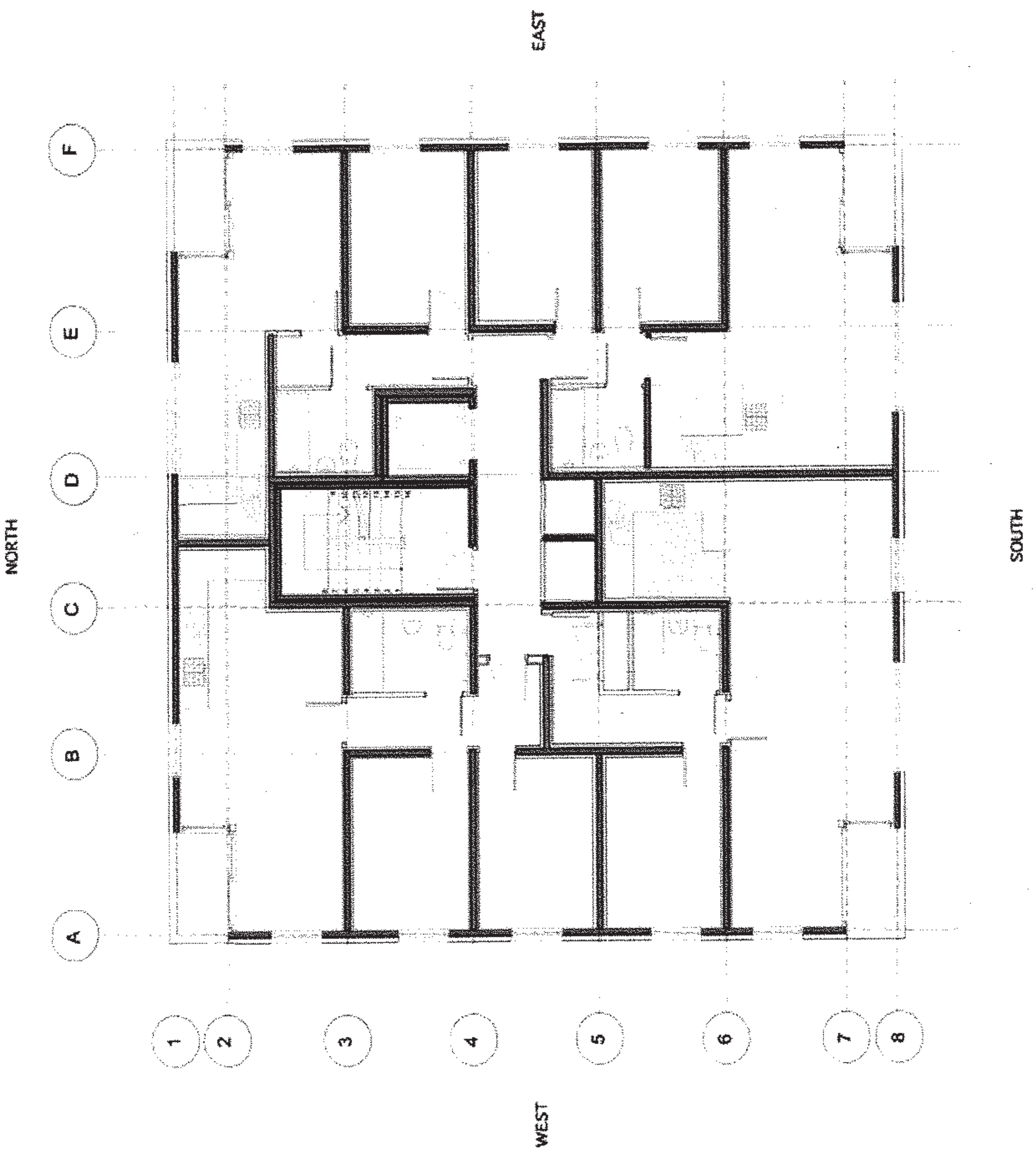
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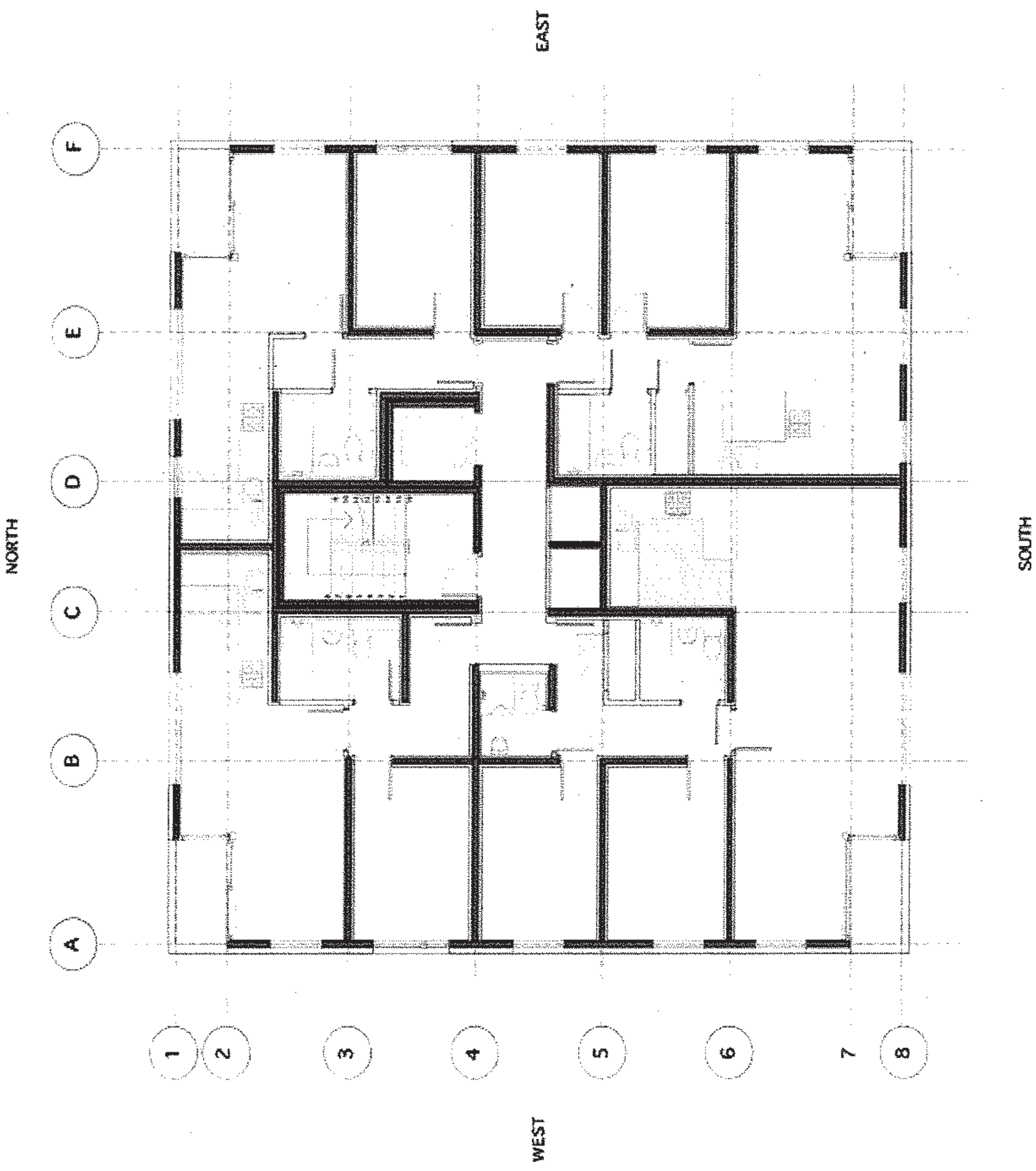
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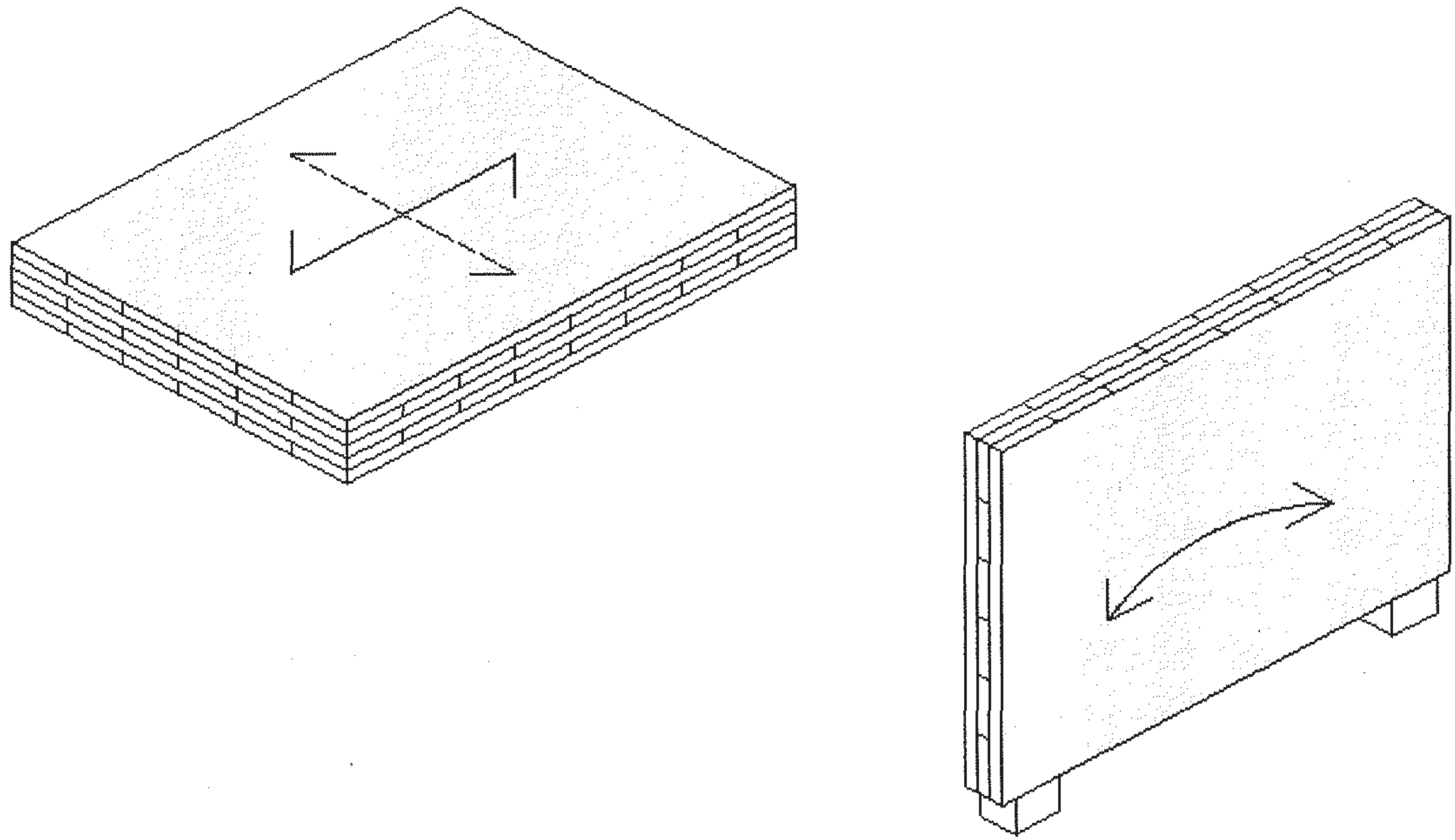
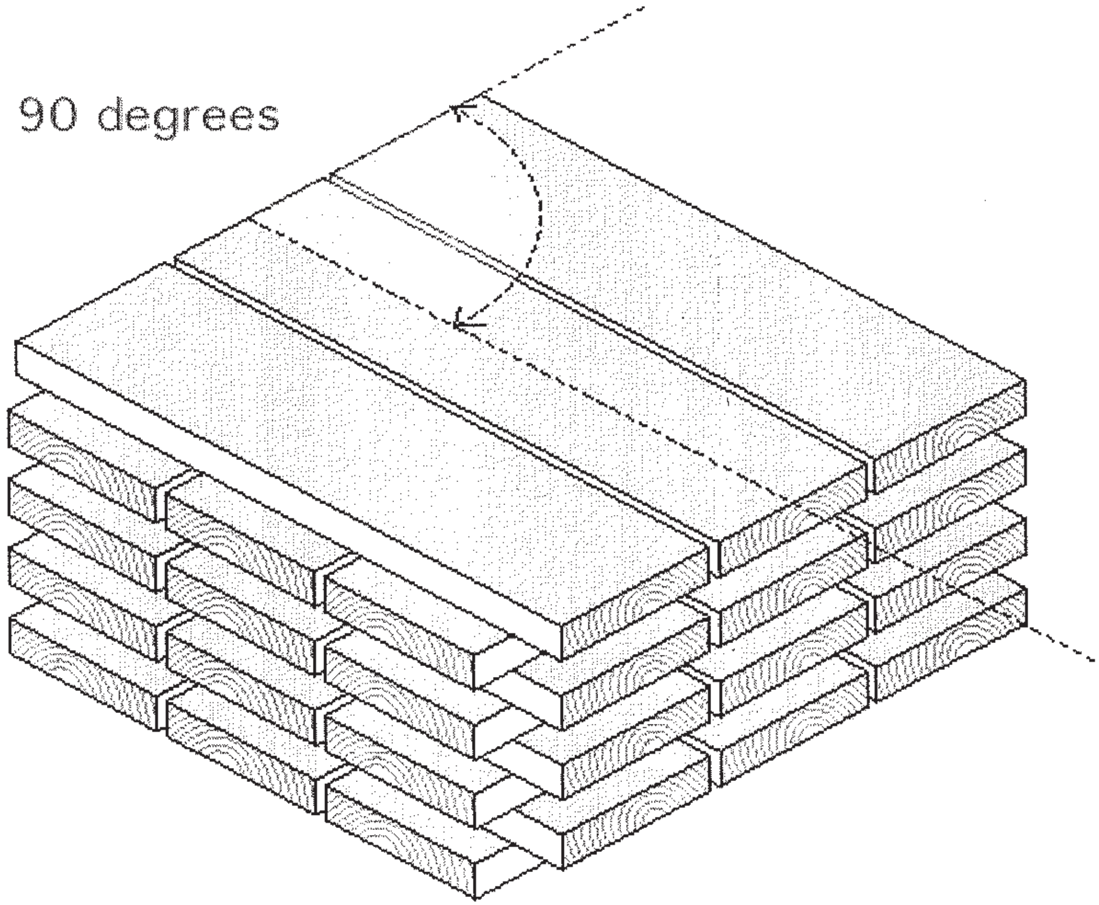


