EGRT CONSTRUCTION

EVERGREEN LINE RAPID TRANSIT PROJECT

SPAN S1-55 INCIDENT INVESTIGATION REPORT

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EGRT Construction

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Table of Contents

1.0 SUMMARY OF EVENTS

At approximately 01:00 on Friday March 14, 2014 Span 1-55 of the elevated Guideway spanning pier P1-55 to pier P1-56 shifted laterally and dropped off its temporary supports, settling on the top of pier 56 and on one temporary support on pier 55. There were no injuries or property damage as a result of this incident.

Span 1-55 of the elevated Guideway spans over Como Lake Avenue at the intersection of Clarke Road in the city of Coquitlam, BC. Local residents heard what was described as a loud bang and called local emergency response when they observed that the Guideway beam had moved. Local police closed the roads in the immediate area. Upon being contacted by the police, the EGRT team initiated their Incident Control Systems (ICS) and emergency response protocols. The control of the immediate incident area and traffic control were quickly transferred from the emergency responders to the project ICS Team. An engineering assessment was conducted by the EGRT team and determined that while the Guideway section had shifted it was stable and well supported by the piers. The decision was made to open Clarke Road to traffic but to keep Como Lake Avenue closed until further analysis could be conducted.

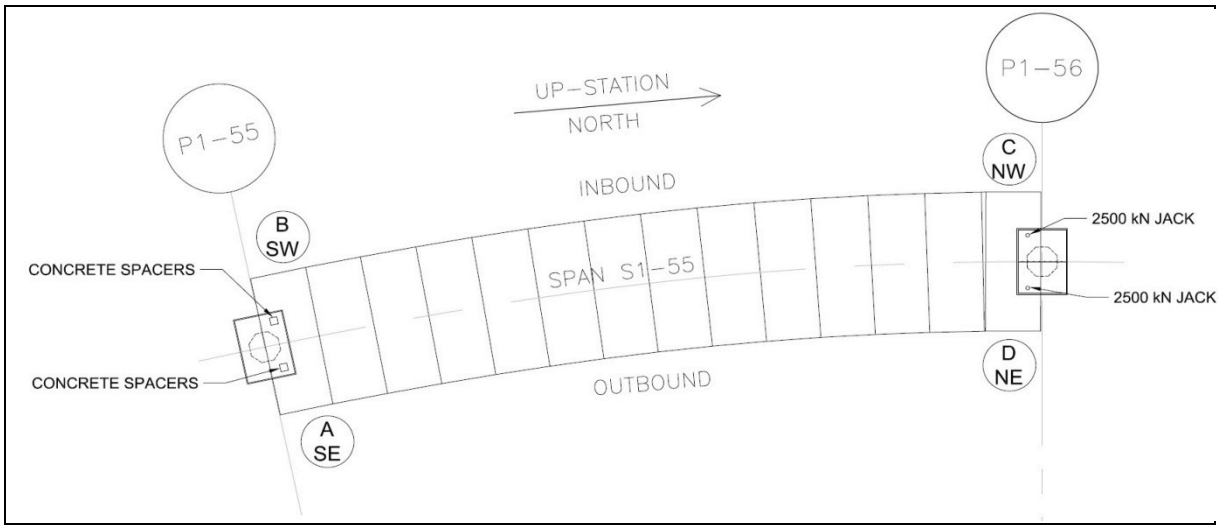
Como Lake Avenue remained closed until Sunday afternoon. During this time, the displaced position of span S1-55 was further evaluated with the Engineer of Record and the Construction Engineer and confirmed to be stable and self-supporting. Several root cause failure scenarios were considered and analyzed and temporary works were identified to further ensure the stability of the span. In addition to the extra vertical supports that were installed immediately following the incident, two lateral restraints were designed and installed on the piers locking in each end of span S1-55 from further movement. Following the installation of the lateral restraints, Como Lake Avenue was re-opened to public traffic at 15:00 on Sunday March 16, 2014.

In the following days, the beam was surveyed and reviewed by the Engineer of Record and confirmed that there was no structural damage to any of the permanent works.

A plan to reinstate the beam to its design location has been developed in conjunction with the Engineer of Record and the Construction Engineer. In simple terms, the plan is to bring the beam to a level horizontal position at piers 55 and 56, then shift it laterally to its design centreline, raise the beam in a level position to its “low” side elevation, then finally raise the west side of the beam to its design cross-fall. All work will be done with hydraulic jacks applied at the pier segments bearings. Work is expected to take place starting April 12, 2014 It is anticipated to close Como Lake Avenue for the first phase only, i.e., while the beam is brought from its current position to level.

