Improving Roadway Safety and Rider Comfort by Implementing Various Design and Construction Solutions – South Fraser Perimeter Road Experience

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1. Introduction

The South Fraser Perimeter Road (SFPR) is an approximately 40 kilometer long, four-lane roadway located in the Greater Vancouver Area of British Columbia. The route extends along the south side of the Fraser River from Deltaport Way in Delta to 176th Street (Highway 15) in Surrey. The SFPR provides an efficient and convenient transportation corridor, with connections to major trade gateways for commercial transportation of goods from Delta and Surrey ports and ferry terminals, as well as for tourists and commuters. The general roadway alignment is shown in Figure 1.

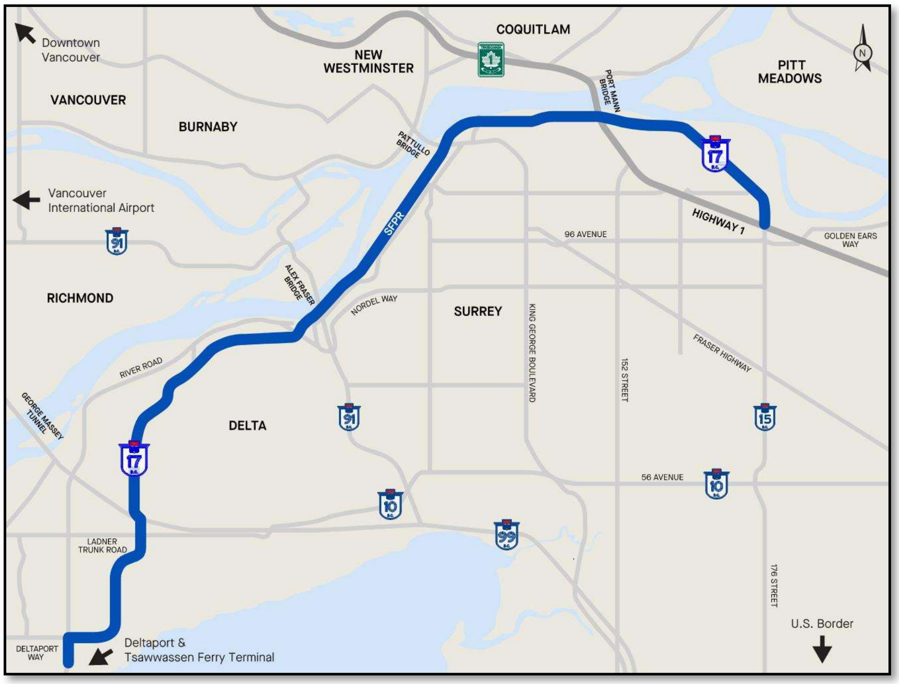

Figure 1: SFPR alignment location

The roadway was procured by the BC Ministry of Transportation and Infrastructure as a P3 using a Design Build Finance and Operate (DBFO) model. It was fully opened to traffic in December 2013 with the design/build phase being completed 6 months ahead of schedule by the Concessionaire, Fraser Transportation Group Partnership (FTG). The road is now in the 9th year of the 20-year operation and maintenance phase.

Applying remediation efforts to improve driver comfort can be challenging in different areas of the SFPR which have site-specific challenges exasperated by differential settlement issues. Through several examples, this paper discusses some of the challenges experienced through the design and implementation of the various site-specific remediation efforts to improve driver comfort and operational safety.

2. Challenges of Applying Remediation Measures

Since opening, some areas of the SFPR have experienced differential settlement issues due to the SFPR being constructed over a variety of challenging geotechnical conditions, including highly compressible soils and former landfill sites, and transitions between areas where differing levels of preload treatments had been applied. Over time in some select areas the differential settlement effects had impacted roadway design elements quite dramatically, notably deviating the vertical profile and superelevation from their as-built conditions. This raised concerns of driver comfort and, if left untreated, further differential settlement effects leading to concerns of operational speed and safety. Additionally, the settlement effects introduced concerns for numerous other aspects of the highway operation and maintenance, such as the integrity of underground utility crossings and drainage patterns.