3D advantages of KLH
Horizontal panel - 5 ply

Building High

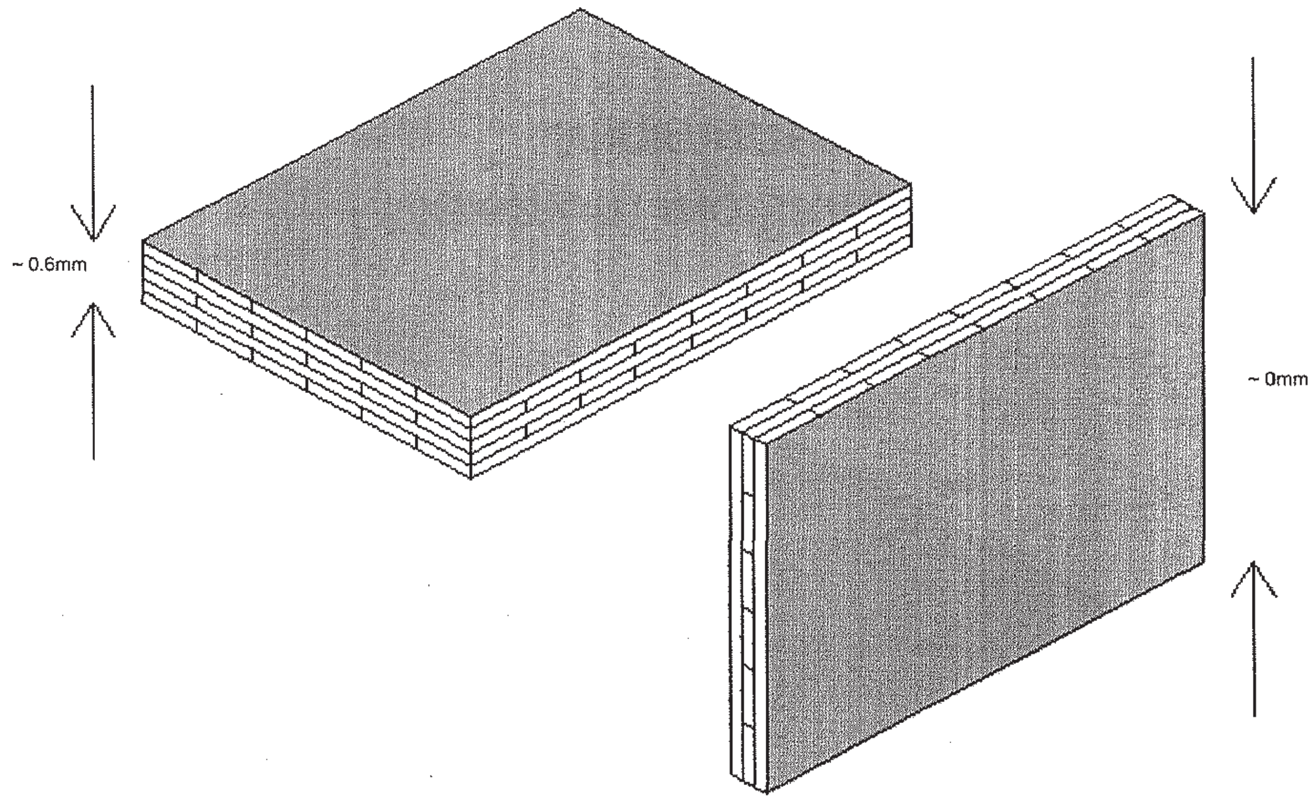
Movement
Stability
Fire
Acoustics



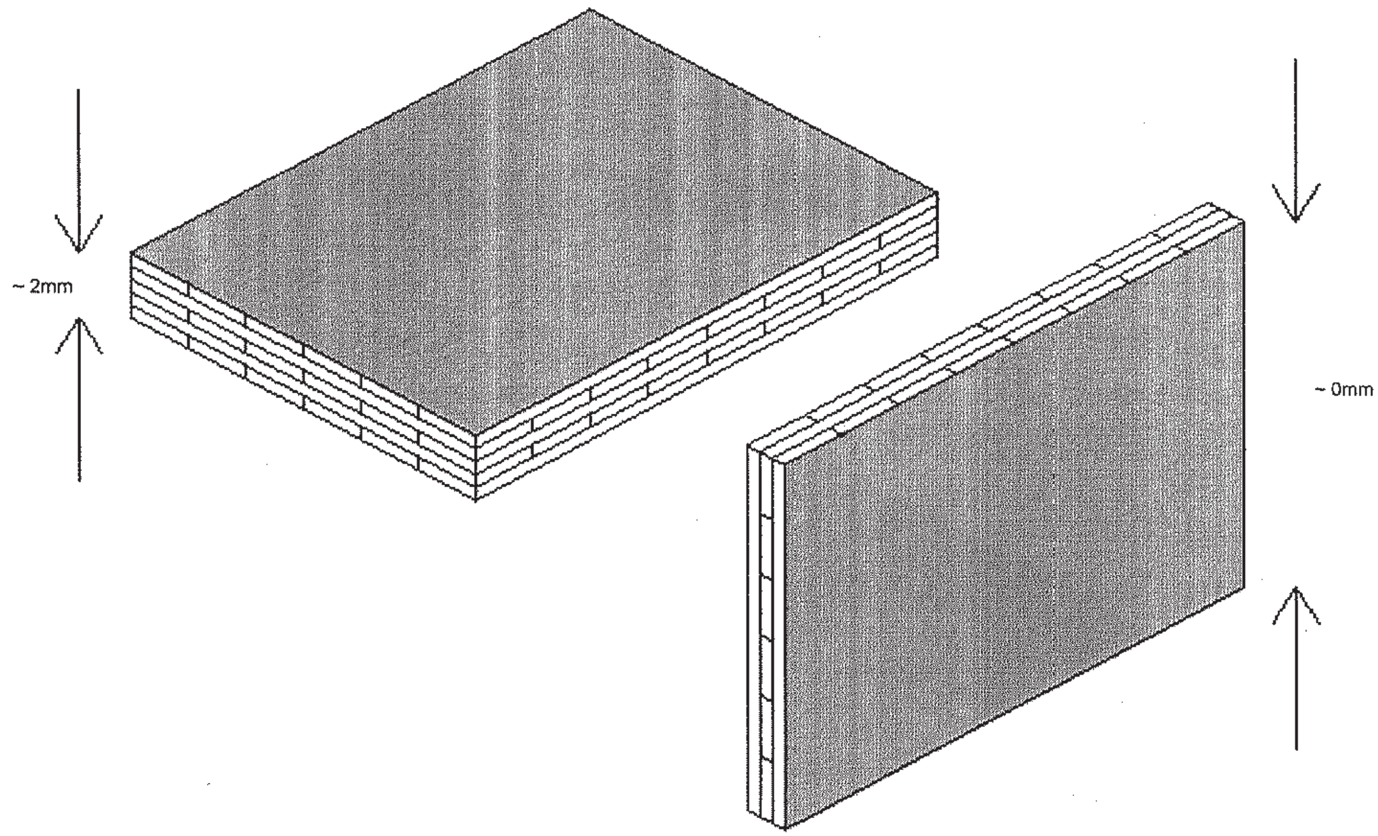
KLH Cross-laminated Panel

Movement

Creep
Moisture
Thermal

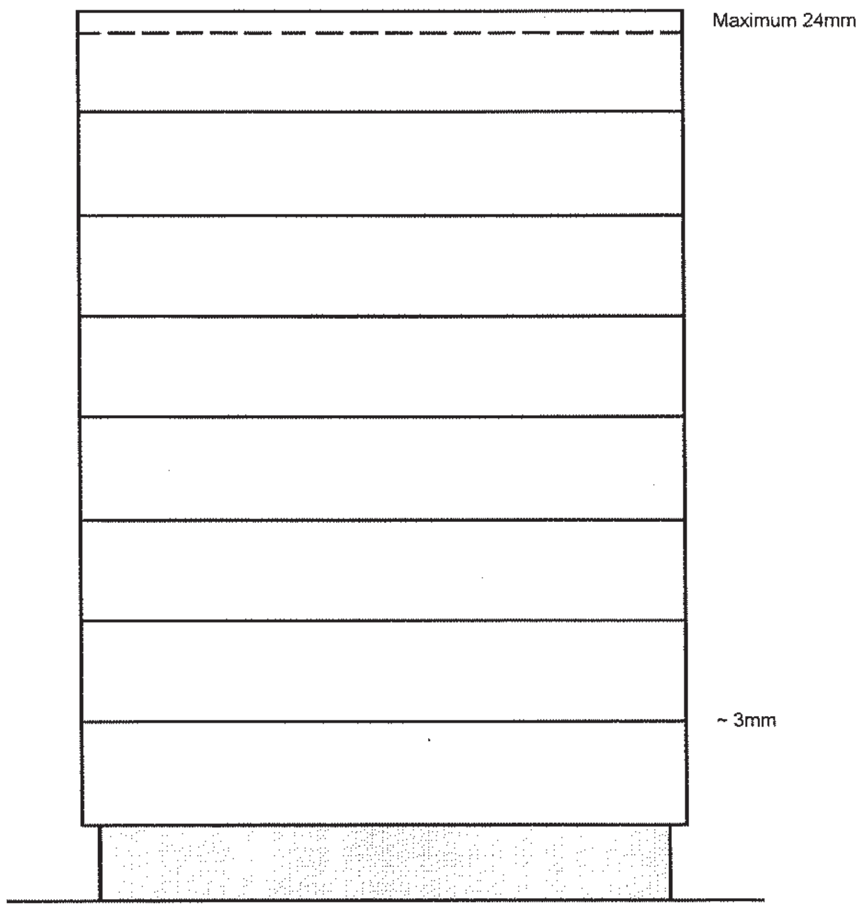


Creep - shortening due to compression under load

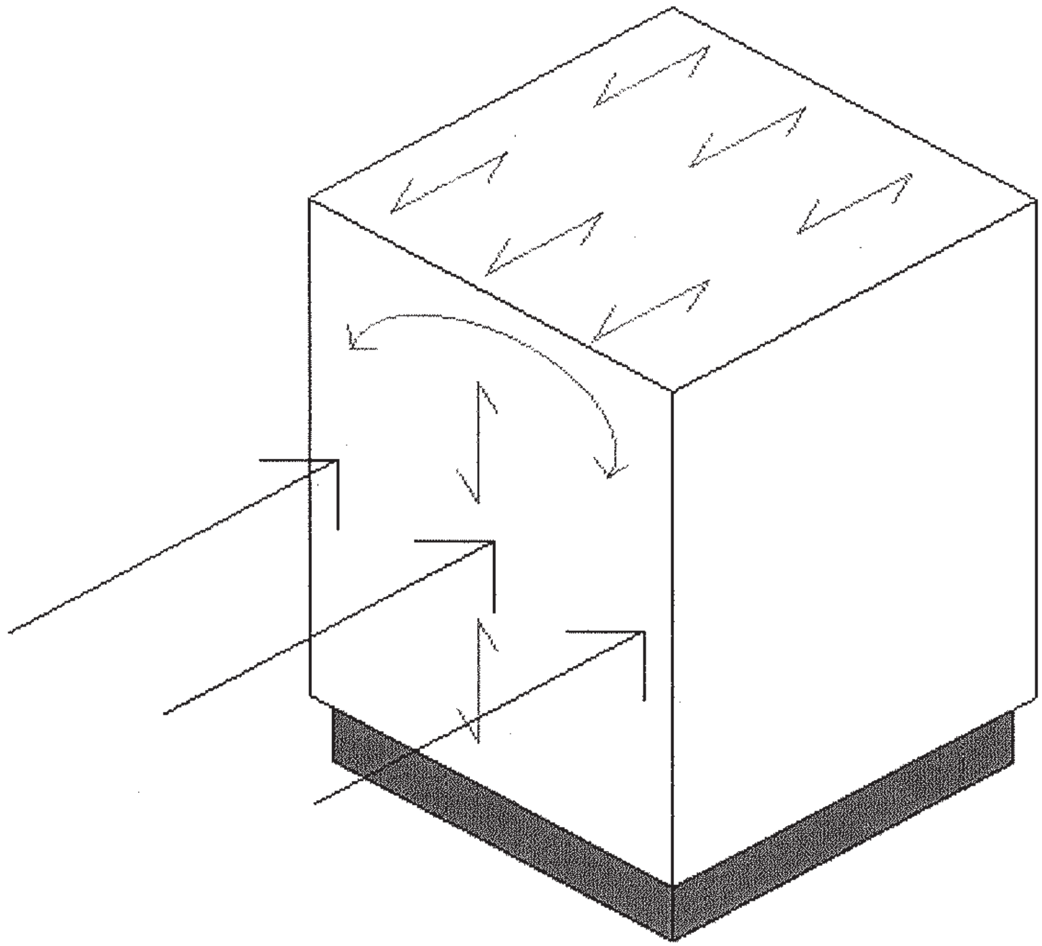


Moisture

Maximum moisture content at erection: 14 - 16%
Minimum moisture content in use: 8 - 10%