2.0 SPAN S1-55 ARRANGEMENT

Span 1-55 is located between piers 1-55 and 1-56 and is a "middle" span of what will ultimately be a four span continuous structure. At the time of the incident it was a simple span supported on four temporary supports (two supports at each pier). For the purposes of this report, North is identified as the direction of the "Up-Station" on the following figure.



Span 1-55 is 42 metres in length, consisting of 14 precast concrete segments, with a total weight of 370 tonnes. The geometry of the beam is in a horizontal curve with a minimum radius of 162 metres at the approximate centre of beam. At pier 56 there is a maximum cross-fall of 6.5% combined with a longitudinal grade of 3.8%. At pier 55 the cross-fall is 4.5% and the longitudinal grade is less than 1.0%.

Because this is part of a four span continuous structure, it has a non-standard bearing arrangement at the piers. There are no upstands cast into the top of the pier cap and no downstands cast into the bottom of the pier segments resulting in a wedge shaped gap between the beam and the pier top. The concrete bearing plinths will be cast in place after completion of the four span continuous structure.

3.0 CONDITIONS PRIOR TO AND AFTER THE INCIDENT

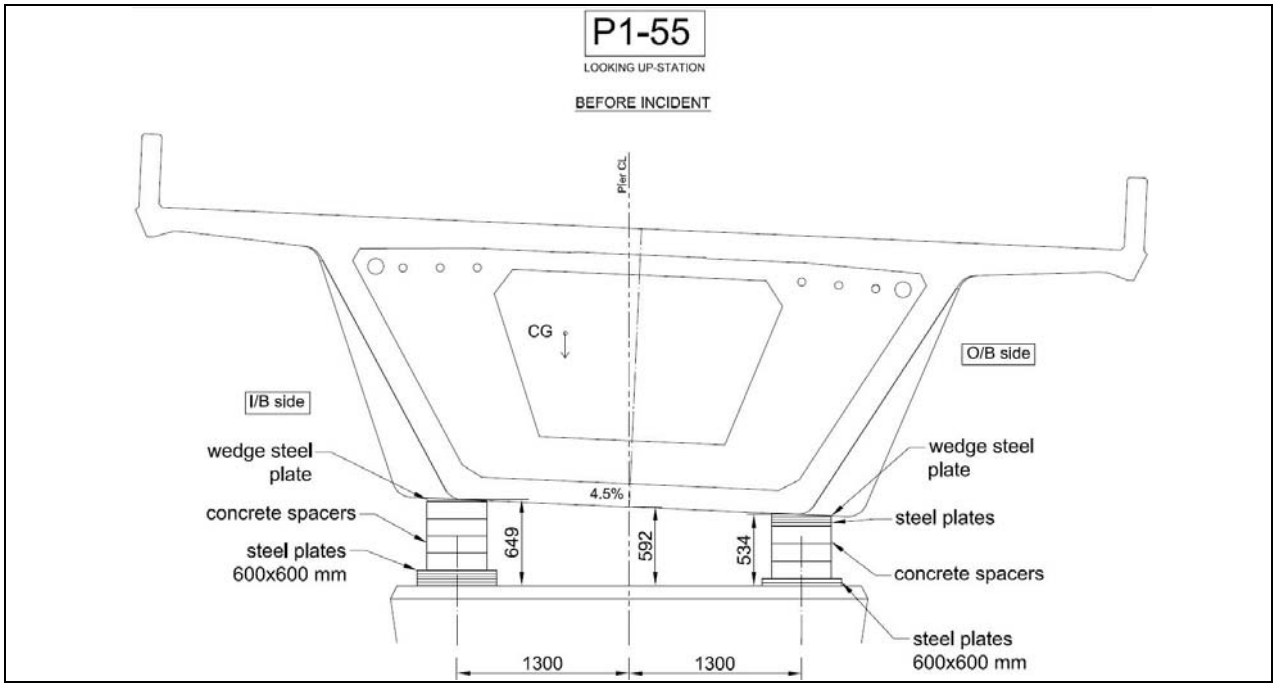
- Span 55 had been erected, segments epoxied together and the four bottom (positive moment) post-tensioning tendons had been fully stressed for this stage by Feb 12, 2014. At this point, span 55 was a self-supporting (dead load + live load of launching truss) simple span sitting on temporary supports.
- The south end of span 55 (pier 55) was on two “fixed” temporary supports consisting of solid steel shims plates on the pier cap concrete, steel C-channel framed boxes with a concrete infill (the “concrete spacers”), and solid steel tapered wedge plates at the underside of the pier segments to accommodate the cross-fall slope. Between the concrete spacers, thin layers of particle board were used to even out the contact surfaces between the concrete spacers.
- The north end of span 55 (pier 56) was on two “sliding” supports each consisting of solid steel shim plates on the pier cap concrete, a steel slider plate with Teflon pads/lithium grease, a 250 ton hydraulic jack with a tilt saddle (to take up the cross-fall and longitudinal slope), and solid steel flat plates at the underside of the pier segments.
- Orientation of the horizontal slider plates. The northwest support (location C in the above figure) had the stop blocks positioned on the uphill (longitudinal) and upslope (lateral) sides. The northeast support (location D in the above figure) had the stop blocks positioned on the uphill (longitudinal) and downslope (lateral) sides.
- The beam had been stable in this configuration for almost one month.

