Ministry of
Transportation

Report BO-99-03

Bridge Office

Ontario

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Semi-Integral Abutment Bridges

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By: Iqbal Husain, P. Eng.
Dino Bagnariol, P. Eng.

To all users of the: **SEMI-INTEGRAL ABUTMENT BRIDGES MANUAL**

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INTRODUCTION

Semi-integral abutment bridges are single or multiple span structures with rigid foundations (spread footings) where the concrete deck is continuous with the approach slabs. Expansion joints are eliminated at the end of the deck, however, the superstructure is not continuous with the abutments. Conventional bearings are used to allow horizontal movements between the deck and the abutments. A control joint is provided at the end of the approach slab that is detailed to slide in between the wingwalls.

The simplicity, economy, durability and performance of integral abutment bridges in recent years has led to increased interest in the semi-integral abutment bridge design concept. This concept eliminates expansion joints on the structure and can be used in situations not suitable for fully integral abutments. However, these bridges may not be as efficient and economical as fully integral abutment bridges due to more complex joint details, rigid abutment foundations, the need for moveable bearings and time consuming construction details. Several of these structures have been built in Ontario recently, and their use is likely to increase in future.

In 1996, the Ministry of Transportation of Ontario issued a report (SO-96-01) on Integral Abutment Bridges. The report highlighted some of the important features, rationalised the design method and imposed limitations based on the available information and literature at the time. This report is intended to serve a similar purpose for semi-integral abutment bridges, in addition to complementing the original report.

BACKGROUND

The first semi-integral abutment bridges were built in Ontario in the late 1960's. It is not surprising that one of these early bridges replaced an existing rigid frame structure out of the necessity to widen the roadway underneath the structure. The use of the semi-integral concept in this case may have resulted from a desire to eliminate expansion joints from the abutment since joints had also been eliminated at the piers by making the precast girders continuous for live load. There has not been a great deal of interest in the design and construction of semi-integral abutment bridges since. The reasons for not attempting more designs of this type are not well documented. It could be attributed to the improved quality of expansion joint systems becoming available to designers or the absence of rational design methods, construction procedures or performance data.

Examples of older semi-integral abutment details are shown in the Appendix (See Figures A1 to A3). However, these bridges are not considered “semi-integral” by our current definition, since the details did not allow longitudinal movements. They used expanded polystyrene or pre-formed expansion joint fillers, that when left in place, did not allow the expected movement to take place. The joints were provided to simply introduce a separation between the superstructure and the substructure to allow for rotation in the vertical plane. The movement was taken care of by making the abutments slender and flexible and perhaps designing the superstructure to withstand some lateral axial load. These structures were either single or two span pre-cast concrete girder deck bridges and the total length did not exceed 40m. Bridges built more recently have used details which allow movements to take place at the interface of the superstructure and the substructure (See Appendix Figure A4).

PLANNING CONSIDERATIONS

The feasibility of using semi-integral abutment details should be considered at the early planning stage. Semi-integral abutments are not feasible for every site and should only be considered in situations where integral abutment bridges cannot be used. The decision to select this type of design is influenced by the following factors.

i) Length of structure

The overall length of semi-integral abutment bridges should not exceed 150 metres. Other jurisdictions have imposed limits of between 90 m and 135 m. However, the limit has been extended to 150 m for Ontario based on our success with integral abutment bridges of this length. In general, special measures must be taken to account for anticipated structure movements at the end of the approach slab. The following two standard joint details have been developed for this purpose:

Figure 1 - For concrete bridges less than 100m in length and steel bridges less than 75m in length.

Figure 2 - For concrete bridges greater than 100m in length and steel bridges greater than 75m in length.

The limitation placed on the total length of the structure is mainly a function of seasonal temperature variations, type of superstructure being considered and the capacity and efficiency of movement system.

ii) Type of Superstructure

Semi –integral abutment details can be used in the following types of superstructures:

1. Steel I-girders with concrete deck
2. Steel box girders with concrete deck
3. CPCI girders with concrete deck
4. Prestressed precast box girders with concrete deck

At this time, it is not recommended that semi-integral abutment details be used for cast-in-place post-tensioned deck type structures. It is recognised that semi-integral details would allow movements due to elastic shortening and short term creep and shrinkage to take place before the deck is made integral with the approach slab. Movements due to temperature variation and long term creep and shrinkage could be accommodated by the movement system at the end of the approach slab. However, details for these structures are still under development, and should be issued in the next release of these guidelines.

iii) Geometry of Structure

Unlike integral abutment bridges, there is no limit on skew angle for semi-integral abutment bridges. However, the following provisions must be satisfied:

(1) Lateral restraint should be provided to prevent rotation of the superstructure caused by an eccentric lateral force in the horizontal plane. This force is usually the result of lateral earth pressure acting on both ends of the superstructure.

(2) The movement system at the end of the approach must be able to accommodate the deformations associated with the skew.

(3) The effects of other geometric constraints (curvatures, flares, etc) should be considered.

The efficiency and durability of joint seals and bearings, including the superstructure to pier attachment details, should also be considered in assessing the skew effects.

v) Use of Retained Soil Systems

The warrant for the use of retained soil systems to resist lateral earth pressure at the abutments is the same as for conventional jointed bridges. This choice is based on geotechnical and economic considerations which are a function of abutment height and wingwall length. The vertical load is transferred to a spread footing through the use of columns placed behind the fascia of the retained soil system (See Figures 3, 4,5,6). In the use of retained soil systems it is imperative that due consideration is given to the location of columns so that they do not interfere with the earth reinforcing strips. In addition, column placement must be co-ordinated with the fascia panel sizes. Where alternative retained soil systems are used, the potential of conflicts between columns and other elements, must be indicated on the contract drawings. This could also be achieved by including the details of the most appropriate retained soil system on the contract drawings.

vi) Articulation of super-structure and multi-span considerations

The articulation of the super-structure at the supports and spans of multi-span structures should be selected such that equal movement would occur at each end of the structure. The deck diaphragms may either be integral with piers, made fixed or allowed to move freely, as appropriate. The super-structure of a semi-integral abutment bridge is supported on movable bearings and is almost independent of the abutment. It receives its longitudinal restraint against externally applied lateral forces from the approach slab (sub-base friction), resistance of bearings and possibly the compressive resistance of structure backfill. The compressive resistance of the backfill cannot be relied upon as the structure may not be in contact with the fill when needed or it may require unacceptable movements to mobilise the resistance. Generally, the longitudinal resistance is sufficient to withstand the longitudinal forces. However, consideration should be given to providing positive restraint for long multi-span structures, skewed structures and where roadway grade or earthquake considerations warrant it. For multi-span structures, anchorage to piers to prevent lateral movement can provide the extra longitudinal restraint, even for large longitudinal forces.

vii) Sub-surface Conditions

Sub-surface conditions for semi-integral bridges are not quite as restrictive as for the integral abutment bridges and are subject to the same general requirements as for the normal jointed bridges. Therefore, where the soil conditions are such that fully integral abutment details cannot be used owing to unfavourable sub-surface conditions, semi-integral abutment details could be utilised to eliminate the expansion joints at the end of the deck.