Total



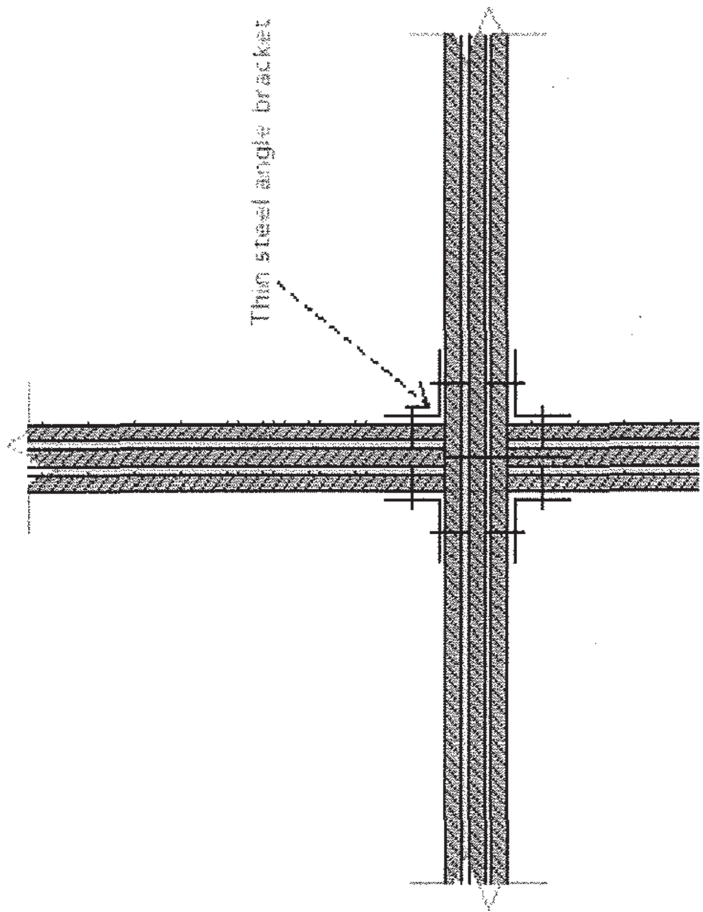
Stability

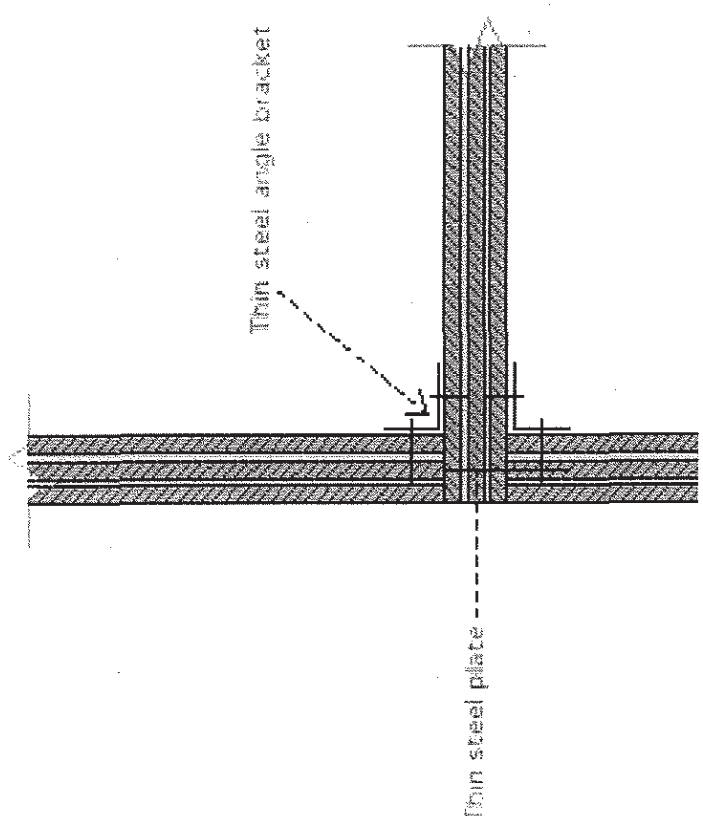
Progressive collapse

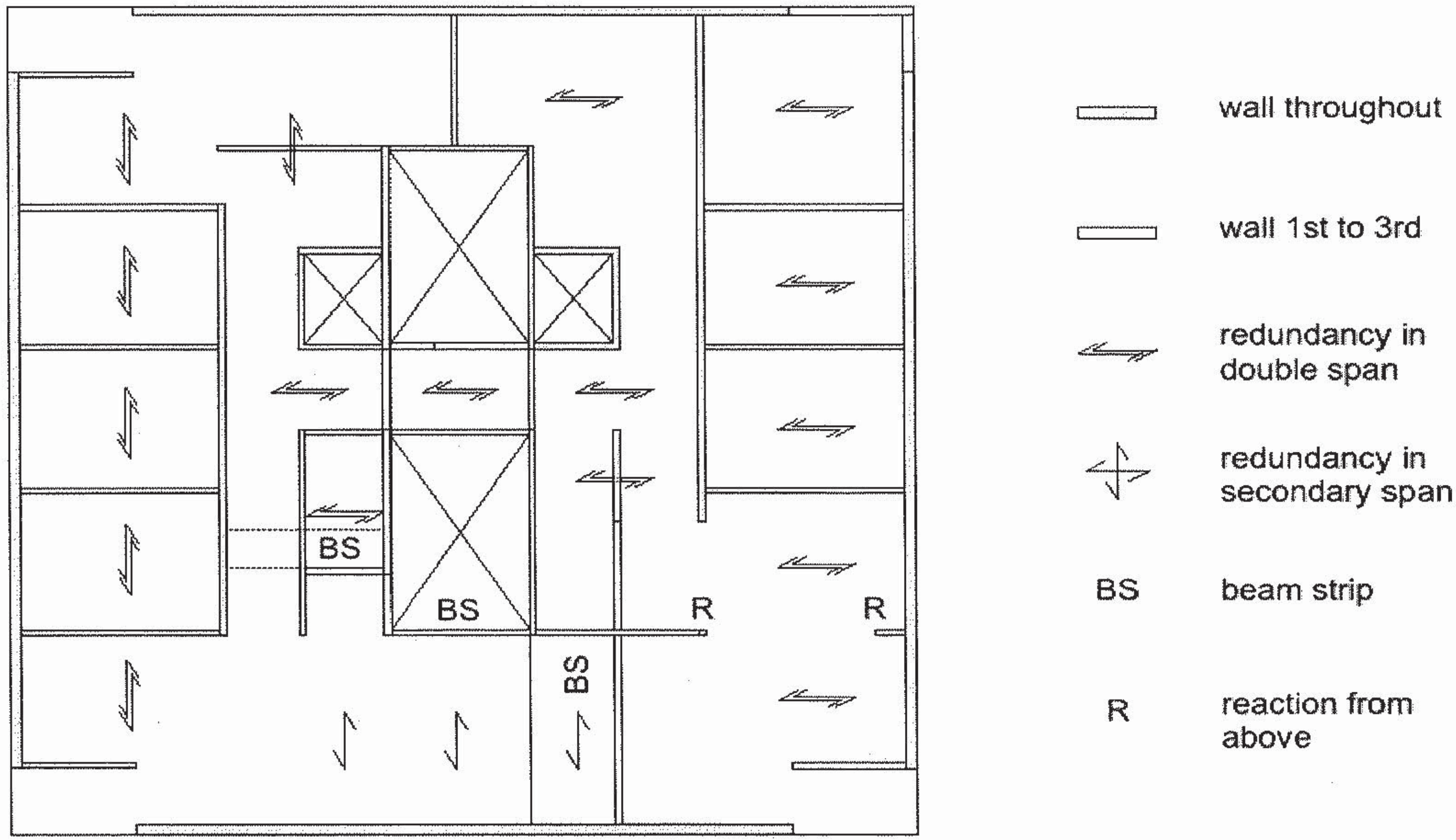
Notional horizontal and vertical ties - min 75kN

