CONSTRUCTION SEQUENCING FOR SEPARATING HIGHWAY-RAIL GRADE CROSSINGS WITH MINIMAL INTERRUPTION TO THE RAILROAD

Art Ivantchouk, Ph.D., P.Eng., President & Chief Engineer, ART Engineering Inc., 844-827-8364, art@artengineering.ca

Eric Carson, P.Eng., Senior Engineer, ART Engineering Inc., 844-827-8364, eric@artengineering.ca

ABSTRACT

In recent years, government bodies and railway companies have been working towards eliminating dangerous highway-rail grade crossings through a variety of means, including grade separation. Due to operational requirements of the railroads, ABC construction techniques are sometimes implemented in these grade separation construction projects to limit interruption to the railway. In response to this trend, Grade Separation Systems (GSS) was developed. GSS is a construction technology allowing for the construction of an at-grade rail bridge and underpassing roadway without causing significant interruption to the railway schedule. Through the use of ABC techniques, GSS is able to eliminate the need for rail relocation (shoofly tracks) and significantly reduce required temporary works. When compared to conventional methods, GSS is able to shorten construction schedules by up to 50% and reduce project costs by up to 45%.

1.0 INTRODUCTION

Highway-rail grade crossings pose a significant safety risk to motorists. Data shows that approximately 1 in 10 crossing collisions result in a fatality., DOT/FHA(1) As a result, federal aid programs such as the Railway-Highway Crossings Program have been created across North America with the purpose of improving grade crossing safety. These programs provide funds to eliminate hazards and improve safety measures at grade crossings., DOT/FHA(2) The majority of grade crossing locations use these funds to install warning devices and signage. While these do help in reducing the number of collisions, the most effective solution is a complete grade separation of road from rail. However, grade separations are often labeled unfeasible due to their high expense and restrictive constraints, the largest of which is the limited allowable track closure time. Using normal construction practices, elaborate temporary works such as detour tracks (shoofly) or temporary bridge structures are often required by the railroad in order to maintain rail service while the permanent bridge is under construction, greatly raising the cost above that of a typical bridge construction project. As a result, a need was identified for a cost-effective way to separate a rail-road grade crossing without the need for costly temporary works while still working within the railway constraints. As such, Grade Separation Systems (GSS) was developed.

GSS is an innovative new construction technology which utilizes ABC practices to construct an at-grade rail bridge and underpassing roadway. By using precast segments and redefining the construction sequence, GSS is able to eliminate the need for temporary works such as detour tracks and temporary bridges, while still operating within the railway constraints.

2.0 GRADE SEPARATION SYSTEMS

GSS uses only traditional heavy civil construction methods with a redefined sequence of steps, resulting in a more efficient grade separation of a highway-rail crossing. By utilizing ABC concepts, GSS is able to fully construct the permanent bridge structure prior to excavation, reducing both the amount of temporary materials used and the track closure time required to construct the bridge. GSS further reduces the track closure time by maximizing the work that is performed outside of the rail clearance envelope, which is work that can be completed without interrupting the railway. The complete methodology of Grade Separation Systems is explained below.

2.1 Method

GSS begins with the substructure construction. To start, caisson liners are installed in pairs along the railway at the abutment locations. The liners are placed such that each is located a minimum of nine feet from the centreline of the track, which is the rail clearance envelope as specified by AREMA (Figure 1). Placing the caisson liners outside of this envelope will allow work to be completed on them without interference to the railway.