DESIGN CONSIDERATIONS

In general, the analysis and design of semi-integral abutment bridges is the same as for conventional jointed bridges. Semi-integral bridges do not require special design considerations except those arising from the backfill pressure against the super-structure at the abutment location (See Figure 7) and the design of the cantilevered wingwalls. As the super-structure expands due to increase in the ambient temperature, the elongation is resisted by backfill. This backfill resistance induces compressive forces into the super-structure. Although it may not have a significant impact, the adverse effects of these forces should be considered in the design of girders. It may also be necessary to provide positive restraint against the lateral movements in the longitudinal or transverse direction, especially where the super-structure is skewed, flared or curved. The partial or full elimination of the ballast wall and the cleat, changes the behaviour and design of wingwalls as the top portion of the wall is not cantilevered from the abutment.

Semi-integral abutments should be supported on rigid foundations capable of supporting all the vertical and lateral loads, individually and in combination, at all stages of construction.

In the design of semi-integral bridges, detailing issues associated with the following items, must be resolved by the designer:

- (i) Joints and bearings
- (ii) Material applications
- (iii) Treatment of wingwalls and approach slabs
- (iv) Drainage and water leakage management

Some of these issues are discussed in more detail under the heading " Semi-integral Abutment Details".

SEISMIC DESIGN

The earthquake design considerations for semi-integral abutment bridges are similar to those for jointed bridges, except that the additional restraint at the bridge ends can be taken advantage of. Even though semi-integral abutment bridges are not fixed or as restrained at the abutment as the integral abutment bridges, they still perform better than their jointed bridge counterparts during an earthquake. There were several observed cases of semi-integral abutment bridges that performed well during the 1994 Northridge earthquake in California.

CONSTRUCTION CONSIDERATIONS

Even though, the construction of semi-integral abutment bridges is more complex and time consuming than fully integral abutment bridges, it does not necessarily require any more care than what is required for a normal jointed bridge. The following should be considered:

1) Diaphragms should be cast integrally with the deck.

2) Joint forming materials such as expanded polystyrene, which are not required after construction is completed, should be removed. This is required since these materials may compromise bearing movement, structure movement and durability of structural components.

3) The following requirements must be satisfied when placing backfill against the super-structure:

   (i) Backfill should not be placed until the deck has reached 75% of its specified strength.

   (ii) Backfill should be placed simultaneously at both ends of the structure keeping the height of backfill the same.

   (iii) At no time shall the difference in height of backfill be greater than 500mm.

   However, these restrictions do not apply to the fill placed below the level of the bearing seat.

SEMI-INTEGRAL ABUTMENT DETAILS

The success of a semi-integral abutment design depends largely on the detailing of joints, the use of appropriate bearings and the arrangement of the wingwall, diaphragm and approach slab. These features must be detailed to allow unrestricted movement of the super-structure with respect to the substructure, while minimising the possibility of leakage through the joints.

The greatest concern with older semi-integral abutment details was leaking joints and the subsequent damage that this caused. In addition, some of the older types of fillers used in expansion joints severely restricted the ability of the superstructure to move freely. Another problem was that the movement system was incapable of preventing compressed backfill from penetrating the joints. This also severely restricted the ability of the structure to move.

The details shown in Figures 8 and 9 are expected to provide a leak free joint at the bearing level and also provide a small movement capability which is restricted by the compressibility of the filler material. It is recommended that these details should only be used for concrete bridges less than 100m in length and steel bridges less than 75m in length. An expansion joint as shown in Figure 1 should be provided at the end of approach slab in conjunction with these details.

For concrete bridges greater than 100m in length and steel bridges greater than 75 m in length the details shown in Figures 10 and 11 should be used. These details are not as desirable as the ones shown in Figures 8 and 9, but have the potential to work well if the geo-textile and the fill around it is carefully placed during construction. One drawback with this system is that there may be a tendency for the geo-textile to get caught in the fill and tear off. This would then allow the backfill to penetrate the joint and restrict the movement of super-structure. An expansion joint detail as shown in Figure 2 should be used in conjunction with the details shown in Figures 10 and 11.

The length of the wingwall cantilevered from the abutment should be minimised if economically feasible. This can be done by either providing additional retaining walls parallel to the abutments (See Figure 12), or by providing a retaining wall at the end of the wingwalls (See Figure 13). The design of wingwalls and the joints at the interface of the fixed wingwalls and the moveable portion of deck and integral approach slab requires careful consideration to ensure a durable design. Some of the details that are used by the ministry are shown in the Figures 14 to 17.

RETROFITTING OF EXISTING STRUCTURES

The conversion of a non-integral abutment to an integral or semi-integral abutment is a recent initiative being considered by the Ministry. Only a few conversions have been made so far but it is expected that this trend will take place at an increased pace in the future. Bridges up to 150 metres in length, supported on rigid or flexible foundations, may be considered for conversion to semi-integral abutments. The details to be used for conversion of existing bridges should be similar to the ones shown in Figures 9 and 11.

The conversion of an existing non-integral abutment bridge to an integral abutment bridge requires a careful consideration. In order for the structure to be integral, it is necessary that the abutment is unrestrained or flexible. An unrestrained abutment is assumed to be the one that is free to rotate, such as a stub abutment on a single row of piles or one with a hinge at the footing or at the interface of substructure and superstructure. Non-integral abutment bridges less than 25m in length, where the creep and shrinkage effects are negligible and operating stress levels for the structure are acceptable, can be considered for integral abutment conversion.

The use of intermediate joints in the deck at pier locations in new construction is discouraged by the ministry and is only provided where it is considered absolutely necessary. The elimination of these joints in existing structures is considered through the study of the existing articulation, bridge layout and joint locations at the time of deck replacement. The continuous conversion not only eliminates the troublesome deck expansion joints, but the continuity achieved may also result in a slightly higher load capacity because positive moments due to live loads are reduced by continuity.