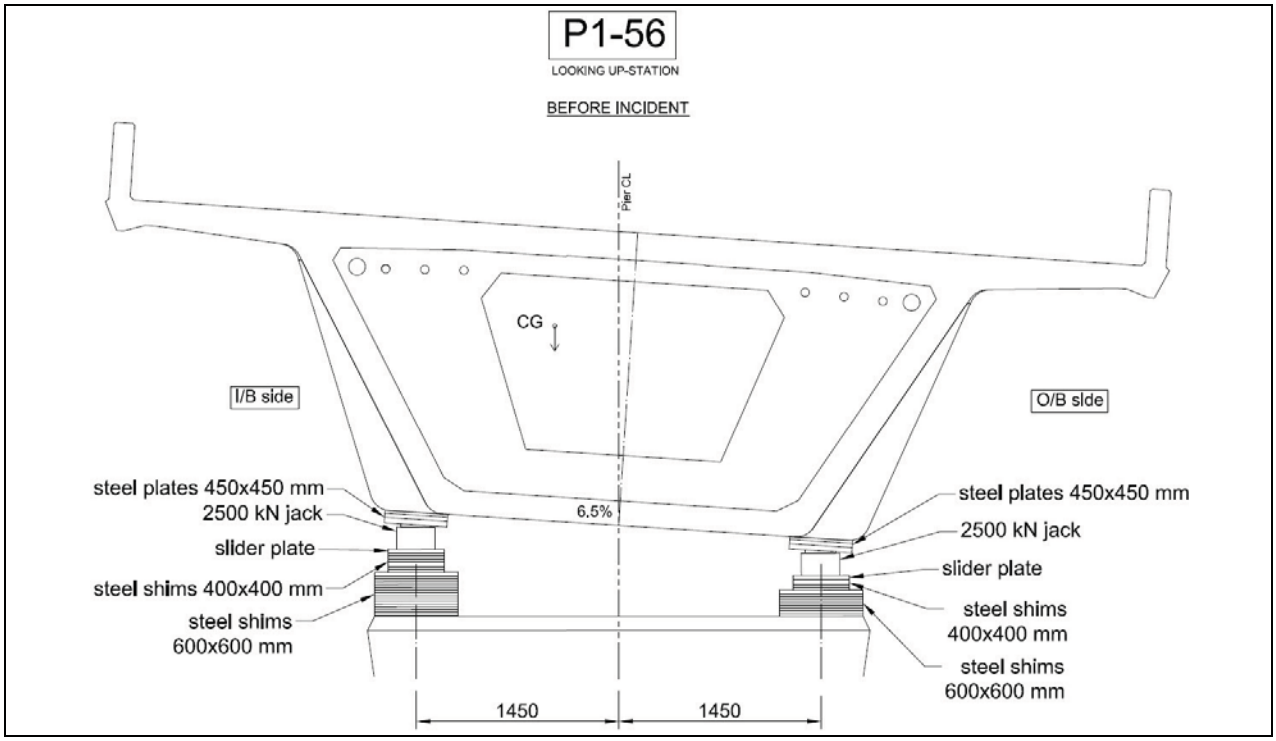
3.1 Conditions immediately prior (+/- 24 hours) to the incident:

There had been some recent cast-in-place concrete works on the top of Pier 56 and the pier top was hoarded in with an insulated tarp and was being heated to promote concrete curing There was a fairly heavy rain storm on the night and early morning of the incident.