Removal of elements - 15% floor area, <$70m^2$

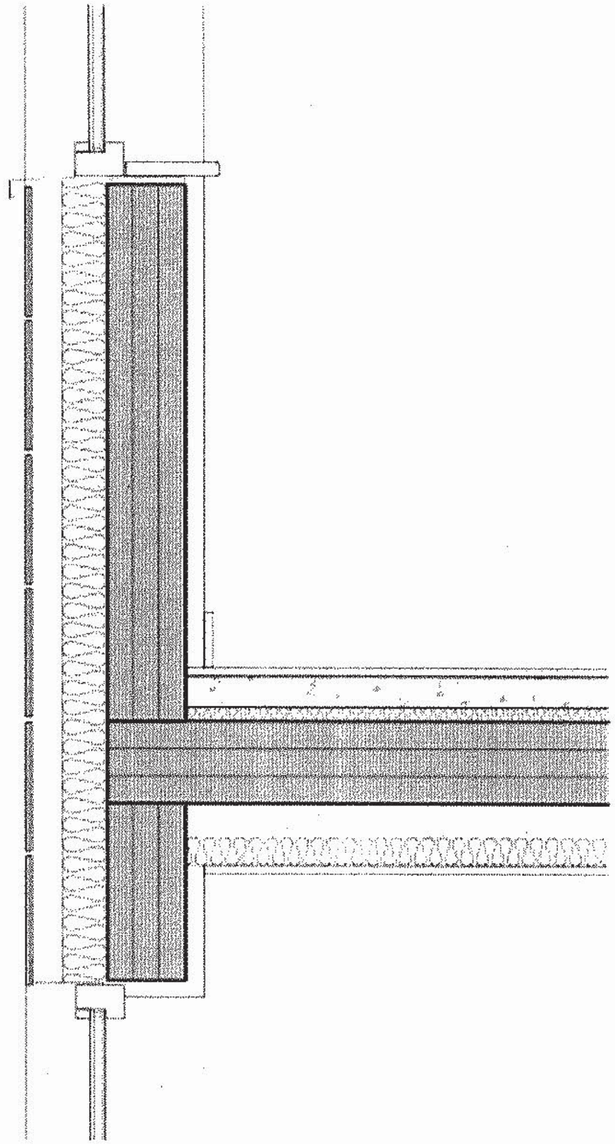
Design of key elements - $34kN/m^2$


Thin steel angle bracket


Thin steel angle bracket
Thin steel plate



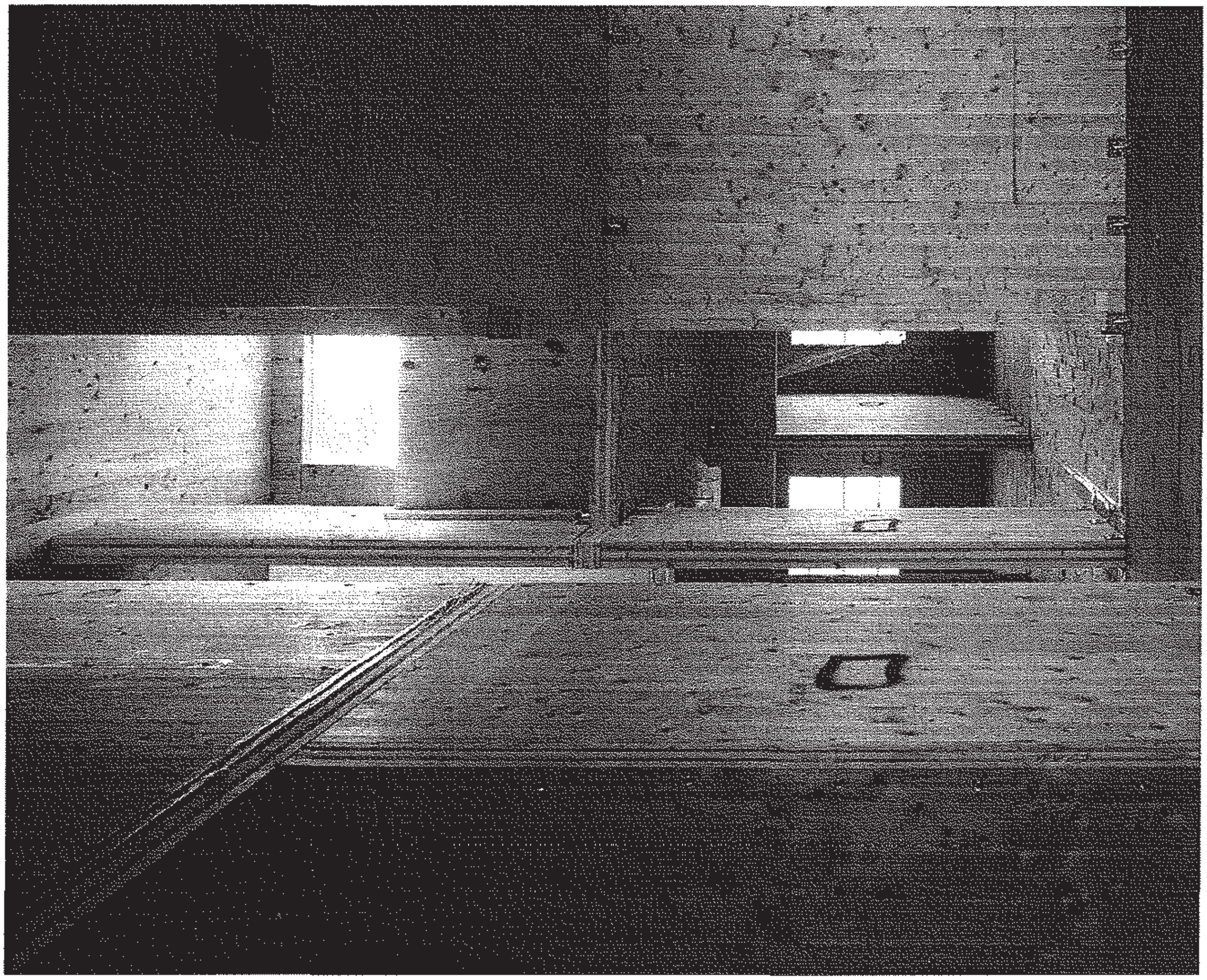
Progressive Collapse

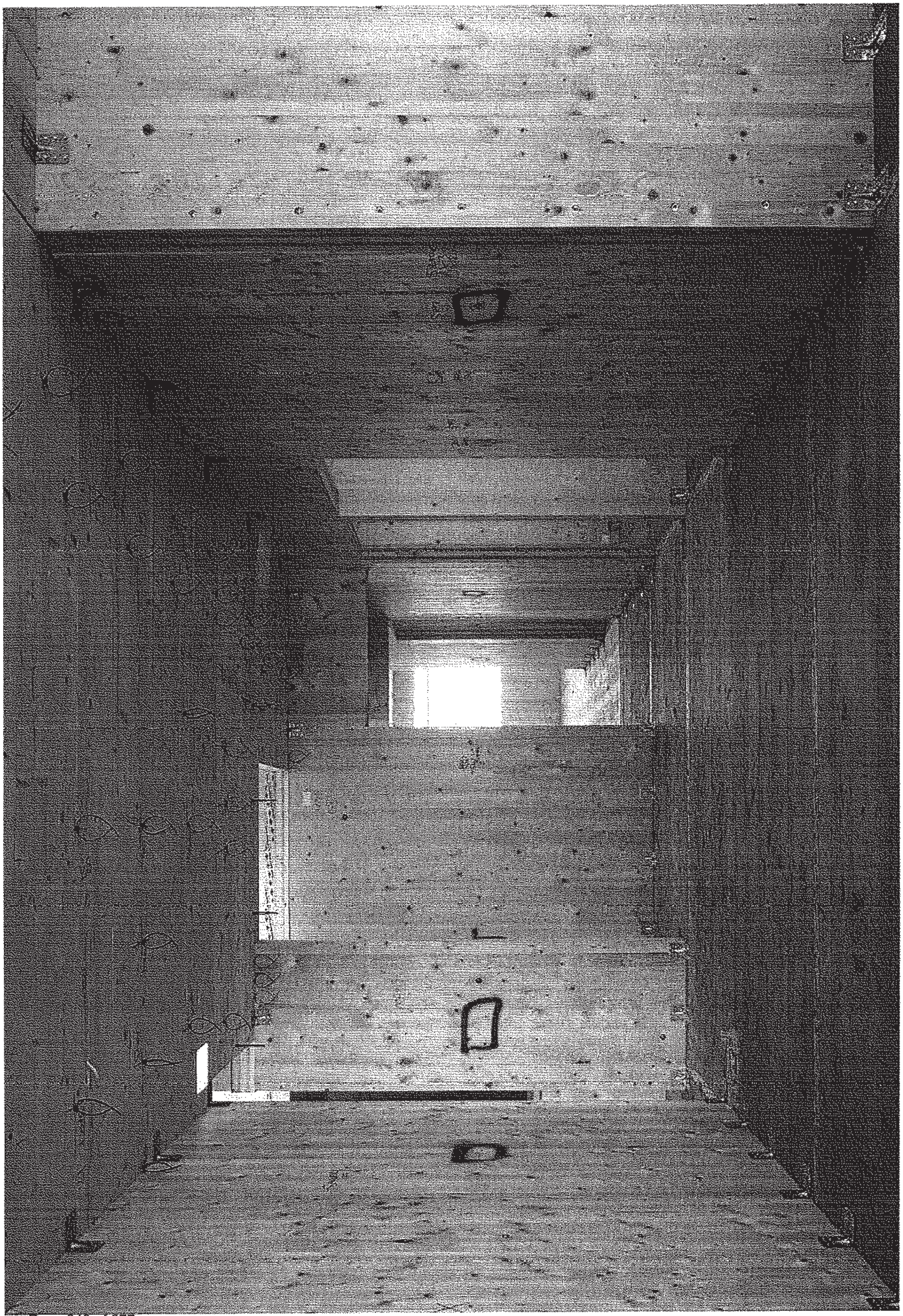


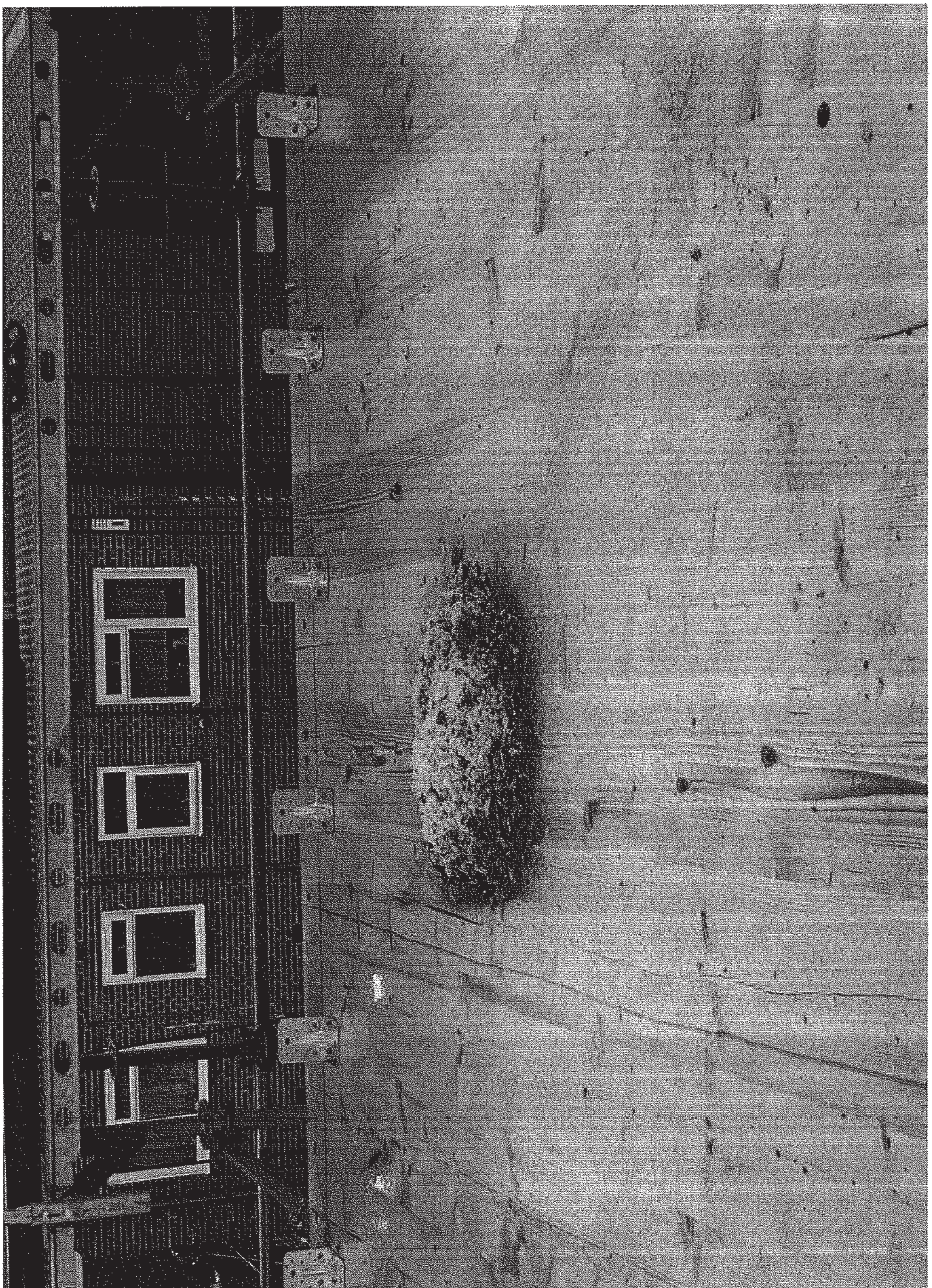
Acoustics

15mm Timber
55mm Screed
25mm Insulation
146mm KLH
75mm Void
50mm Insulation
1 layer of Plasterboard

QuickTime™ and a
H.264 decompressor
are needed to see this picture.