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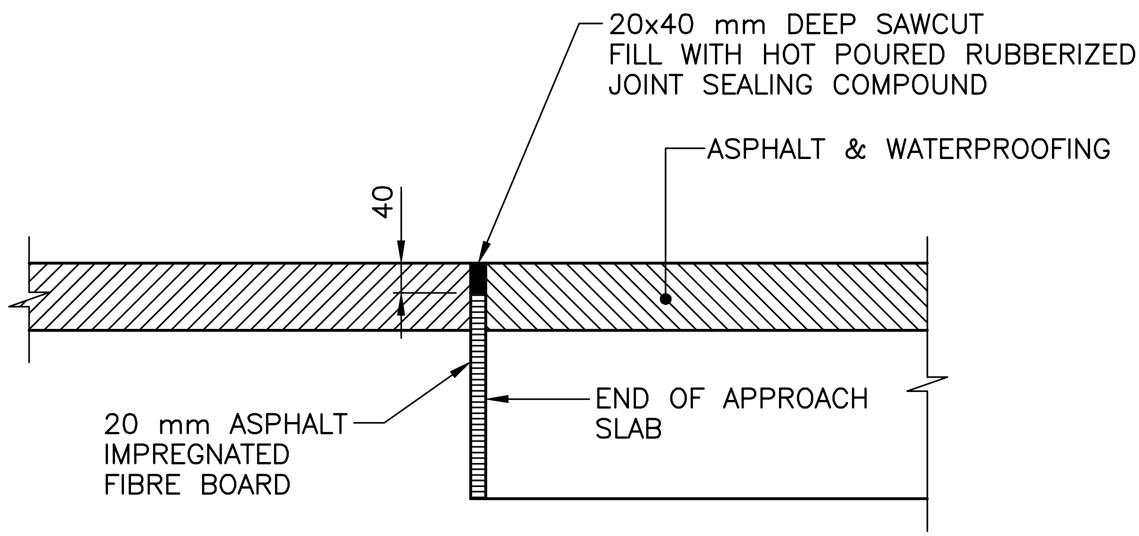
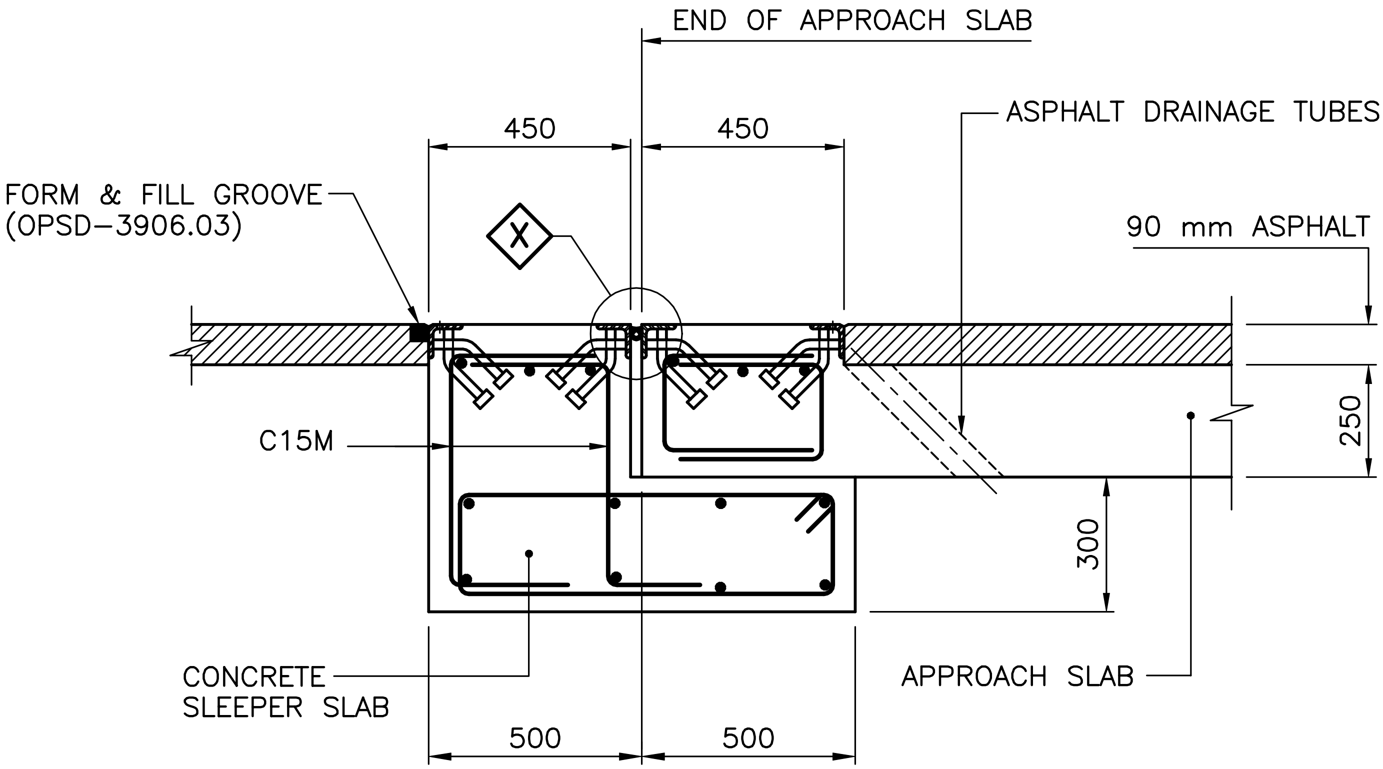
Figures