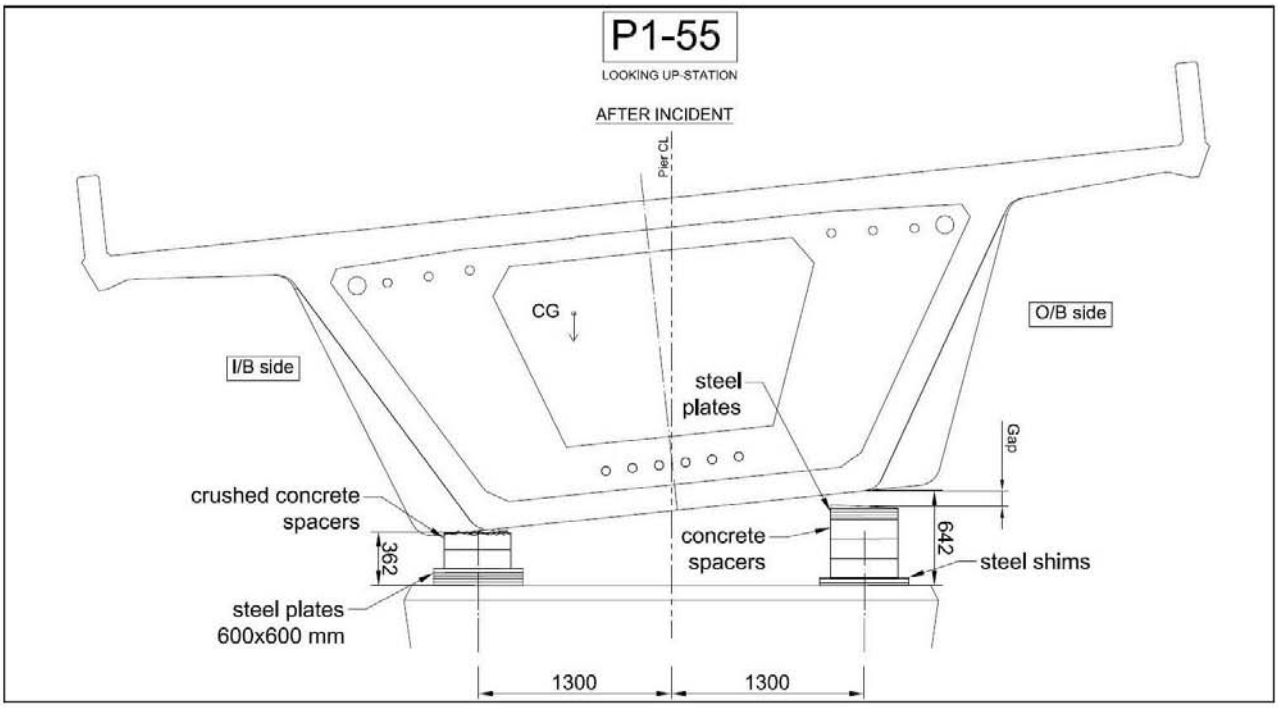
Refer to the following sketches for the configuration of the beam and supports before and after the incident.