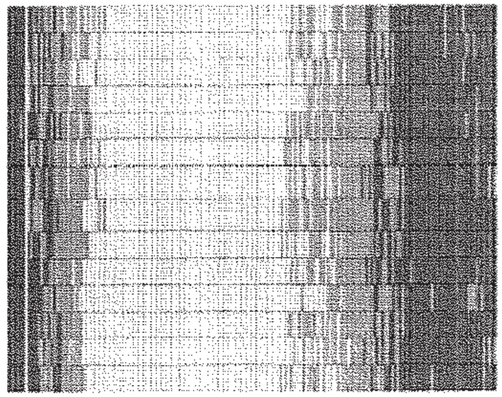


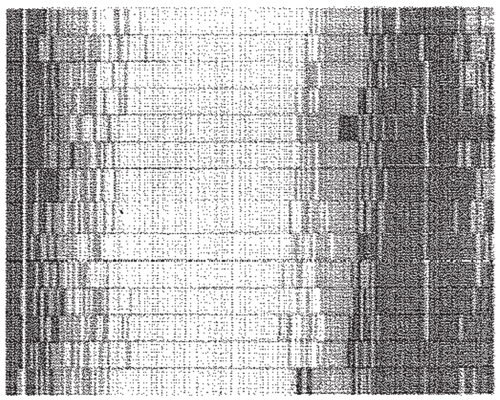


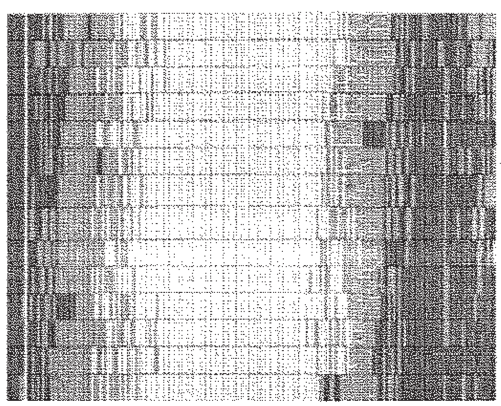


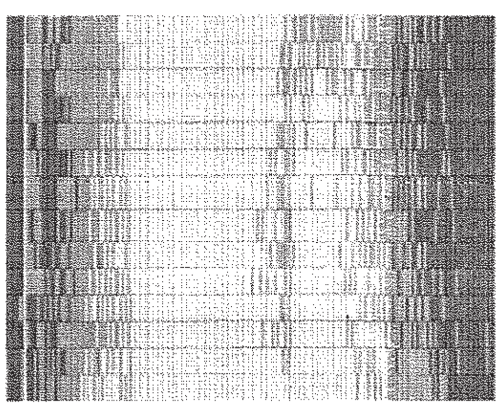
Nine storeys in nine weeks

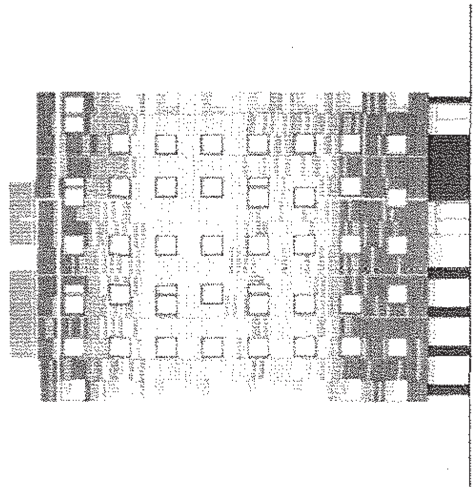
Time saving of 20 weeks

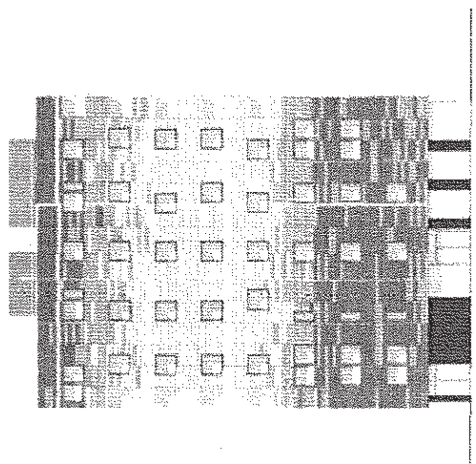


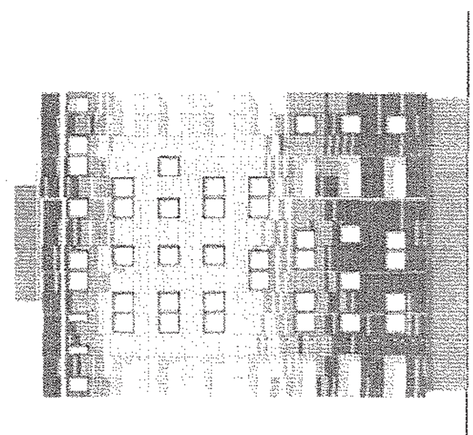