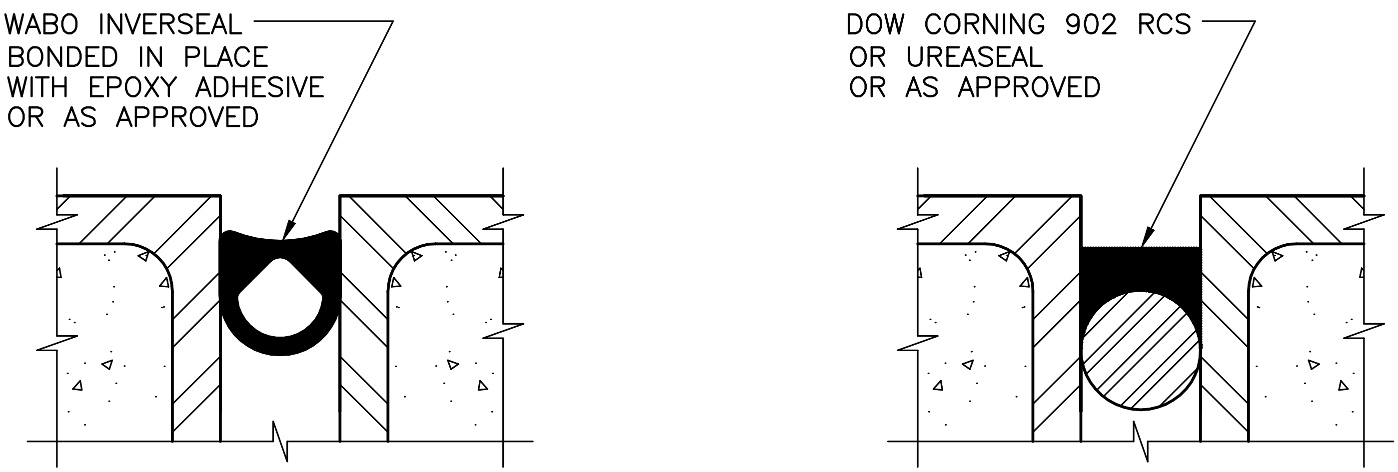


EXPANSION JOINT AT END OF APPROACH SLAB

FOR CONCRETE BRIDGES LESS THAN 100 m IN LENGTH
AND STEEL BRIDGES LESS THAN 75 m IN LENGTH

FIG. 1



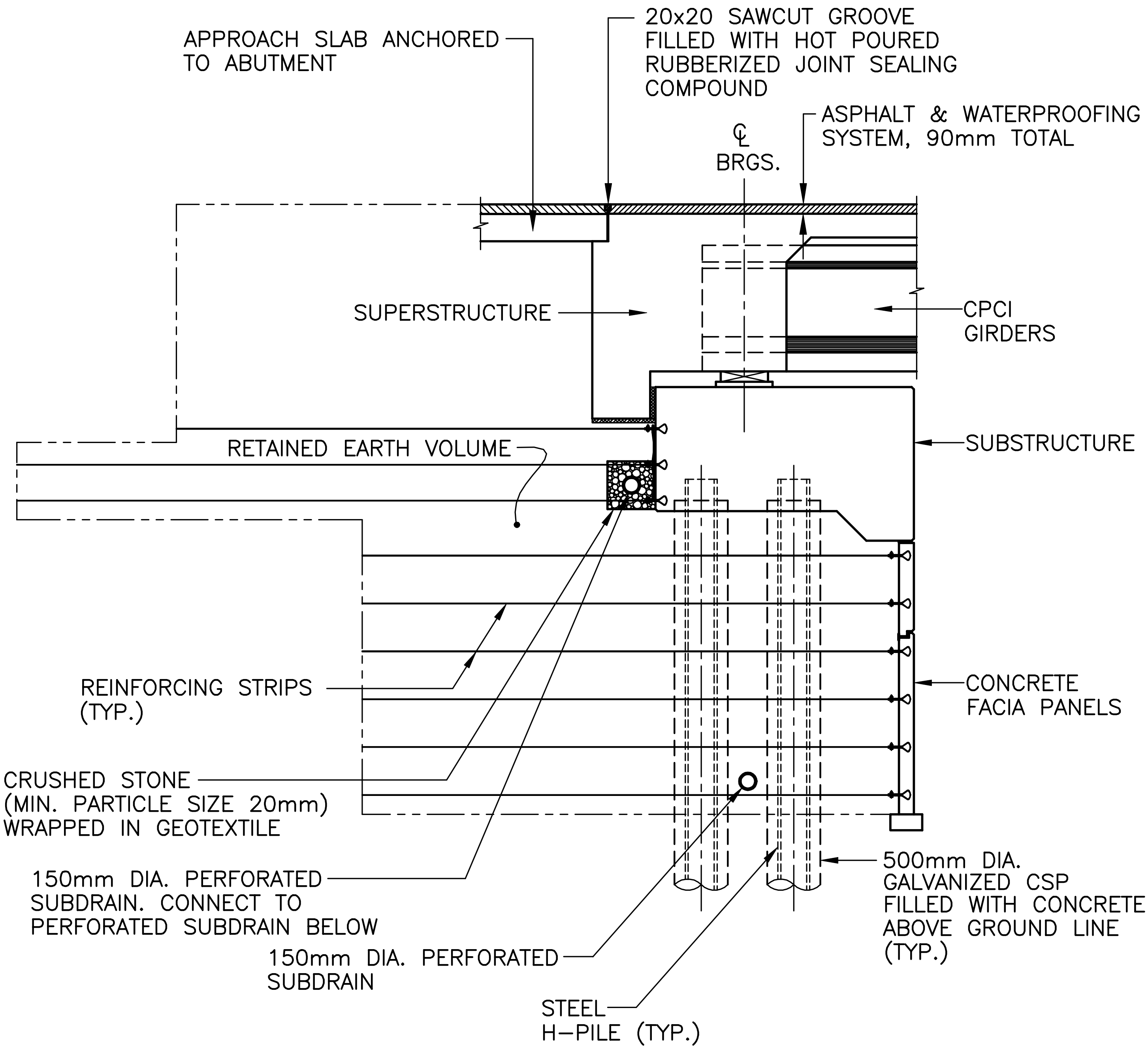


DETAIL X

EXPANSION JOINT AT END OF APPROACH SLAB