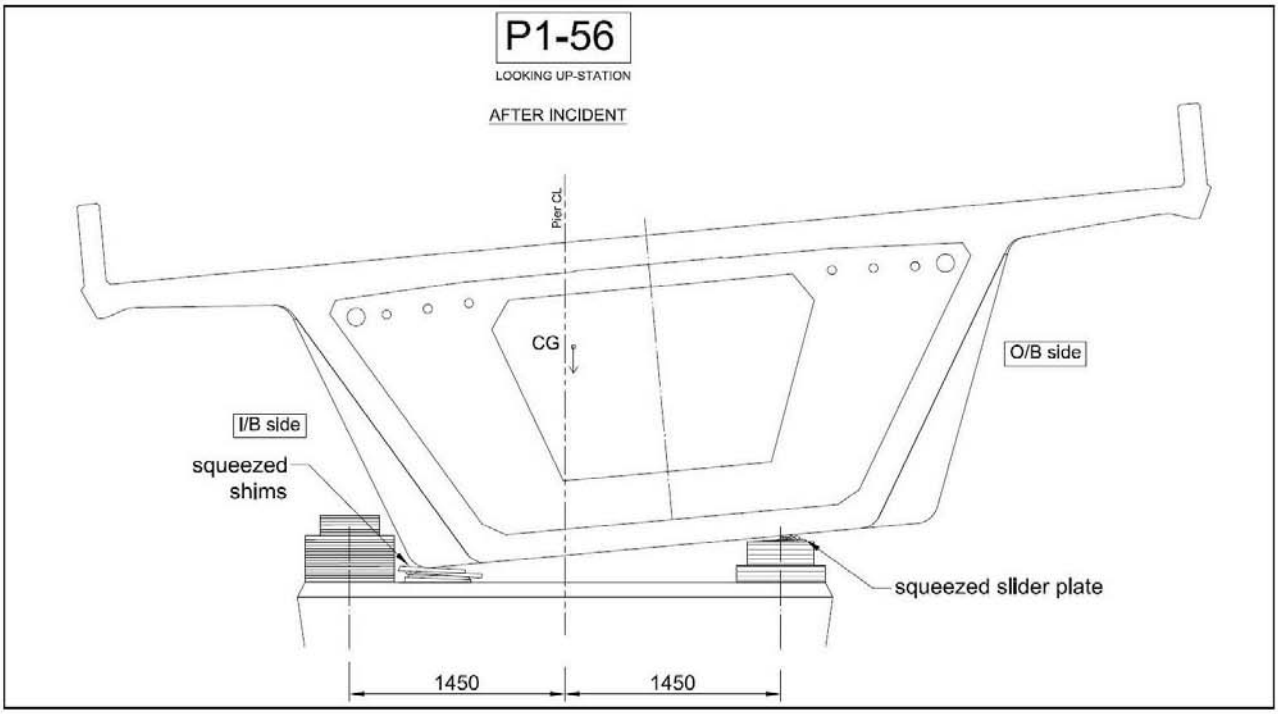
3.2 Before the incident, the supports at Pier P1-55 and P1-56 were as shown below:





3.3 After the incident, the supports at Pier P1-55 and P1-56 were as shown below:





4.0 CAUSE AND CONTRIBUTING FACTORS

4.1 Failure Scenarios

There are two feasible failure scenarios for this incident that were investigated.

1. The concrete spacer on pier 55 failed first resulting in the lateral movement and drop at pier 56.
2. The lateral movement occurred at pier 56 first causing a redistribution of loads at pier 56 crushing the concrete spacer.

The most likely failure mechanism is scenario two where the lateral movement occurred first at pier 56. At the time of the incident, insufficient lateral restraint at the north pier allowed the north end of span 55 to slide eastwards, displacing the hydraulic jacks, and dropping off the supports. The resulting rotation of the beam caused a upward and then downward motion of the south west corner of the beam, failing two concrete spacers at the southwest support (location B).

The triggering event for the movement at the north end is attributed to a reduction in the friction between the hydraulic jacks and the Teflon pad / lithium grease that the jacks sit on. This reduction of friction occurred while the top of the pier cap was being heated to promote curing for a concrete pour at this location. The higher heat at the pier top reduced the coefficient of friction of the lithium grease which reduced the restraining friction force allowing the beam to move. Once the beam began to move, it overcame the lateral restraints that were in place at the jack stop blocks.

Immediately following the incident, both failure scenarios were analyzed and temporary works were identified to ensure the stability of the span regardless of the root cause. Additional hydraulic jacks were installed around the temporary supports to provide redundant vertical support. Prior to re-opening Como Lake Avenue, and in preparation for the re-instatement works, two lateral restraints were designed and installed on the piers locking in each end of span S1-55 against any horizontal movement.

5.0 RECOMMENDATIONS TO PREVENT A RECURRENCE

Regardless of the failure scenario, the following corrective actions will be implemented to prevent a recurrence of such an incident.

- In addition to the standard erection plans for typical spans, site specific temporary support plans shall be designed at all non-typical locations and areas of high grades and cross-slopes, identifying shimming materials and configuration, use of wedge plates, hydraulic jacks and provisions for additional lateral restraints if required,.

- The site erection engineer shall review all temporary support set-ups and confirm they meet the design.