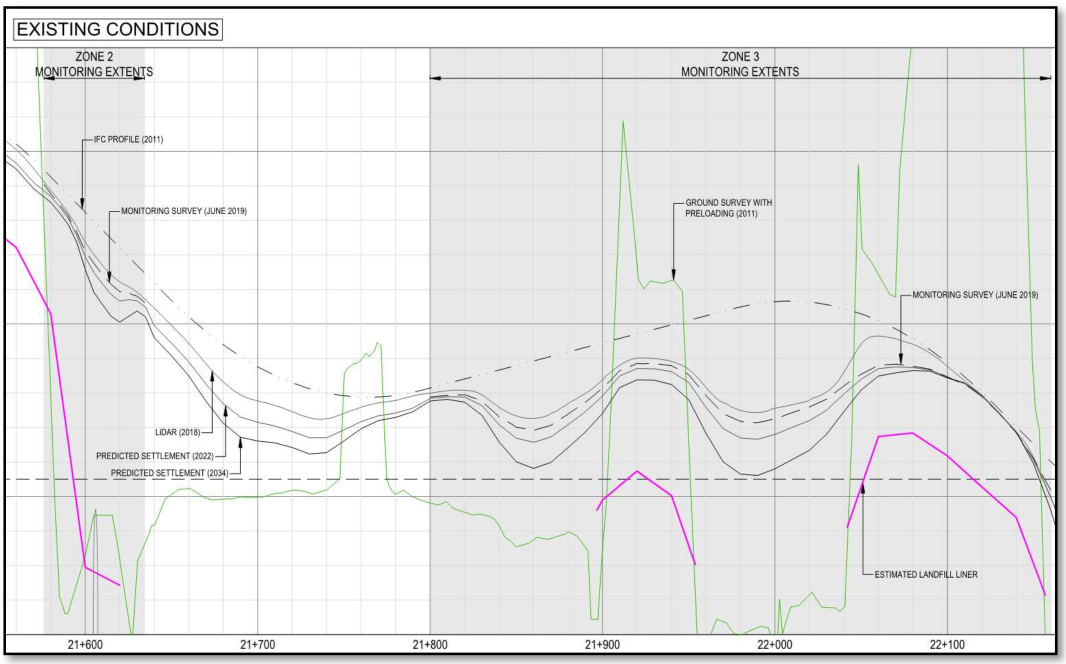

Figure 2: Example location showing change from IFC design profile (dashed line) to surveyed profiles (solid gray lines) overtime due to settlement effects.

To address the various issues caused by settlement effects, remediation efforts have been undertaken at several locations of the SFPR to address its site-specific conditions and requirements. However, implementation of these have not come without their challenges. Conventional methods of roadway reconstruction to reinstate the as-built conditions are often unsuitable, as they do not sufficiently address future settlement effects and can even exasperate ongoing settlement if not designed appropriately. To reduce future settlement effects, a net load reduction or reduction of the deadload, is often desired. As such, in addition to consideration given to the road base material, the road profile was designed to attain reduction of deadload weight on the road to mitigate the undesirable settlement effects.

The following sections showcases three selected examples of different tactics that were utilized to address settlement effects by remediating the road and improve driver comfort.

2.1 Example 1: Closed Landfill Area

Areas of former landfill sites presented its own unique set of challenges associated with balancing the requirement of net load reduction through reprofiling to mitigate future settlement effects, while adhering to limited excavation depths due to the presence of the landfill cap liner below the road base. Further complicating the matter, some areas were within a superelevation transition zone, needing to account for the additional fill or cut of the transverse plane to reinstate the superelevation. Settlement modelling showed that if conventional granular road structure were to be utilized in the reconstruction, it would result in only being able to provide a short-term improvement that would require additional intervention within the concession period, and thus was deemed uneconomical. A solution utilizing Lightweight Cellular Concrete (LCC) fill as part of the road structure was chosen as it was predicted to provide a longer-term and thus more effective solution. The LCC fill would reduce the net loading in comparison to the traditional granular road structure and therefore would mitigate future settlement effects by avoiding retriggering of the secondary settlement.

However, several constructability requirements specific to the LCC material were required to be incorporated in the design were not required for traditional granular fill. The LCC fill is a self-leveling product, and thus sections of the roadway to be reconstructed using LCC on a vertical grade required the LCC to be poured in “steps” in a terraced form with partitions made of geofabric and rebar placed between the steps to attain the desired finished road grade.