FOR CONCRETE BRIDGES GREATER THAN 100 m IN LENGTH
AND STEEL BRIDGES GREATER THAN 75 m IN LENGTH

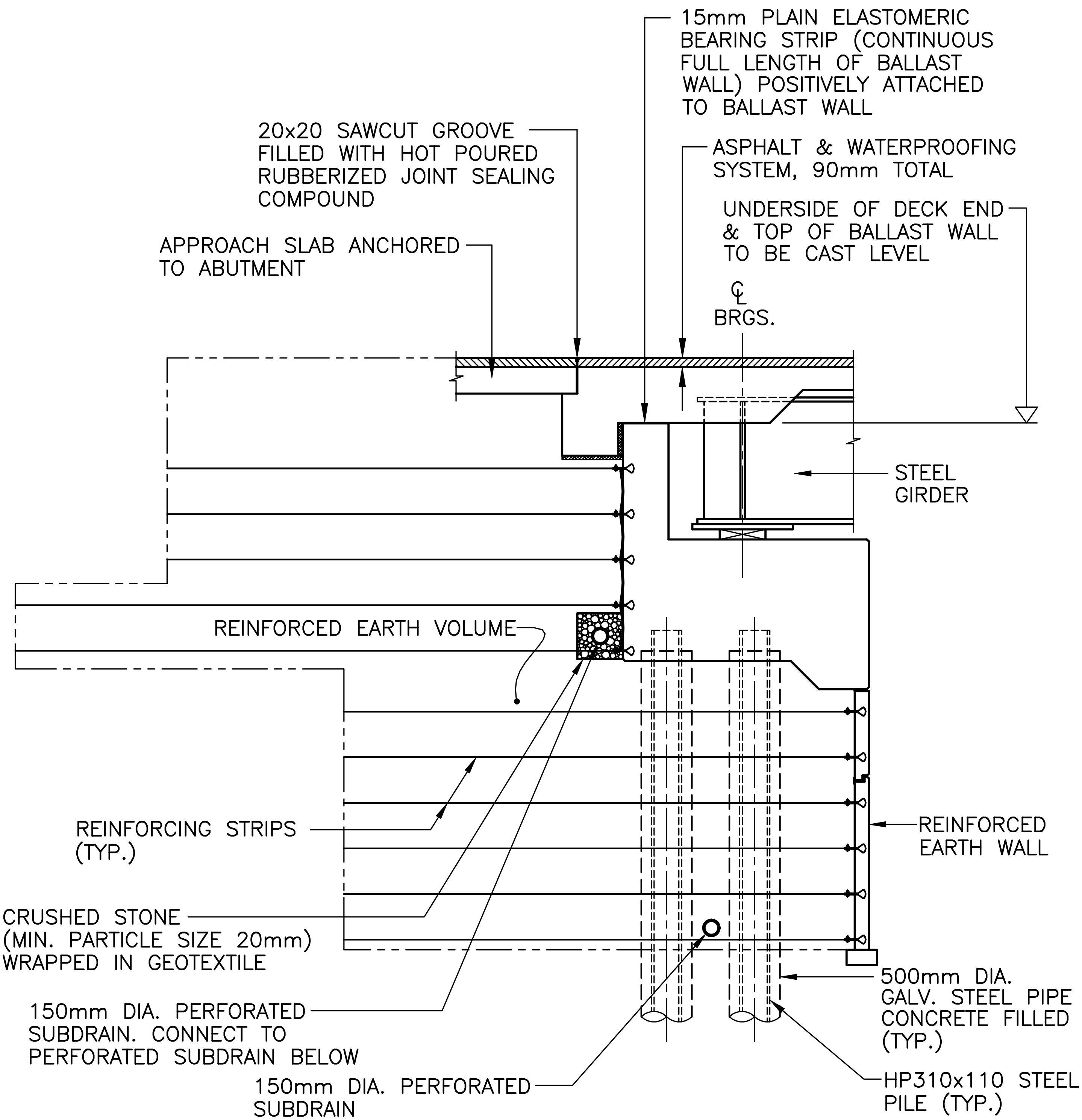
FIG. 2



USE OF RSS WITH SEMI–INTEGRAL ABUTMENT

CPCI GIRDER WITH CONCRETE DECK

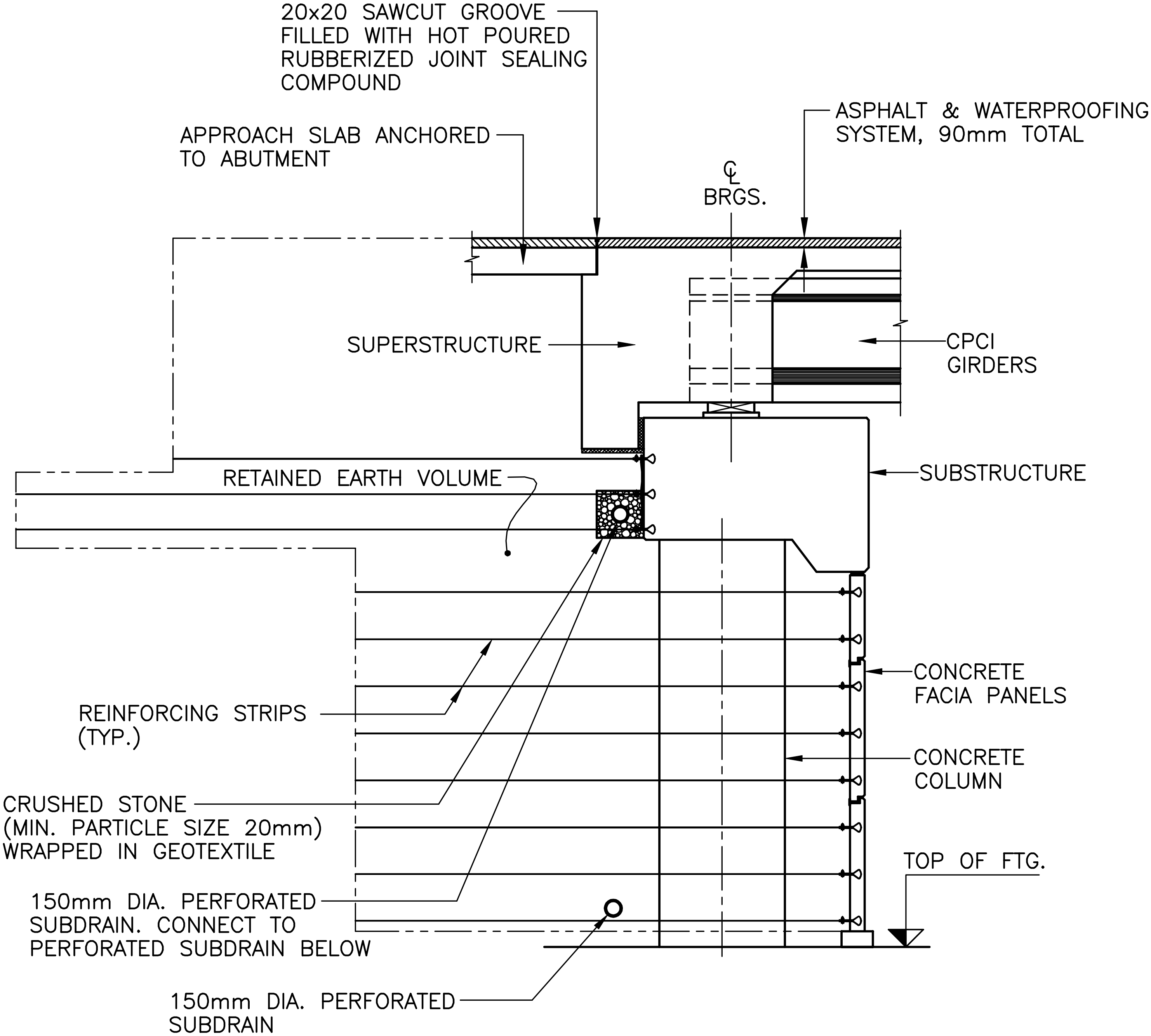
FIG. 3