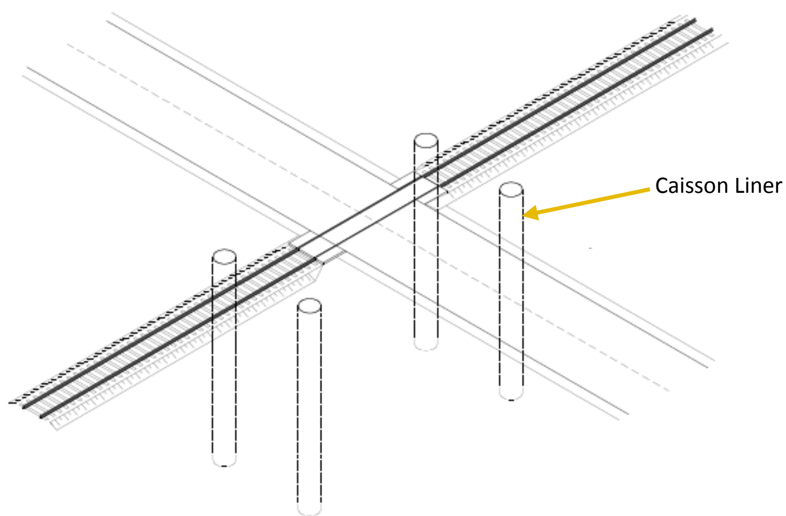

Figure 1: Caisson liner placement

Meanwhile, partial abutment segments are precast. These segments are long enough to span the rail clearance envelope, which allows them to be buried beneath the railroad and extend such that work can be completed at their ends without interruption to the railway. Prior to placing the precast segments, the ends are fastened to modular trench boxes as shown in Figure 2. The trench boxes are designed to withstand both train and soil loads, and will also serve as formwork when the abutment extensions are poured.

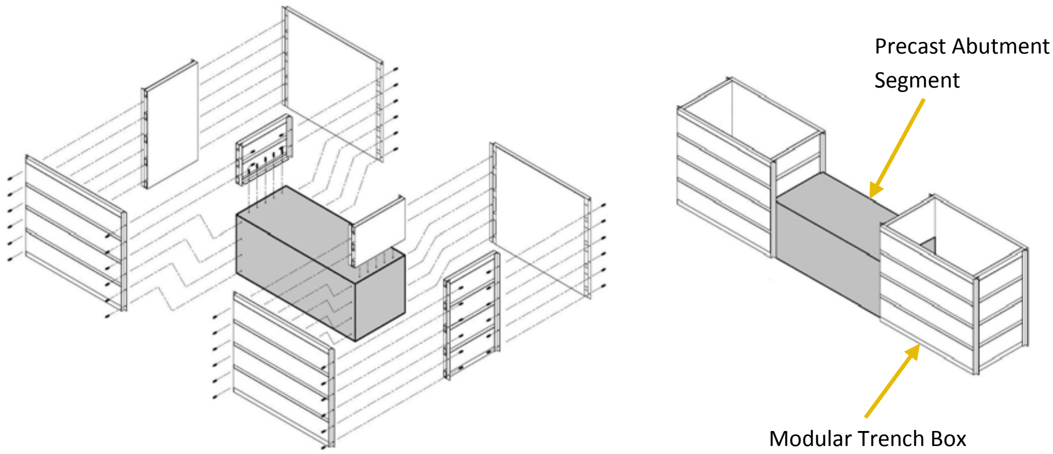

Figure 2: Precast Assembly: precast segment joined to two modular trench boxes

The complete assembly, called the precast assembly, is buried beneath the railway in a short rail closure – as little as 4 hours – to be expanded into the permanent substructure. During the closure, a trench is dug across the track around a pair of caisson liners. A guide channel housing a steel waler is welded onto the caisson liners before the precast assembly is crane-lifted into place. The precast assembly will sit above the guide channel, which will be utilized later on to excavate beneath the bridge, and such that a caisson liner is within each trench box. This is shown in Figure 3.