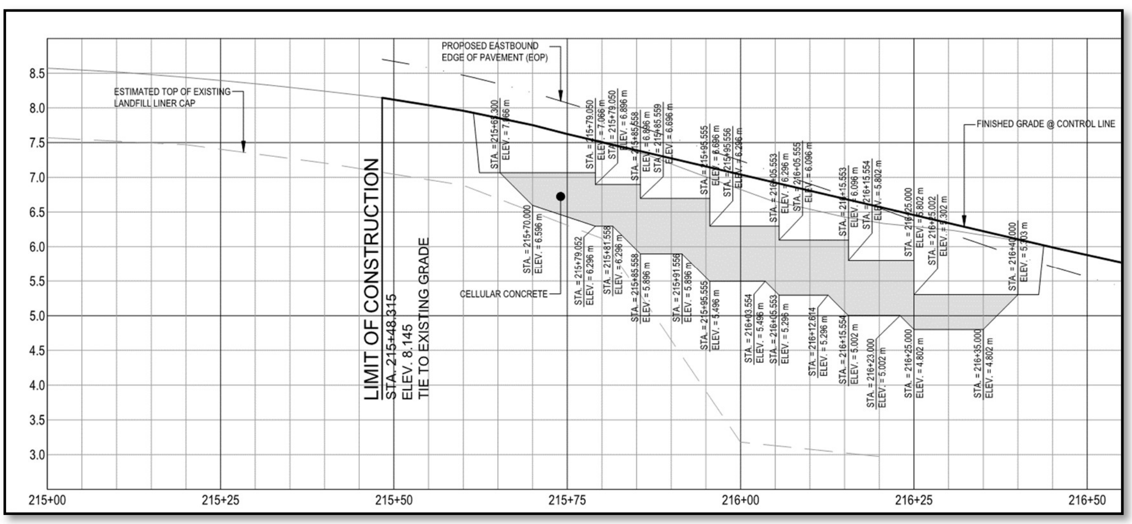

Figure 3: Profile design example showing profile of stepped/terraced Light-weight Cellular Concrete fill extents (shown as shaded hatch).

Additionally, construction of the LCC required adhering to the minimum cure time for the LCC to achieve minimum strengths required for placement of granular backfill atop of it. Typically, this was a twenty-four-hour period. Placement of the initial granular backfill material atop the LCC had to be performed in lifts and compacted using static methods. Vibratory methods were only allowed after a specified minimum cover of granular material was compacted.

The minimum granular fill thickness required above the LCC meant that the top corners of the LCC fill "steps" became the limiting factors for the required minimum fill/cover. This minimum cover needed to be attained whilst constrained by a maximum excavation depth to avoid breaching the existing landfill liner, all while meeting the objective of reducing the net loading.

As of this writing, the initial six-month post-construction monitoring data have been analyzed and shows the reconstructed portion of the roadway utilizing LCC fill to be performing as predicted showing maximum ground displacements of 3-4 mm, which are considered within the expected values.

Figure 4: Construction of Light-weight Cellular Concrete (LCC) fill being placed in terraced steps. Partitions, made of geotextile and rebar, were utilized between the steps of different elevations and/or depths of LCC fill.

2.2 Example 2: Utility Crossings Placed on Piled Structures

At some areas of the highway the existing utility crossings had been placed on piled structures within the roadway to mitigate any potential damage to the utility from the surrounding differential settlement effects. Though the piled utility crossing structures were in large part successful in reducing undesirable movement to the utility from differential settlement, a separate issued formed at the road surface. While the utility crossing over the piled structure remained fairly stable, the area immediately surrounding the crossing settled more aggressively, thus the utility crossing appeared as a noticeable protrusion at the roadway surface. Reduction or elimination of the protrusion was desired to improve the driver comfort.

Initially, the asphalt surface of the protruding area was milled off to reduce the "bump" that had formed on the road surface. However, as this resulted in a reduced pavement structure it was not a sustainable solution for further reprofiling as the settlement effects were expected to continue. Further ongoing settlement necessitated an alternative solution which would be able to maintain the required pavement strength, but also provide a method to reduce the protrusion. The protrusion was expected to develop over time as the area was located at the interface between two areas of differing settlement rates.