USE OF RSS WITH SEMI-INTEGRAL ABUTMENT

STEEL GIRDER WITH CONCRETE DECK

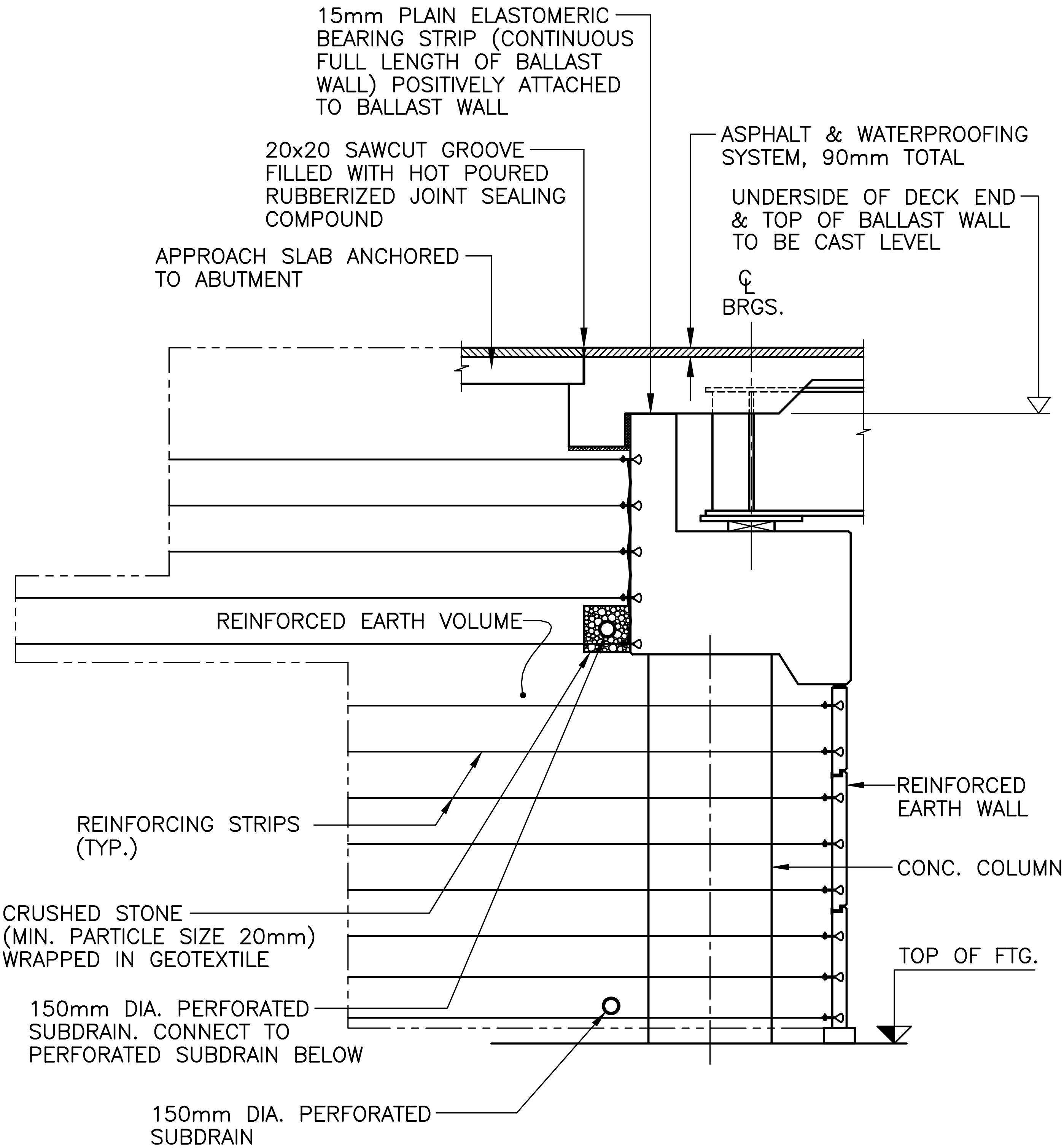
FIG. 4



USE OF RSS WITH SEMI-INTEGRAL ABUTMENT

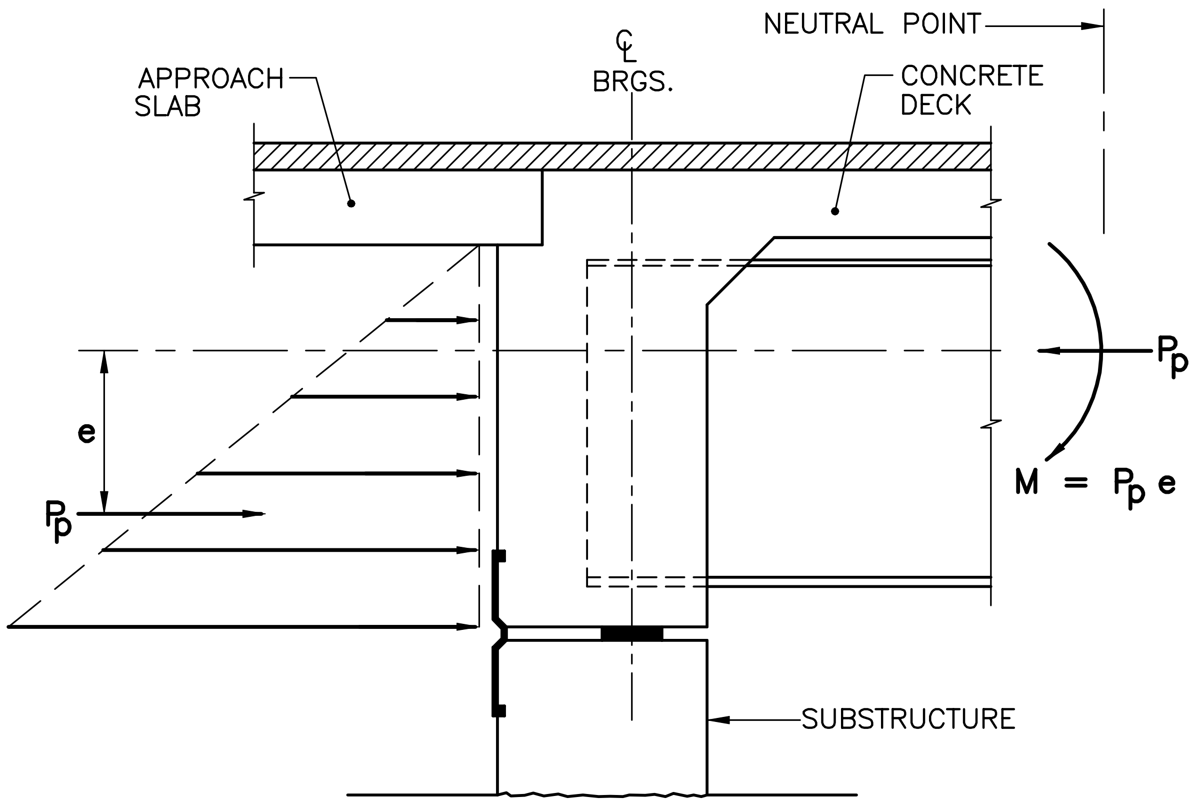
CPCI GIRDER WITH CONCRETE DECK

FIG. 5



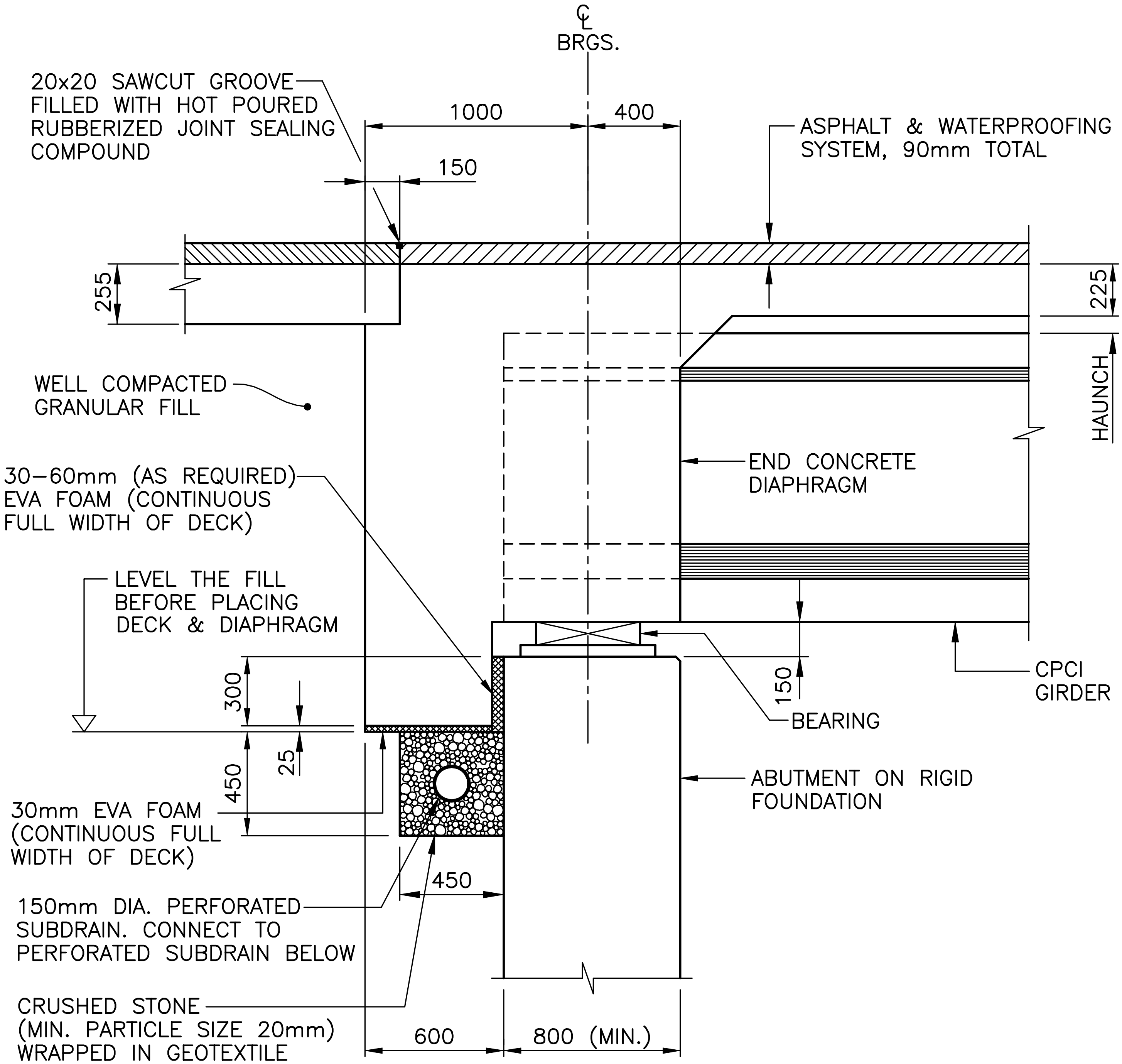