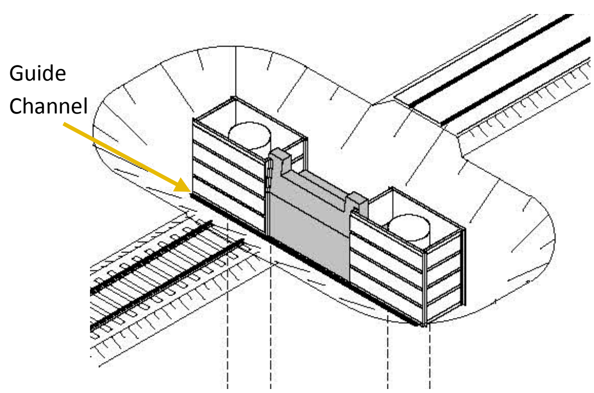

Figure 3a: Guide channel and precast assembly placement relative to railroad

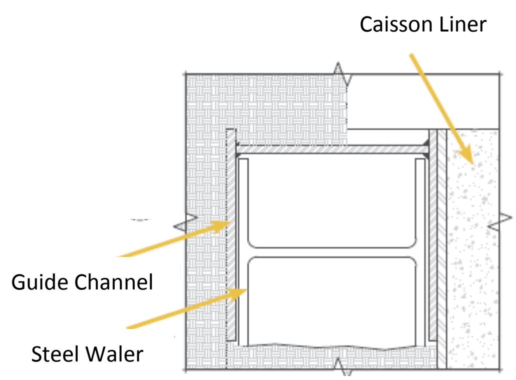

Figure 3b: Guide channel containing steel waler fastened to caisson liners

Once the assembly is in place, the trench is backfilled over the precast segment and around the trench boxes. The area is re-ballasted, the track is reconnected and the railway is reinstated over the now buried assembly (Figure 4).

A precast assembly is required at each abutment or pier location. The precast assemblies can be placed all at once or over separate closure times. If placed over separate closure times, work can continue within the trench boxes of the placed assembly while waiting for the additional precast assembly placements.

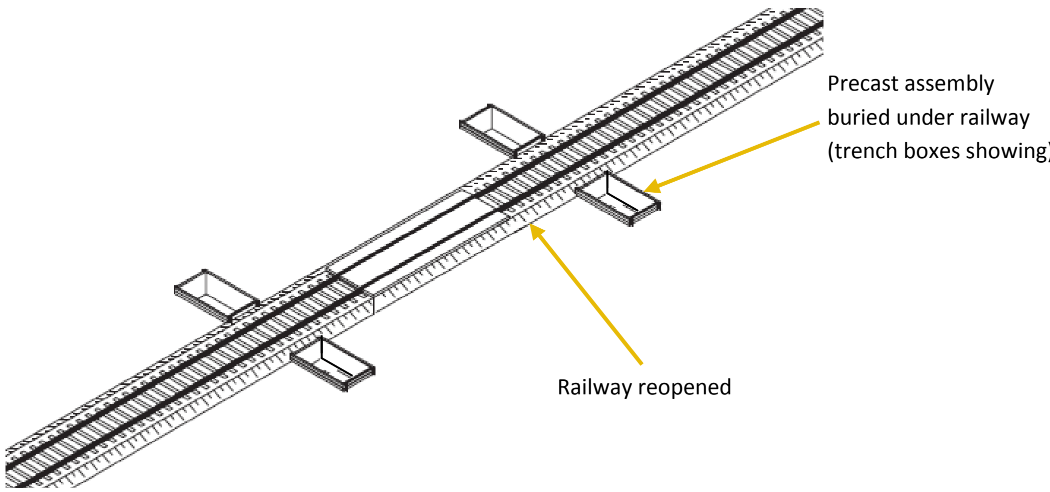

Figure 4: Railway reinstated over precast assemblies

The use of the trench boxes allows work to continue from outside of the rail clearance envelope. The top portions of the caisson liners are cut off, reinforcing steel is placed throughout the caisson liners and trench boxes, and the precast segment is integrated with the cast-in-place portion through either post-tensioned steel or mechanical couplers. With this complete, concrete is poured for the abutment extensions. Finally bearing pads are placed with precision to ensure the superstructure will bear on the cast-in-place portion of the substructure. Figure 5 shows the work to be completed within the trench boxes.