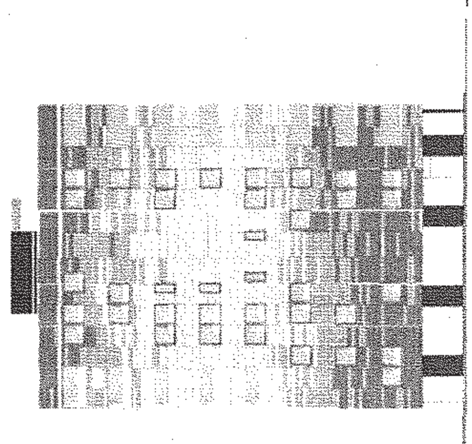


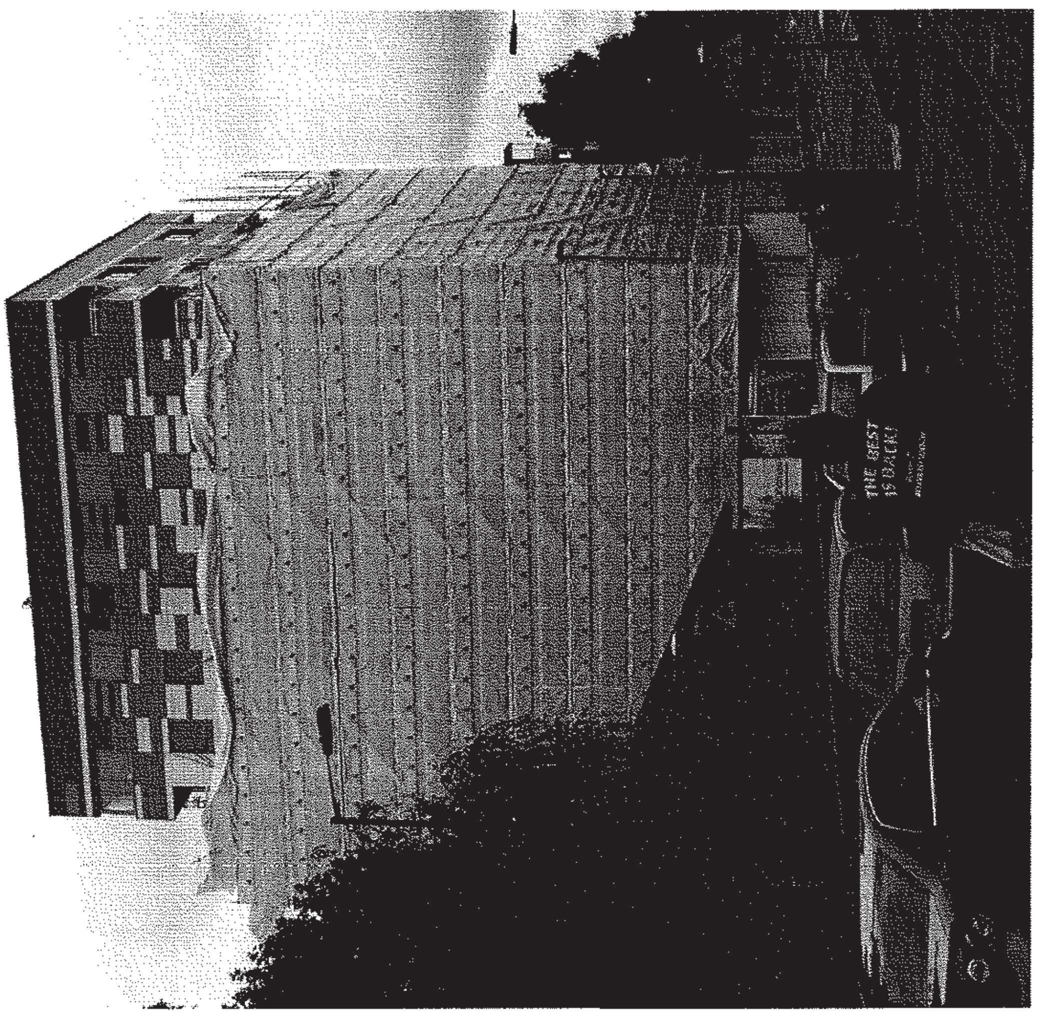


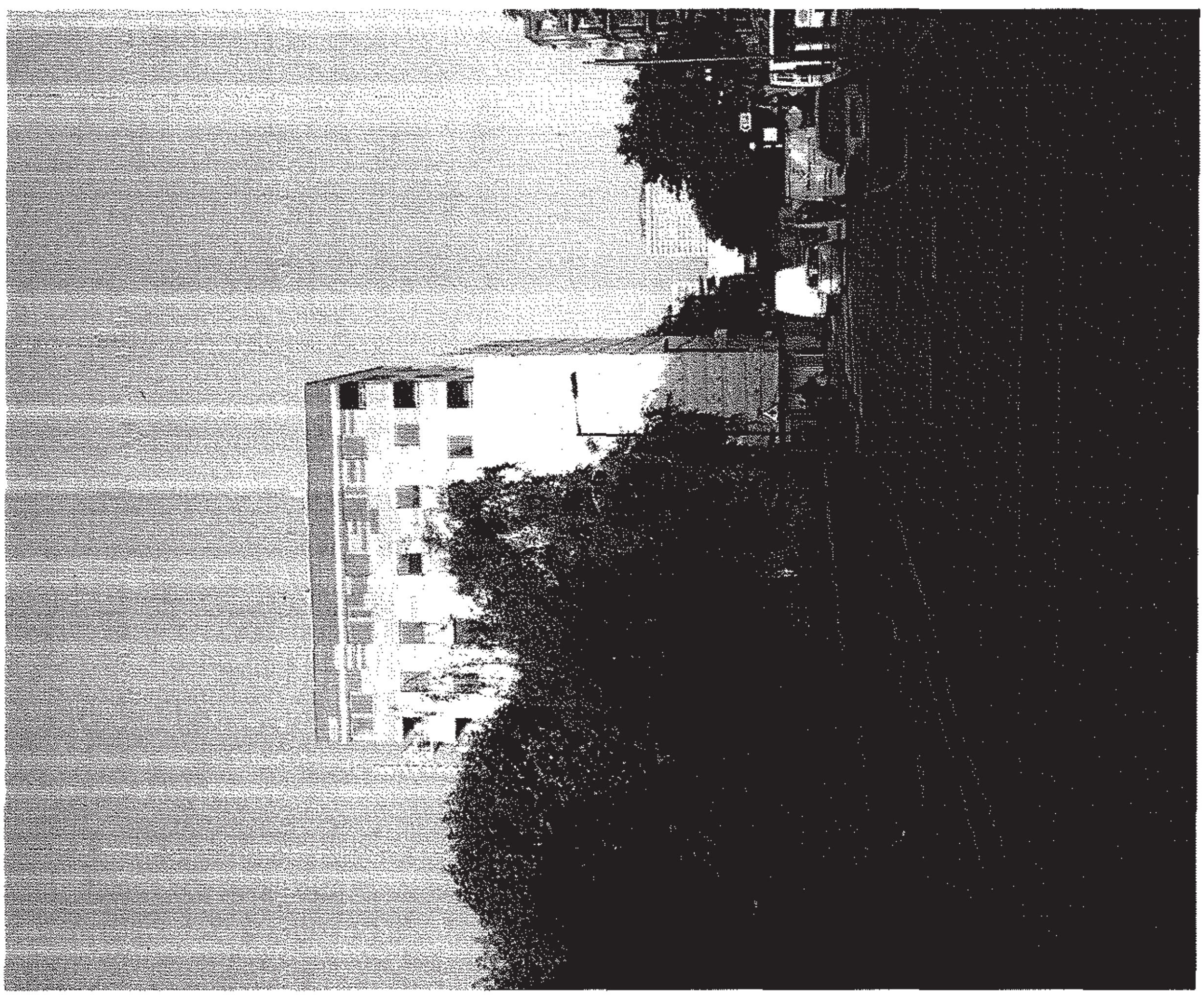


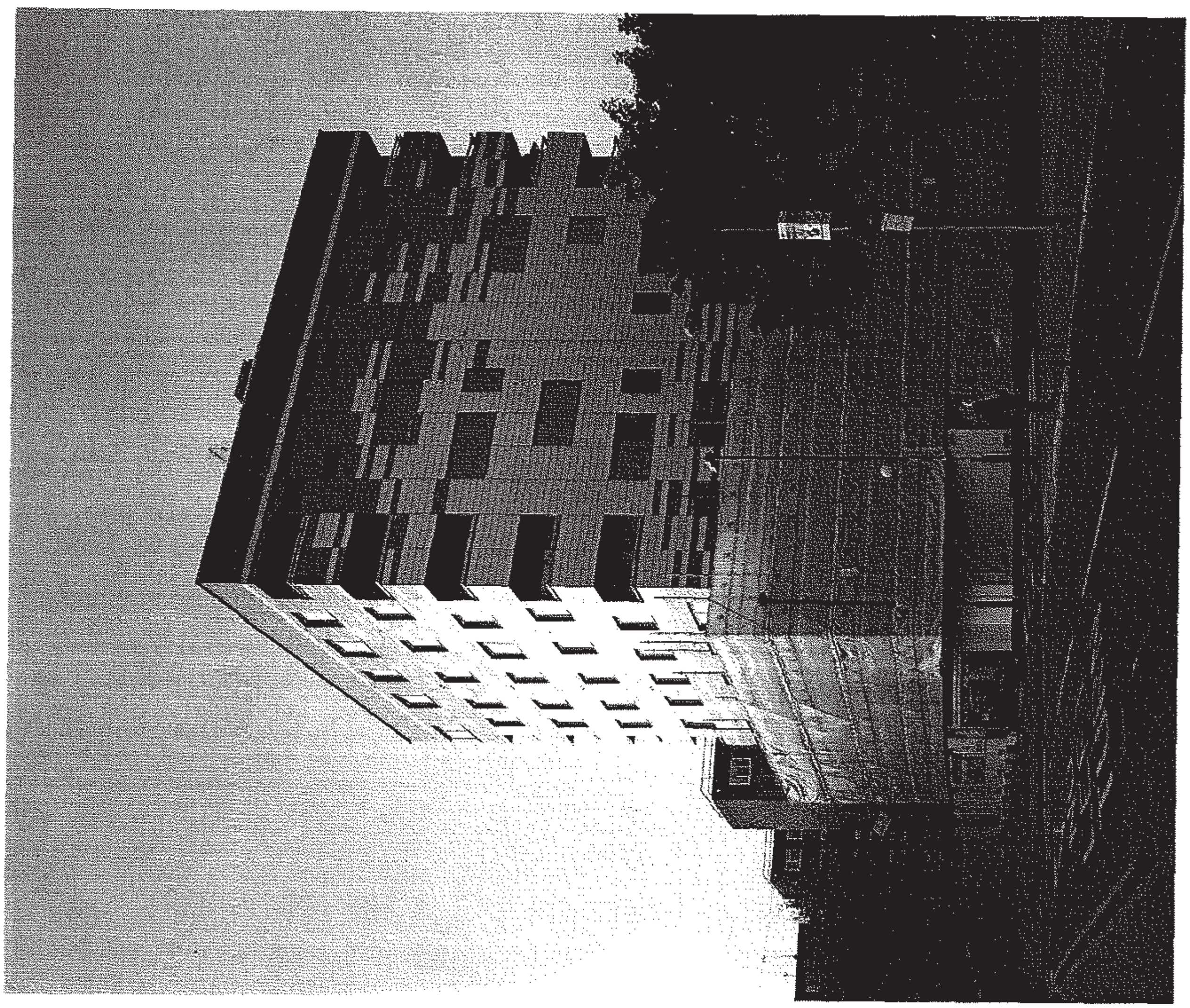


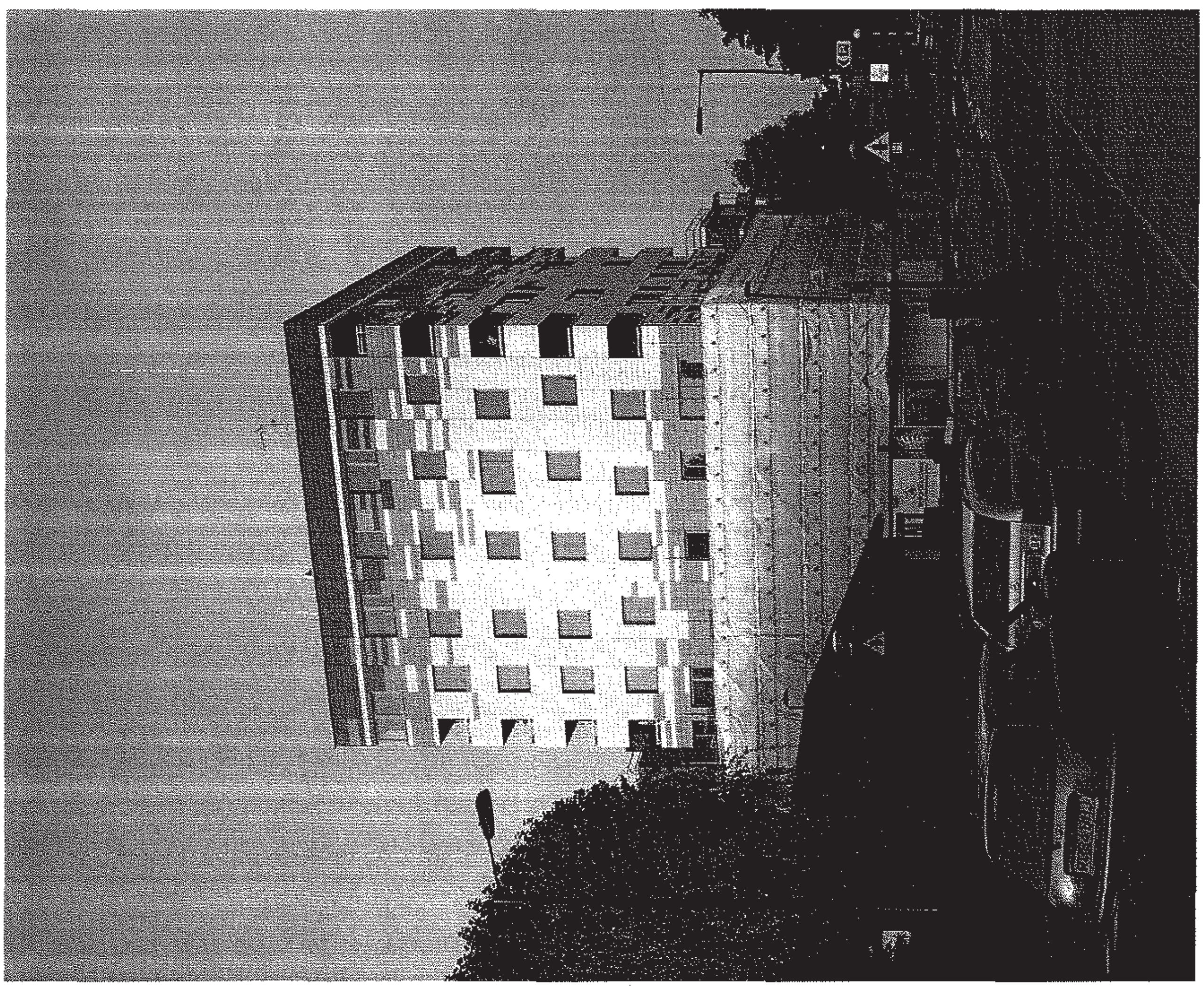


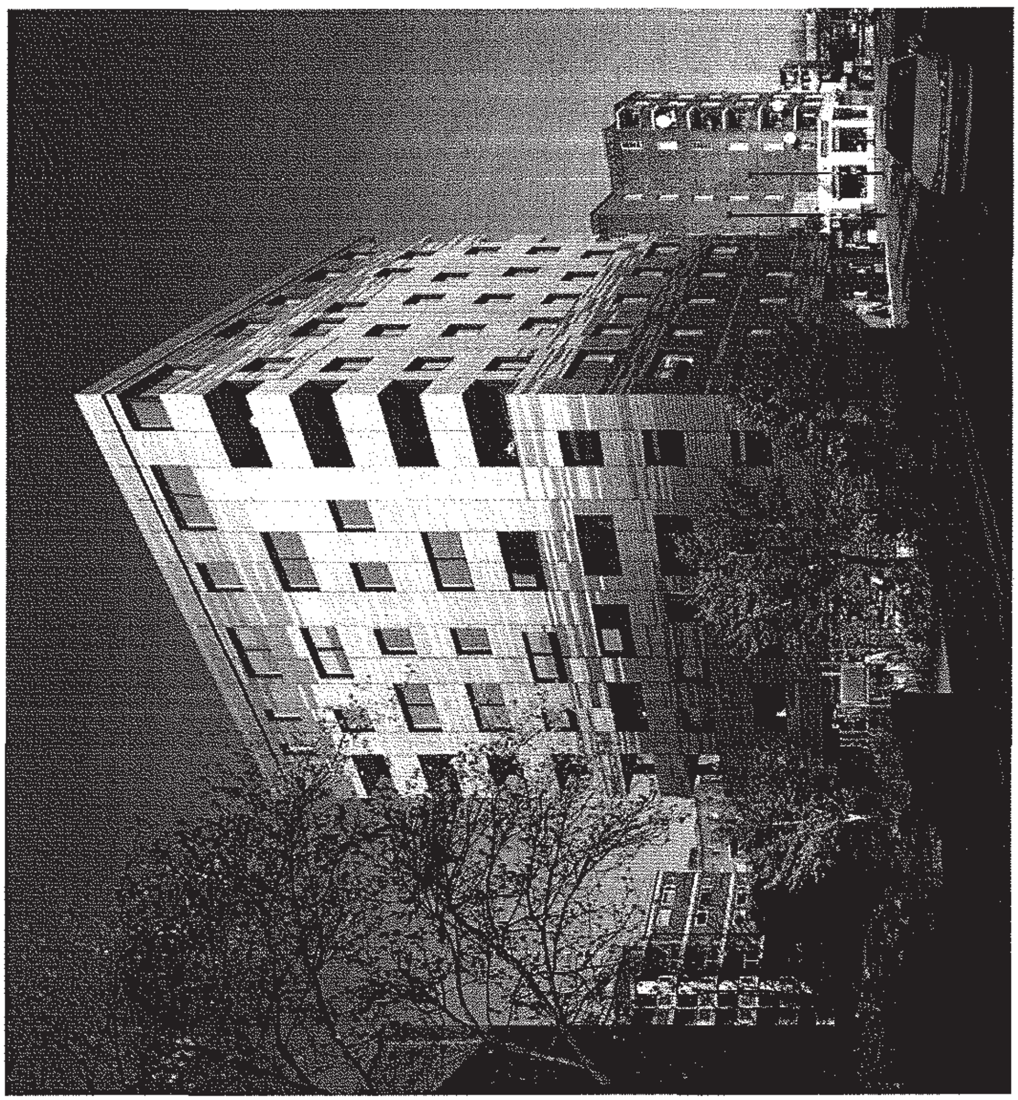


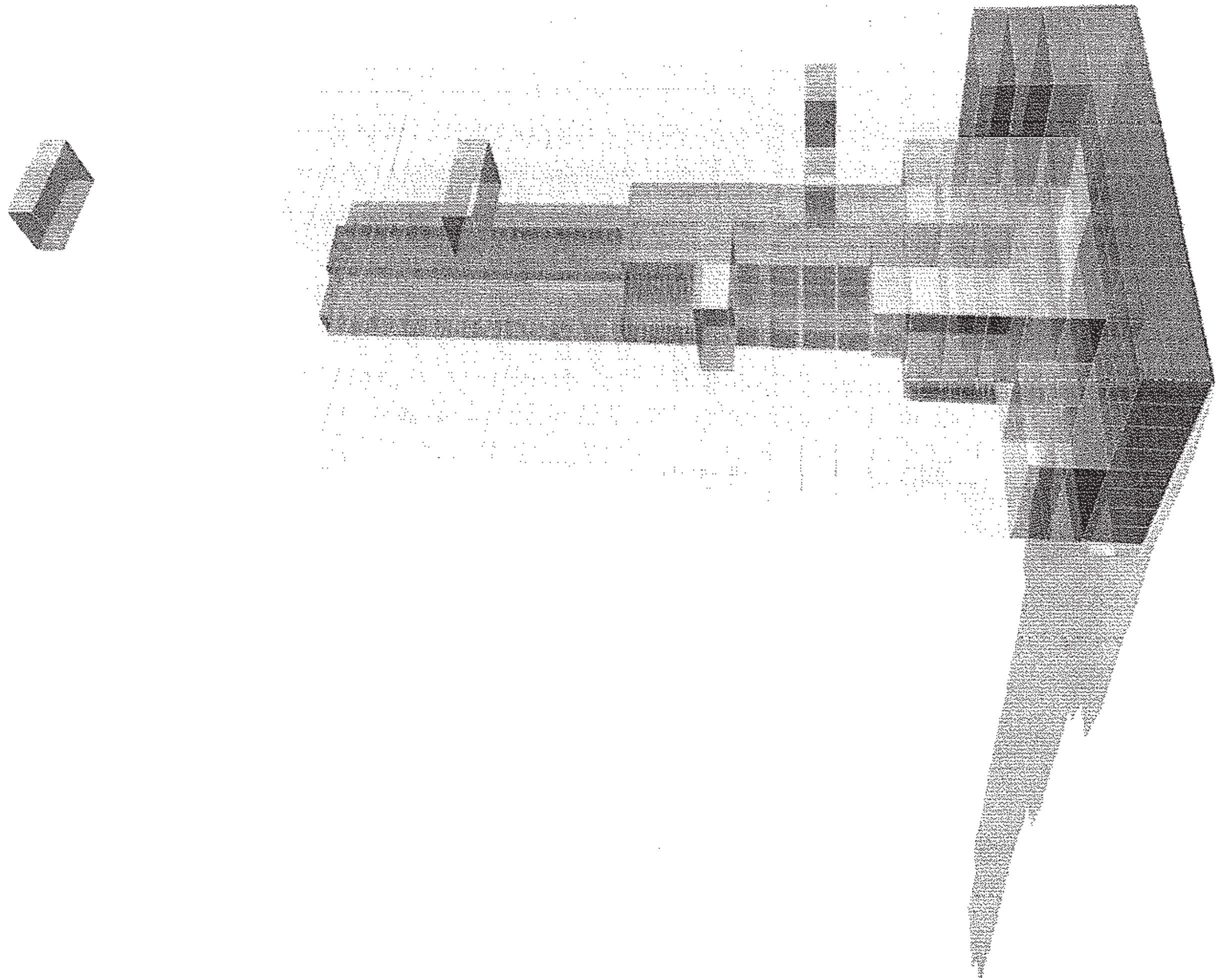

THE BEST
IS BACK!