USE OF RSS WITH SEMI-INTEGRAL ABUTMENT
STEEL GIRDER WITH CONCRETE DECK

FIG. 6



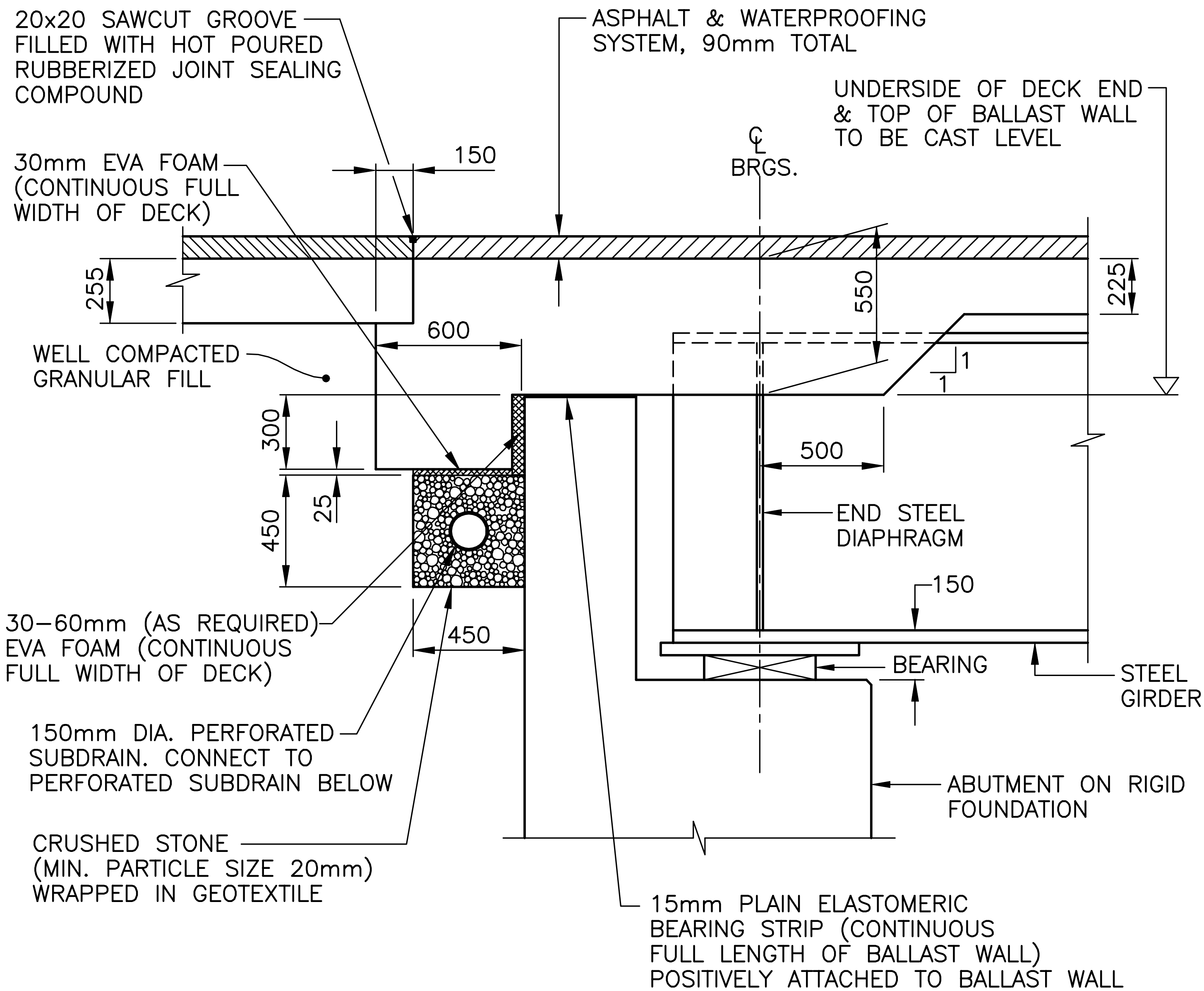
BACKFILL PRESSURE AGAINST SUPERSTRUCTURE

FIG. 7



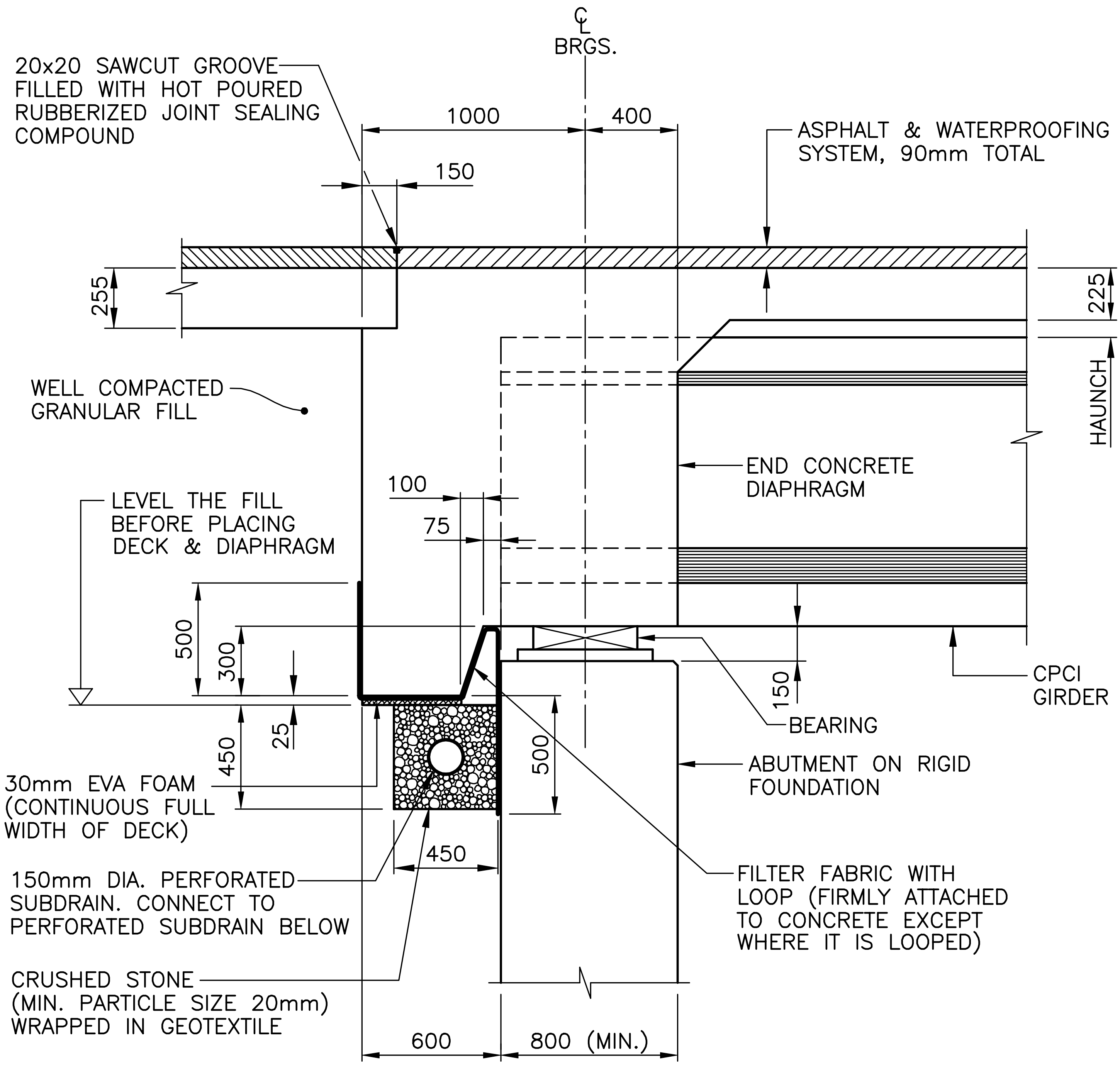
CPCI GIRDER WITH CONCRETE DECK AND END DIAPHRAGM