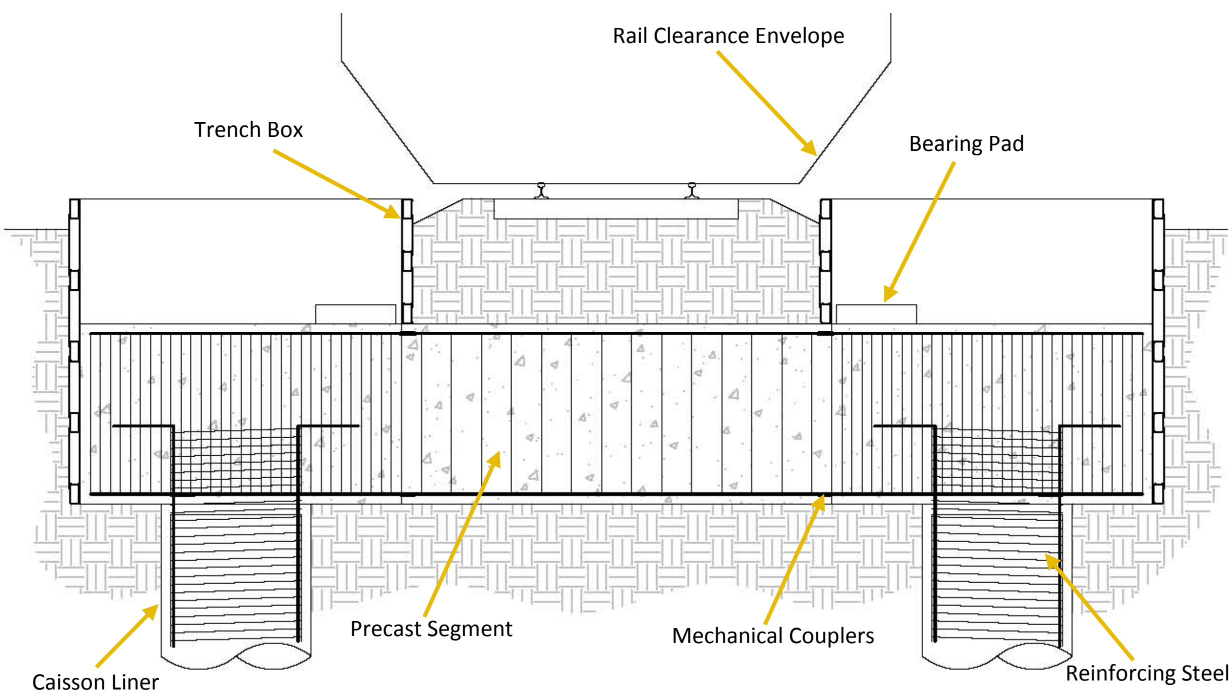

Figure 5: Cross-section of precast assembly after abutment extensions are poured

With the substructure constructed, work moves to the superstructure. GSS can accommodate any type of bridge span, but the method of placement may vary based on the weight of the span. A steel span 60ft long, complete with ballast and rails weights approximately 200,000lbs and can be lifted into place using tandem cranes. Heavier spans can be assembled on rails beside the track and moved into place with a lateral slide. In each instance, a 4-6 hour rail closure is required to trench between the abutments and place the span. With the trench dug, the trench boxes are removed prior to the span placement (Figure 6).