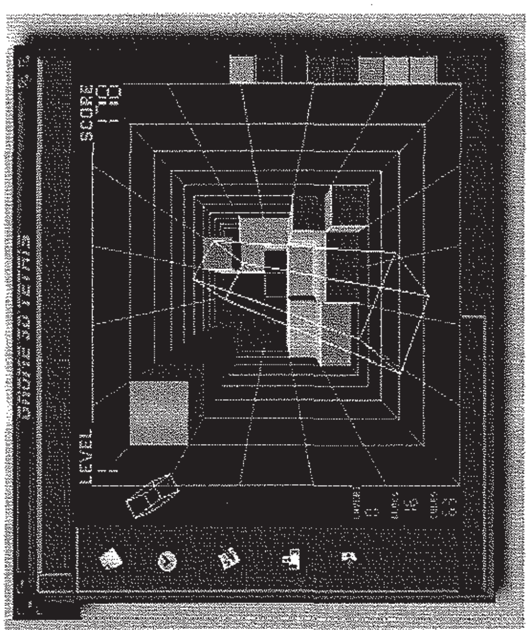


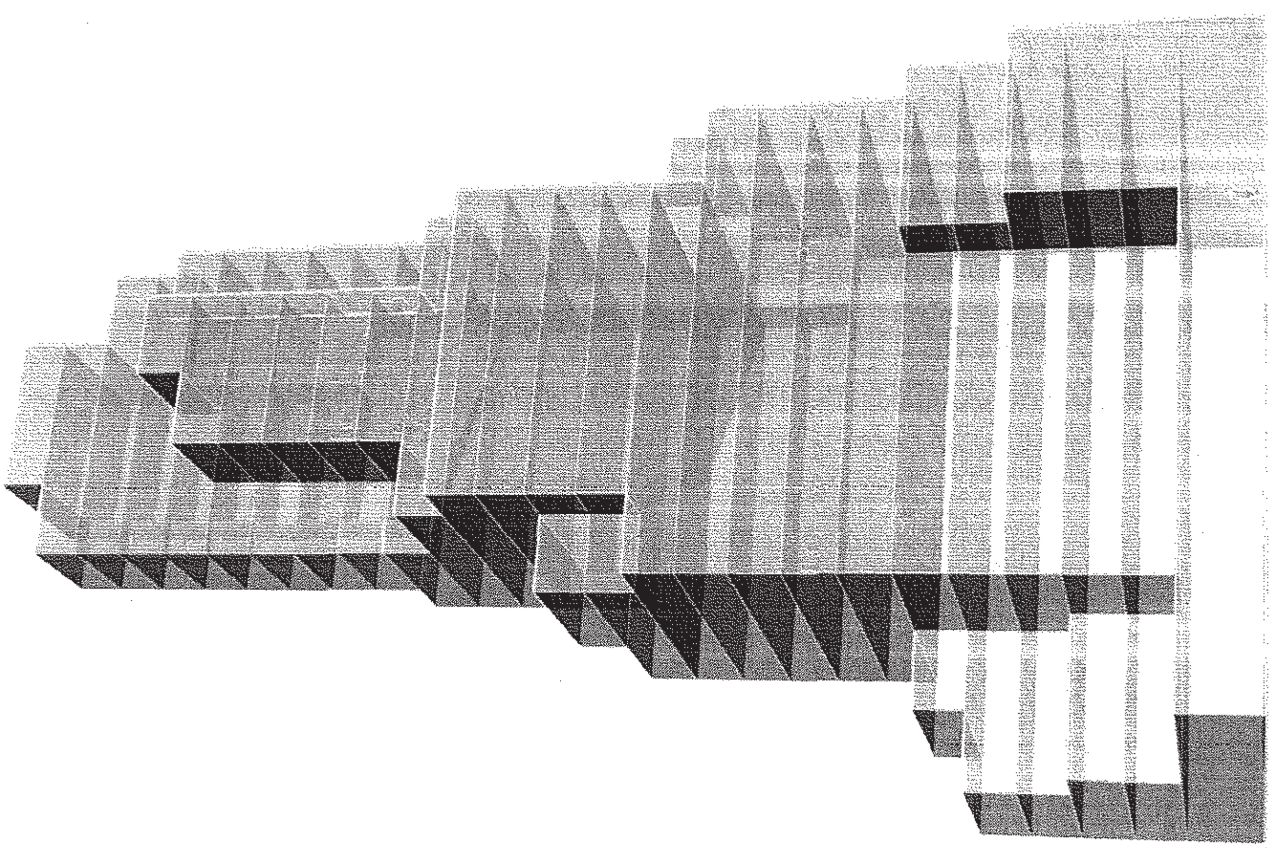


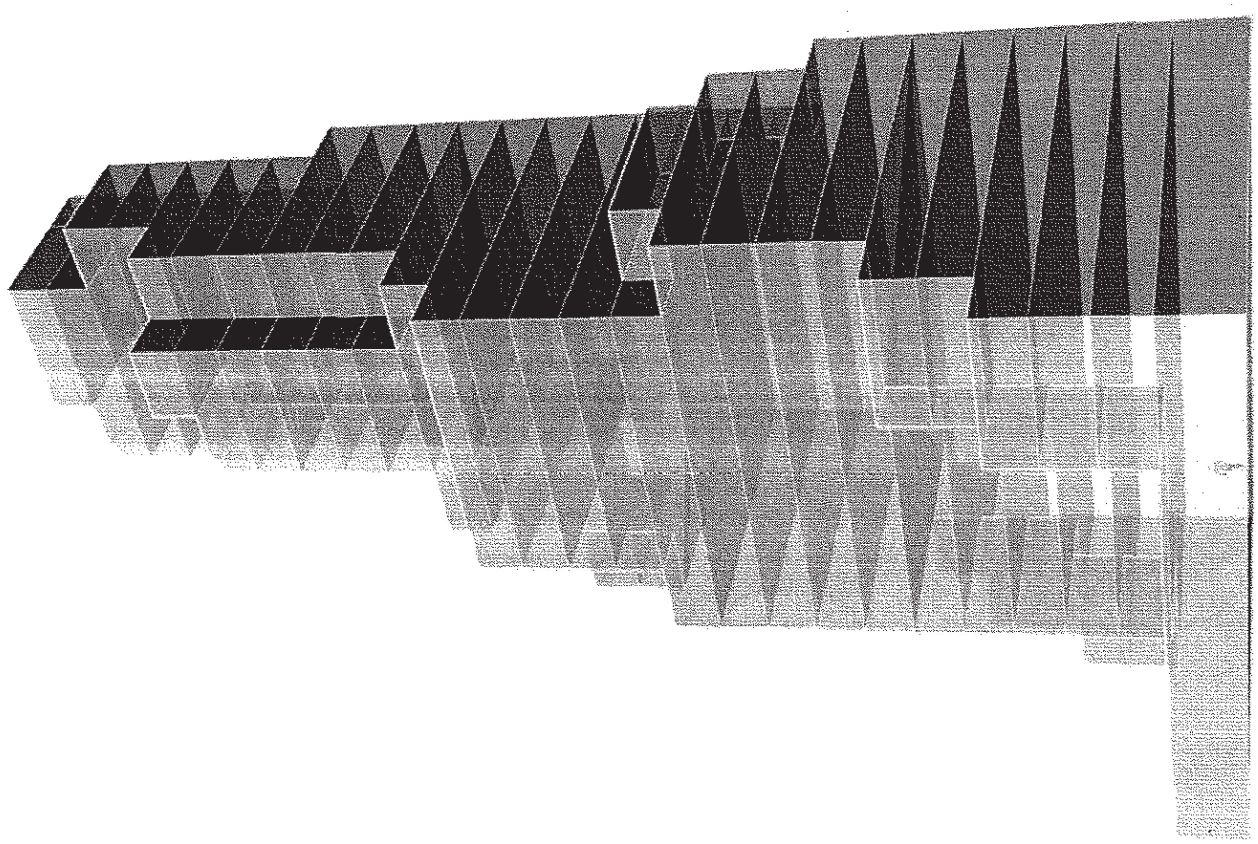







SCORE
LEVEL





From: Lam, Roger SG:EX
Sent: Thursday, February 12, 2009 10:31 AM
To: Rotgans, Trudy SG:EX
Subject: FW: Letter Regarding Recommended Building Code Changes - From Grant Newfield
Attachments: VAN.100419.0001 - GN - 08Dec22 - Ltr re Proposed B. Code Changes.pdf

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From: Anneliese Burns [mailto:aburns@rjc.ca]
Sent: Tuesday, December 23, 2008 10:20 AM
To: Rotgans, Trudy HSD:EX; Building and Safety Policy Branch FOR:EX; Vasey, Jeff HSD:EX; Kuan, Steven Y HSD:EX; Lam, Roger HSD:EX
Cc: Grant Newfield
Subject: Letter Regarding Recommended Building Code Changes - From Grant Newfield

Dear Madam and Sirs,

Please find attached the letter of Concerns Regarding the Recommended Building Code Changes from Grant Newfield of Read Jones Christoffersen LTD. Please do not hesitate to contact Grant should you have any questions.

Happy Holidays!

Anneliese Burns
Senior Administrative Assistant

Read Jones Christoffersen Ltd.
Innovative thinking. Practical results.
Suite 300, 1285 West Broadway
Vancouver, BC
Canada V6H 3X8
Office: (604) 738-0048
Fax: (604) 738-1107
Email: aburns@rjc.ca
http://www.rjc.ca/

Read Jones Christoffersen
Consulting Engineers

Suite 300
1285 West Broadway
Vancouver, BC V6H 3X8
Canada

604 738-0048
Fax 604 738-1107
www.rjc.ca

December 23, 2008

Ministry of Housing and Social Development
PO Box 9844, Stn Prov Govt
Victoria, BC V8W 9T2

Attention: Trudy Rotgans, MAIBC — *via email: Trudy.Rotgans@gov.bc.ca*
Manager, Building & Safety Policy Branch
Office of Housing and Construction Standards

Steven Kuan, Ph.D., P.Eng — *via email: Steven.Kuan@gov.bc.ca*
Senior Seismic Engineer
Building & Safety Policy Branch

Dear Ms. Rotgan and Mr. Kuan:

RE: Concerns Regarding the Recommended Building Code Changes
For 5 and 6 story wood frame buildings — RJC No.: VAN.100419.0001

The following letter is to outline concerns we have regarding the proposed Building Code Changes to permit 5- and 6-story wood frame buildings of residential occupancy based on the latest online public consultation.

As per our discussions, we proposed code changes in our Phase 2 report that would help to address some of the process risks associated with the structural design and construction of wood frame buildings with the hope that these recommendations would set ground work for all large and complex wood frame buildings. As noted in our discussions, it is our opinion, as well as the opinion of the Structural Engineers Association of BC (SEABC), that the status quo for the design and construction of wood frame buildings can lead to a great variability in safety when comparing different projects designed and constructed by different parties. In other words, there are concerns that inadequate design, detailing, or construction practices may already be leading to buildings that do not provide the minimum acceptable level of structural safety. There are many process risks which result in this variability. As such, we proposed certain code clauses in our Phase 2 report to try and provide some uniformity and enforcement within the industry. These included referencing a "best practices guide" which would ultimately deal with many of the process risks as well as additional reviews and a higher professional designation for those partaking in the design of 5- and 6-story buildings.

Furthermore, we note that the Canadian Wood Council (CWC) is driving an initiative to increase the proposed height from four to possibly eight stories. The CWC has many industry players involved in this process and will work on this initiative over the next several years. They noted that the 2010 NBC will be too soon for them to make any proposed changes, which will likely push the time they have to work on this initiative. Furthermore, we note that the BC Government's initiative has taken place over a relatively short duration, as we only started work on this in September.

In order to ensure that many of the process risks are dealt with, we are of the strong opinion that the government needs to consider the appropriate steps to minimize any potential impact to safety by reviewing the process risks and identifying how they can minimize their impact. They should also seek to support the industry in producing a "best practice guidelines" and ensure that the timing is such that the release of the code does not precede a best practice guideline being available. Our concern is that the current process risks that may exist for current wood frame projects will increase exponentially when going to 5- and 6-story projects.

As the BCBC proposed revisions to allow 5- and 6-story wood frame projects are a departure from the current 4-story limit, we urge you to strongly consider temporary provisions within the code that go above and beyond standard practice to ensure a uniform level of safety. From the study I am performing for FP Innovations (Ultimately Building Safety Policy Branch), I am of the opinion that the current standard of practice with respect to lateral design may also lead to safety concerns for 5- and 6-story buildings.

With regards to the practice for lateral design of wood frame projects, we not that their were significant changes in 1993 as a result of a SECBC document. However, since this time, there has been little development with respect to the design methodology within BC. We do note however, that the design approach, level of detail and level of enforcement has evolved considerably in many jurisdictions of the United States and has substantially surpassed the standard of practice here in British Columbia.

Based on the above I would suggest that as an interim measurement, you consider referencing any potential "best practices guide" in the code or at least in the appendix, as well as requiring third party drawing and field reviews at least for this round of code changes. Also, please closely review the comments to your public poll provided by SEABC (David Harvey) and our phases 2 report in consideration your final changes.

I will be available to discuss any questions you may have; please contact me regarding this letter.

Yours truly,
Read Jones Christoffersen Ltd.

Grant Newfield, M.Eng., P.Eng., Struct. Eng.
Principal

GN/ab/lp

cc: Roger Lam, Executive Director, BPB - Building and Safety Policy Branch - Roger.Lam@gov.bc.ca
Jeff Vasey, Senior Policy Analyst, Office of Housing and Construction Standards - Jeff.Vasey@gov.bc.ca

Non-Responsive

From: Tony Gioventu [mailto:tony@choa.bc.ca]
Sent: Monday, February 9, 2009 12:05 PM
To: Vasey, Jeff HSD:EX
Cc: XT:Cameron, Ken CASe:IN; Page, Doug HSD:EX
Subject: 6 floor wood frame

Dear Jeff:

I want to bring a chronic problem to your attention that is likely going to impact 6 floor wood frame structures, especially if they are mixed residential commercial.