Attaining a net load reduction for the areas outside of the piled crossing would not entirely eliminate the protrusion from appearing in the future, as the piled utility structure was in effect, fixed in comparison and the surrounded areas which would continue to settle at a higher rate. Therefore, rather than reducing the settlement effects, a planned maintenance strategy to mitigate the undesirable effects on driver comfort and potential safety was proposed. The pavement structure above the piled crossing was removed and replaced entirely with asphalt. While not reducing settlement, the additional asphalt provides a "sacrificial" depth which can be milled out during future maintenance interventions to allow for a quick reprofiling of the crossing area that would require minimal disruption to the traffic and would reduce or eliminate the protrusion and improve comfort.

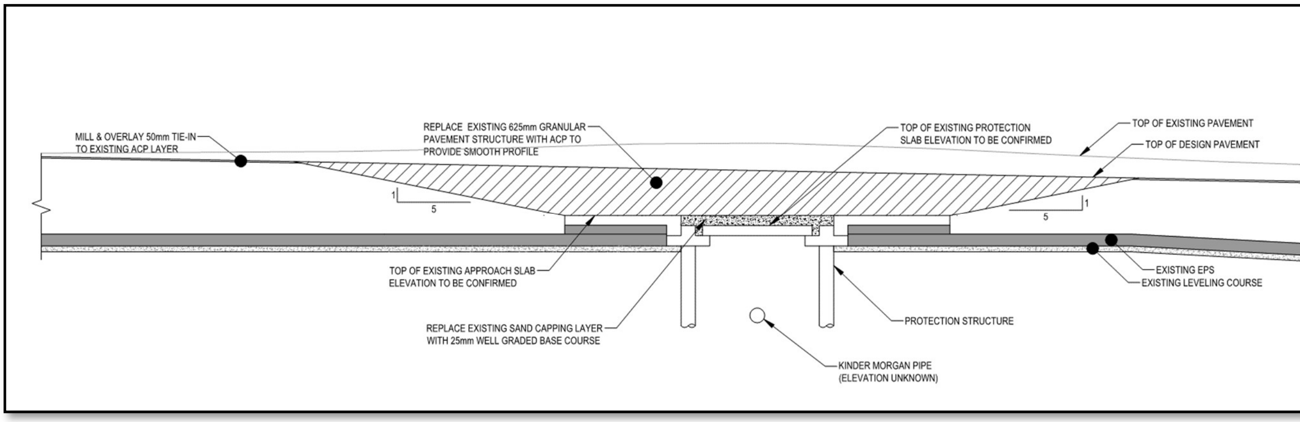

Figure 5: Cross-section of design showing of the "over-paved" asphalt structure designed to be milled off in the future.

2.3 Example 3: Expanded Polystyrene (EPS) Block Embankments

EPS blocks have been utilized as part of the original road embankment at some locations along the highway to relieve deadload weight and thereby reduce future settlement effects. For example, the North Surrey Interceptor forced sewer crosses the highway corridor at two locations and are supported on piled foundations located deep beneath the EPS embankment which is approximately 5 meters in height. Issues with the EPS embankment settlement were experienced in isolated areas where "hog fuel" is present, and in the area of hard points (local differential settlement locations) caused by the North Surrey Interceptor crossings. This resulted in the movement of the EPS blocks, causing voids between the blocks to form, which in turn resulted in the migration of fines/granular materials causing both rideability issues and on some occasions sink holes in the road pavement.

To address this issue, and to prevent further loss of fines and movement of the EPS blocks, the pavement and road structure above the EPS blocks were removed to expose the EPS blocks, and the voids between the blocks were injection-filled with high density expanding polyurethane closed-cell foam. Following this, the road structure and pavement above the EPS block was reconstructed.

Figures 6 & 7: Application of high-density expanding polyurethane closed-cell foam via injection to fill the voids between the EPS blocks.

3. Conclusion

Since opening, some particular areas of the SFPR have experienced differential settlement issues leading to concerns related to key performance indicator compliance and rider comfort. However, The P3's drive for innovation has resulted in a diverse set of tactics aimed at addressing some of these issues, with implementation of various technological and construction solutions to cater to these site-specific challenges. The development of these solutions often involves a multidisciplinary approach to both design and construction, as well as the input and endorsement from a variety of stakeholder perspectives. Applications of these solutions have come with their own challenges of both design and construction management but have also allowed the Concessionaire to accumulate a diverse range of tools to apply to future remediation measures in a cost-effective manner to both improve and maintain driver comfort.

4. References

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