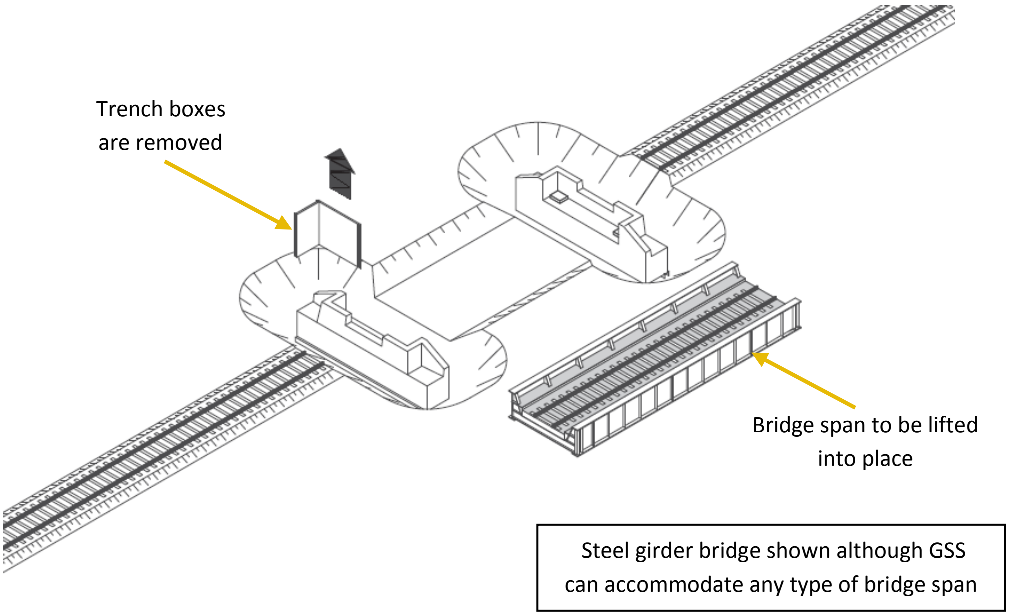

Figure 6: Rail closure to place bride span

The spans include both the ballast and rails prior to their placement to reduce the required track closure time. Once the spans are moved into place, the new track only needs to be connected to the existing before the railway can be reopened. As this is the final rail closure required in the GSS method, the railway is permanently reopened (Figure 7).

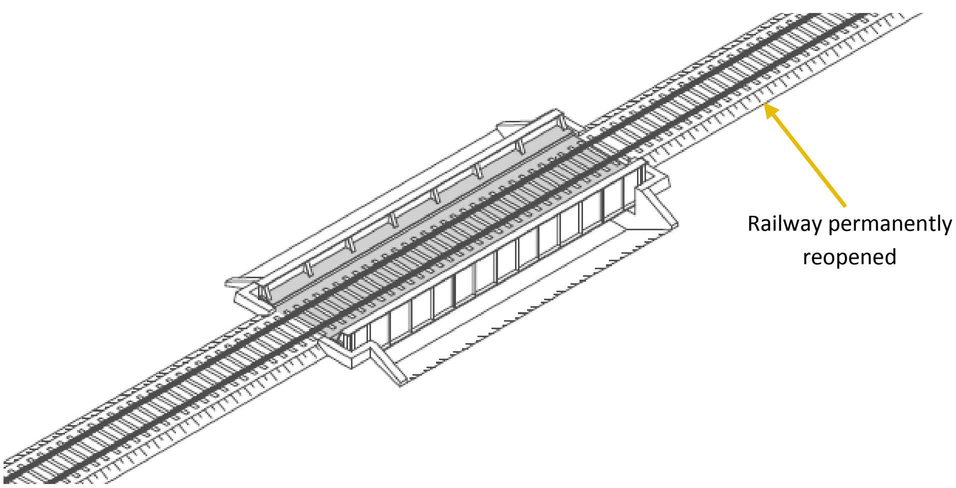

Figure 7: Railway reinstated after span placement

With the bridge fully constructed, the next step in the GSS procedure is excavation for the new underpass road. Either sloped or vertical excavation can be used. Sloped excavation is done using standard construction practices; vertical excavation requires a new method to safely excavate beneath the fully constructed bridge. Therefore the foot-at-a-time vertical excavation method was developed. This procedure utilizes the guide channel and steel waler that were previously placed beneath the precast assembly.

2.2 Vertical Excavation Procedure

The foot-at-a-time vertical excavation procedure begins by locally excavating directly beneath the guide channel to a depth of one foot until the steel waler that is housed within the guide channel can be lowered. A second steel waler is then slid into the guide channel so that it sits on top of the original waler. One foot below the original waler is again excavated until the two walers can be lowered together, and a third is slid into the space within the guide channel. This process is continued until the desired excavation depth is reached. To facilitate integration and sliding, guide plates can be welded onto the steel walers prior to their placement in the guide channel. The walers will drop due to their self-weight, or can be lowered with the help of a hydraulic jack if required. Throughout this method, a temporary retaining wall is built with the walers that can double as the back formwork for the permanent abutment walls. Figure 8 below illustrates the procedure.