The recent heavy weather season has put the 2nd floor of the 4 floor structures to a significant test and we are now following 6 buildings where there is waterproofing and drainage problems associated with the 2nd floor. The anomaly is unique to 4 floor wood frame buildings that are mixed commercial and residential where the ground floor and parking garage are concrete structures and the 2nd 3rd and 4th floors are wood frame mounted on the concrete. The 2nd floor, being the ground floor of the residential has an unusual configuration in that the wood frame structures are often a smaller footprint, leaving very large patios on the 2nd floor. The waterproofing membranes between the concrete, the concrete curbs and the wood frame access are being compromised resulting in water ingress in to the ground floor units. There are 2 specific buildings in Vancouver undergoing engineering reviews which we are closely following. One at the south east corner of Bayswater and 4th in Kitsilano and the other is the southeast corner of Cardero and Davie in the West End.

It is difficult to estimate the number of building constructed in the similar fashion but we have identified 21 through our membership in Vancouver alone. Eight of those are currently encountering water proofing issues.
They vary from lack of drainage, to failed membranes, to reduced curb walls to accommodate access doors and penetrations for services such as external services.

Obviously with 6 floor wood frame there is a high likely hood of the same type of construction, and with the additional weight and envelope management factors we could see a potential increase in claims if there are not minimum standards to address the issue of water proofing.

Tony Gioventu, Executive Director
Condominium Home Owners' Association (CHOA)
website: www.choa.bc.ca
604-584-2462 ext.1
****

Jensen, Jun'ichi MEM:EX

From: Peter Moonen [pmoonen@wood-works.ca]
Sent: Thursday, February 5, 2009 4:06 PM
To: msmitton@fpoa.bc.ca; s.22
Cc: s.22 Rotgans, Trudy SG:EX
Subject: Six-storey presentation

Mark,

s.22 suggested I contact you.

As you are aware, the government is planning to implement building code changes which would allow certain building types to be up to 6-storeys high.

Wood *WORKS! B.C.* and the Canadian Wood Council are hosting a Wood SOlutions Fair on March 18th in Vancouver in which there is a panel discussion about some of the technical, economic, code and environmental issues of these buildings. One of the presenters, Andrew Waugh from London England, has designed a nine-storey solid wood wall structure and has made himself available for post WSF meetings. As well, Trudy Rotgans from the Building Safety and Policy Branch is available.

We'd like to offer some fire protection officers a chance to perhaps discuss some of the issues facing these building types and perhaps get an insight into the code changes and what is happening. Moreover, it may be a really good chance for your members to air some of their concerns and make sure they are being addressed.

I will try and contact you, but if IU do not, could you please call me at your convenience to discuss if there is any interest in doing this?

Thanks.

Peter Moonen
Leader, Sustainable Building Coalition,
Sustainability and Special Projects Coordinator,
Wood *WORKS!* B.C. / Canadian Wood Council
2312 Lower Road
Roberts Creek, B.C. V0N 2W6
Canada Toll-free: 1.877.929.9663, ext. 5
Ph: 604.886.0033
Fax 604.886.6878
pmoonen@wood-works.ca

Jensen, Jun'ichi MEM:EX

From: Michael Ernest [MErnest@aibc.ca]
Sent: Thursday, January 29, 2009 10:36 AM
To: s.22 albert leung; andrew vizer; brian bydwell; chris@caa-architecture.com; duanesiegrist@integra-arch.com; s.22 mernest@aibc.ca; MHickman@omicronaec.com; peter toneguzzo; s.22 tl@ghl.ca; Rotgans, Trudy SG:EX; Yijin Wen (Yijin.Wen@fraserhealth.ca)
Cc: Erica Holt
Subject: FW: 6-storey wood-frame buildings

Dear Colleagues:

Further to yesterday's RCC session, below please find my note to Diane Archibald, our Director of Professional Development.

Cheers;

Mike

From: Michael Ernest
Sent: January 28, 2009 5:48 PM
To: Diane Archibald
Subject: 6-storey wood-frame buildings

Hi, Diane:

Further to today's Regulatory Coordination Committee meeting and related events, earlier conversations, correspondence et al ... inquiring minds are keen to learn what plans are afoot for our members' Professional Development in this topic area ... especially with the newly implemented code revisions to enable 6-storey wood-frame building having been brought into being on 15 January and with their being in effect as of the second week in April.

Kindly advise what sessions are being planned, if not committed for delivery, in the time period prior to April's implementation date; during the annual conference; and perhaps beyond.

That would be most informative and helpful.

Cheers;

Mike

From: s.22
Sent: Wednesday, January 21, 2009 8:08 PM
To: Rotgans, Trudy SG:EX
Subject: Growing High Quality Wood
Attachments: Jozsa Stand Development Comparison.jpeg

Hi Trudy:

I enjoyed your presentation today on the Six Story Initiative at the UDI luncheon in Victoria.

To follow up our conversation I have attached a figure provided by Les Josza, formerly of Forintek, the illustrates the relationship between stocking (trees/ha) and wood quality (all three trees in this figure have the same age).

Open grown trees have 100 % green crown, trees in low stocking stands (700 trees/ha) have 50 % live crown, and trees growing in dense stands (2,000 plus trees/ha, has 35 percent live crown). Wood quality varies significantly with the degree of stocking.

The widest annual growth ring in a tree have green branches growing adjacent to it. In open grown trees, the green crown extends the full height of the tree (like the redwood on the legislature grounds). Wood quality is low, because of wide annual rings, big green knots, high taper and high percentage of juvenile wood.

To grow high quality wood (high ring count, dense, low taper, low percentage of juvenile wood, small tight green knots or no knots etc), trees in stands with high stocking (2000 stems/ha) grow the highest quality wood. This silvicultural regime is practiced widely in Sweden's pine and spruce stands.

Stocking standards in BC forest plantations are commonly between about 700 and 1000/ stems hectare.

The following website records a conversation with Les Jozsa, on this topic.

http://www.forrex.org/JEM/ISS27/vol6_no1_art7.pdf

Best wishes, s.22

Non-Responsive

From: George Frater [mailto:gfrater@cisc-icca.ca]
Sent: Wednesday, November 19, 2008 3:55 PM
To: Nicol, John HSD:EX
Subject: RE: Six Storey Wood Buildings Project

Hello John

As per my telephone message I'd follow up by email. I'd like to report to others in the steel industry and I'd like to know more about the process being used to make these code changes, i.e., I understand there was 7 TAG meetings. Is it possible to know more about these, i.e., attendees (20 to 40 was mentioned last week as far as numbers) , makeup of group (stakeholder types?), meeting duration, selection of attendees, etc. The four files below in your previous email, three of which only indicate a date for meeting, so I'm missing three other meetings and relevant details on where the input was coming from. If this information is in the public domain it would be of interest to know.

It would be good for me to know the name given to this type of code change process coming as a directive from the Government (premier and housing minister both? or just housing minister?) I.e., is it somewhat different from the process used to include the new BC building code part for energy efficiency introduced this September which probably followed more traditional methods to follow through with BC code amendments?

Anyways, just trying to get more detail on this process as I report back to others, as I inform them about the ongoing public review period now in effect.

Thank you for your consideration to this request, and I just saw your recent email listing the seven TAG subject category, however if more details possible, in regards to attendees, stakeholder groups represented, etc. - that would be of interest, and next week would be OK for me if possible.

Regards for now,

George S. Frater, Ph.D., P.Eng.
Codes & Standards Engineer
Canadian Steel Construction Council

****** NEW, starting July 14, 2008 ******
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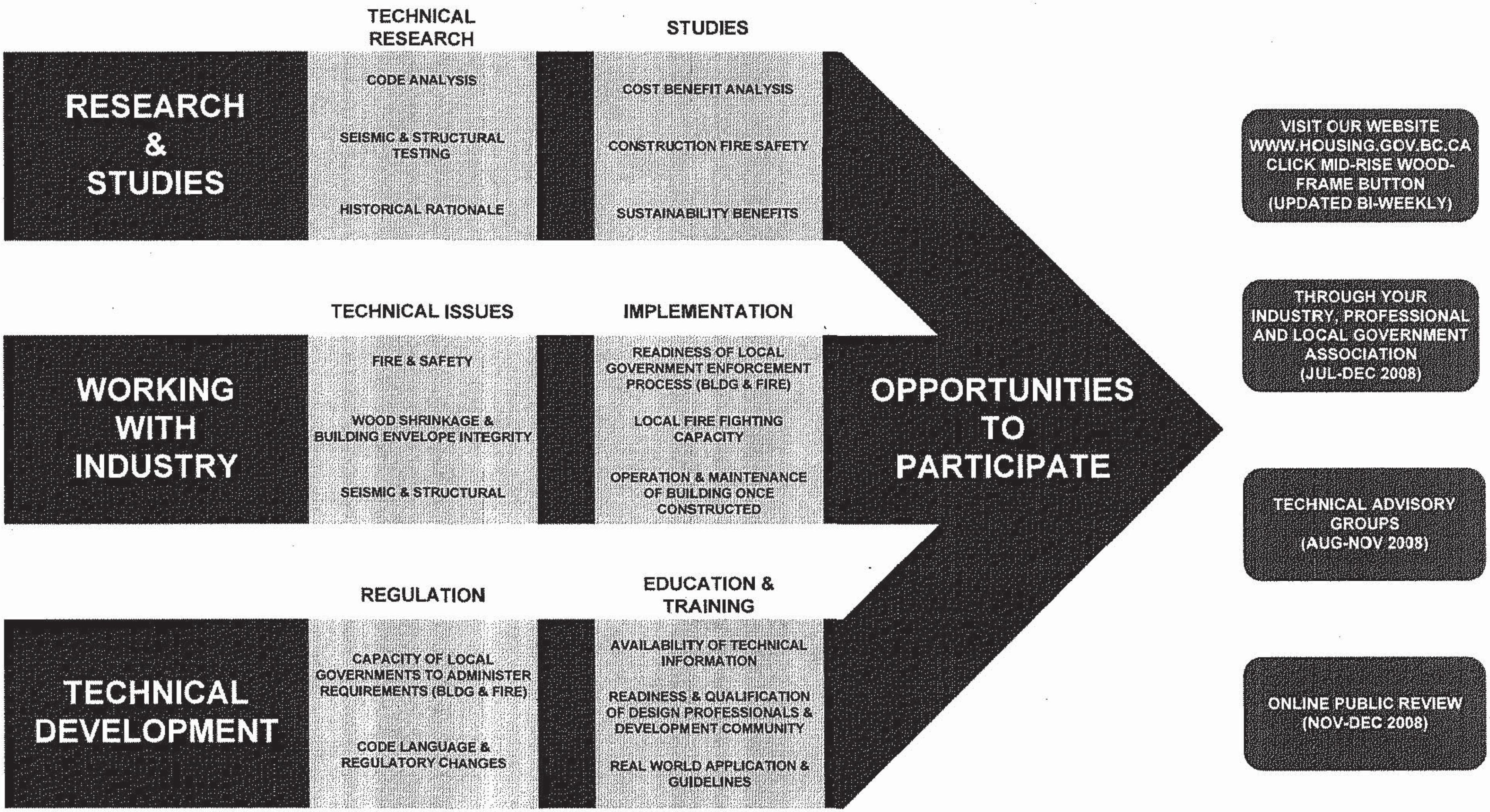
Non-Responsive

ALLOWING 6 STOREY WOOD-FRAMED RESIDENTIAL CONSTRUCTION

CHANGES TO THE BRITISH COLUMBIA BUILDING CODE



Ministry of Housing and Social Development
Building and Safety Policy Branch
Office of Housing and
Construction Standards

Tel: (250) 356-9011
Email: Building.Safety@gov.bc.ca

Prepared for September 17th, 2008
Multi-Stakeholder Meeting
Vancouver, BC

Non-Responsive

From: Emmanuel Domingo [mailto:edomingo@lmdg.com]
Sent: Thursday, January 22, 2009 10:42 AM
To: Nicol, John HSD:EX
Subject: RE: New Mid-Rise Wood Building Code Provisions Announced

Hi John,
There seems to be an error in the code change (new Sentence 3.2.2.45.(3)). See attached.
Regards,
Emmanuel A. Domingo, P.Eng.
LMDG Building Code Consultants Ltd.
T. 604.682.7146 F. 604.682.7149
E. edomingo@LMDG.com

Non-Responsive

s.22

s.22

Non-Responsive

From: Herbert Kwan [mailto:hkwan@hkwanarchitect.com]
Sent: Wednesday, December 17, 2008 10:27 AM
To: Building and Safety Policy Branch FOR:EX
Subject: Code changes to mid rise buildings

Please advise when the wood frame mid rise code changes will take effect.

Thanks

Herbert Kwan, MAIBC

Non-Responsive

From: Mary Tracey [mailto:mtracey@wood-works.ca]
Sent: Monday, September 15, 2008 11:27 AM
To: cchangfoot@bchousing.org
Cc: Rotgans, Trudy HSD:EX
Subject: Mid rise project in Seattle

Trudy, Craig

Attached is a short report on a mid-rise building currently under construction in Seattle. One of our staff, Sukh Johal, went to the site and talked to the designers and the builders at the site. He has copies of the plans and prepared this short report for our information.

Please distribute as you see fit.

I will also forward, in a separate email, some pictures of the project.

Mary

Mary Tracey
Wood *WORKS!* BC Executive Director

Canadian Wood Council
877 929 9663
www.wood-works.ca