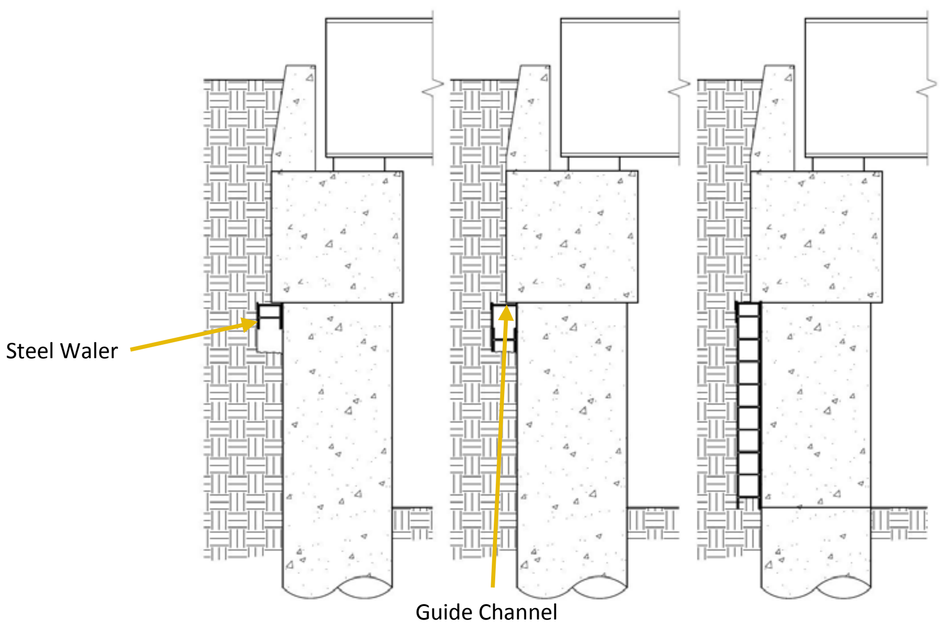

Figure 8: Foot-at-a-time vertical excavation procedure

Once the vertical excavation is complete, the permanent abutment walls are poured using the walers as the back formwork. Similarly, retaining walls are poured as required along the excavated length. With all structures completed, the underpass roadwork is performed, completing the grade separation (Figure 9).

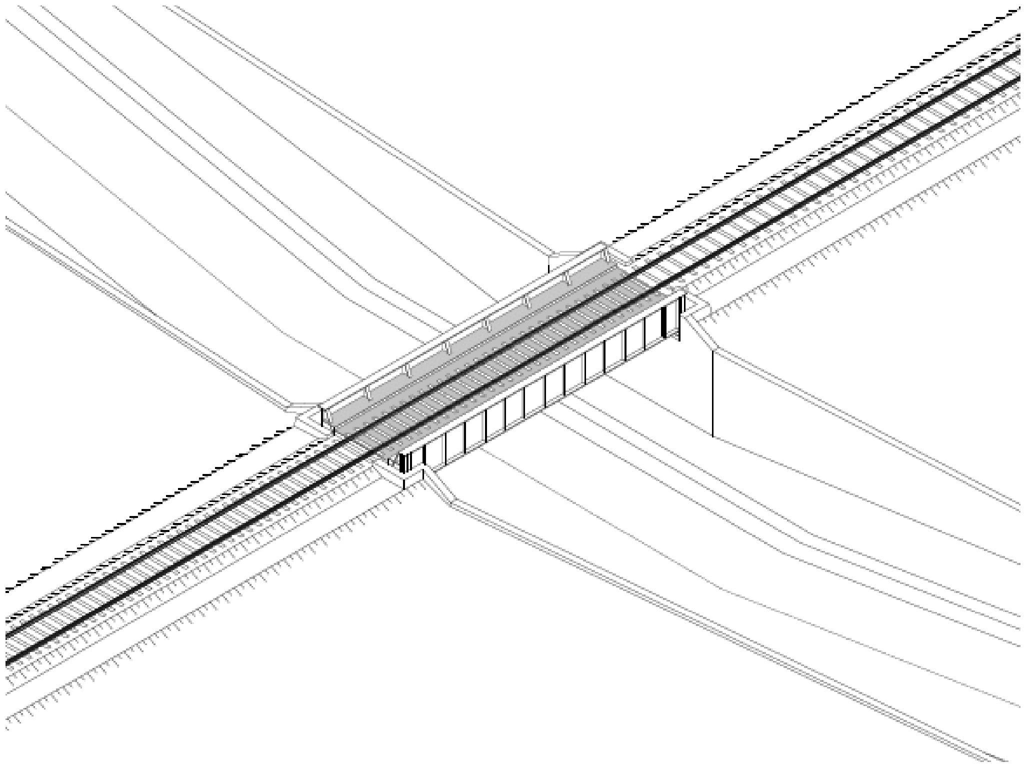

Figure 9: Completed grade separation

3.0 COMPARISON TO CURRENT GRADE SEPARATION METHODS

3.1 No Temporary Rail Structures

The innovation of GSS lies within the altered sequence of construction, specifically with excavating at the end of construction. One of the benefits that results is eliminating the need for a rail detour or a temporary bridge structure, both of which are constructed to allow the rail to operate in spite of the excavation beneath the main railway. With GSS, the permanent bridge itself serves this purpose, as it is fully constructed prior to excavation. Since its construction is coordinated with the railroad and only requires very short closure periods, the need for a rail detour during the bridge construction is also eliminated. By eliminating the need for either a temporary track or a temporary bridge without the need of any other temporary structure to replace them, both the project schedule and cost can be greatly reduced.

3.2 Ability to Keep Roadway Open throughout Construction

Another benefit over traditional grade separation practices is the ability to keep the road open to traffic throughout construction. This is possible for multi span bridges with a pier in the center of the road. Traffic is maintained at a reduced lane capacity by first deviating traffic away from the centre of the road to provide space for the abutment construction. Then, traffic is detoured onto one side of the road, allowing the opposite bridge span to be placed. Traffic remains on this half of the road while temporary shoring is installed along the middle and far side of the road, then also while excavation occurs between thetemporary shoring. Permanent abutment and retaining walls are poured and roadwork is completed on the newly excavated half of the road, which allows traffic to be moved over to this side. With traffic then operating on the completed half of the road, the remaining bridge span is assembled and placed, and excavation occurs. Retaining walls and abutment extensions are poured on the second half of the road, roadwork is completed, and traffic can be restored to its full capacity on the new underpass. Figure 10 below demonstrates the construction staging required.

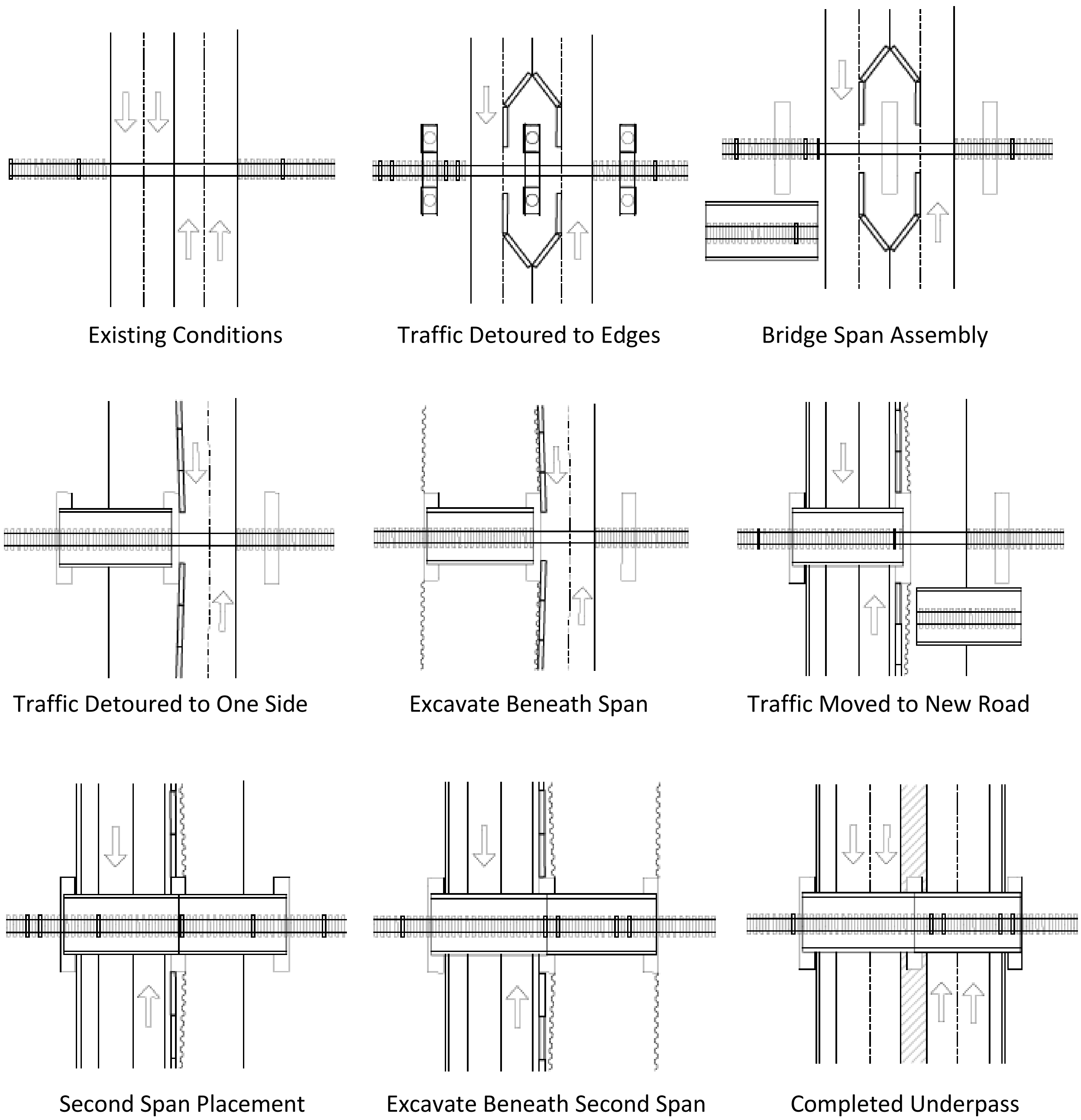

Figure 10: Construction staging to keep road open throughout construction

3.3 Cost Benefits

GSS technology offers significant savings in overall project costs. Using only permanent elements during construction eliminates both the need for temporary materials and unnecessary steps in the construction procedure, saving costs on material and labour. It is forecast that GSS can save up to 45% when compared to conventional construction methods. This increased efficiency is also predicted to reduce the overall construction schedule by up to 50%.

4.0 OTHER APPLICATIONS OF GRADE SEPARATION SYSTEMS

In addition to the single track, single span procedure outlined above, GSS can also be used in both multi-track and multi-span procedures. The system can be modified as required based on the number of tracks and spacing between tracks to accommodate almost every situation. Additionally, GSS can be applied specifically for road-widening scenarios, where similar construction sequencing can be used to add lanes to an underpassing thoroughfare. For more information about GSS, visit www.artengineering.ca/GSS.

5.0 CONCLUSION

Grade Separation Systems was developed in response to the need for a more efficient and affordable highway-rail grade separation. By using ABC concepts and altering the traditional sequence of bridge construction, GSS is able to meet all railway constraints without requiring costly temporary structures. The result is a cost-effective grade separation method, leading to a safer transportation network across North America.

6.0 REFERENCES

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