FIG. 8



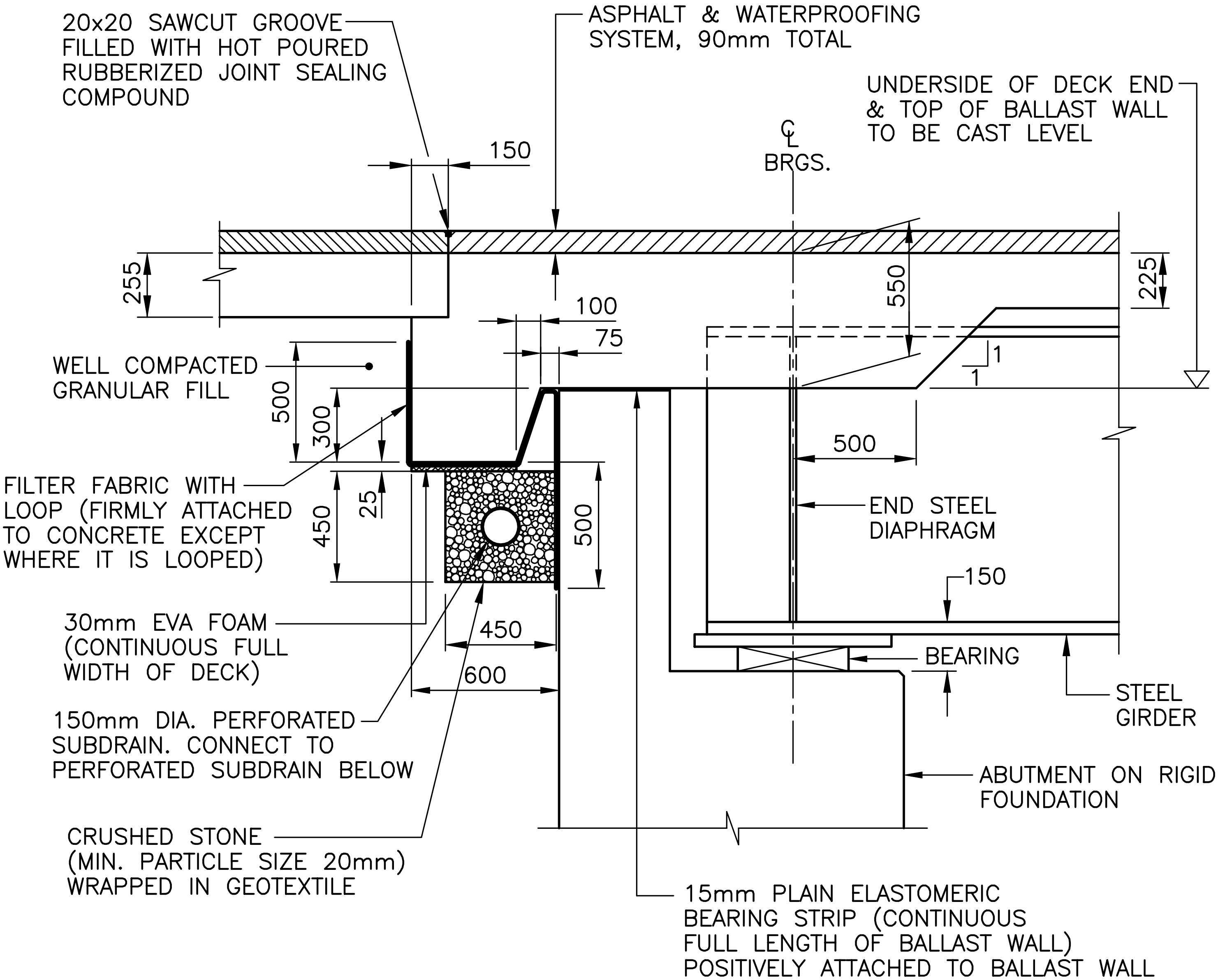
STEEL GIRDER WITH CONCRETE DECK OVERHANGING THE BALLAST WALL

FIG. 9



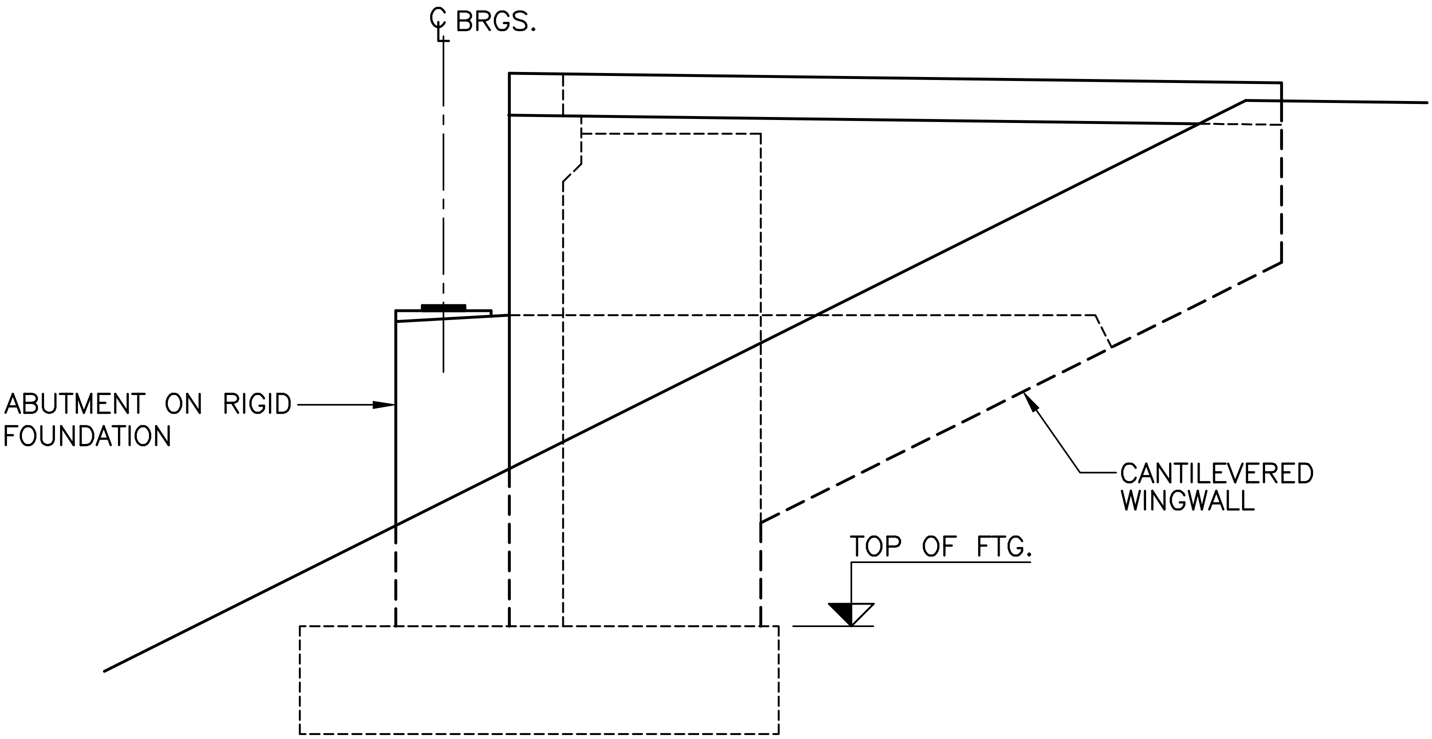
CPCI GIRDER WITH CONCRETE DECK AND END DIAPHRAGM

FIG. 10

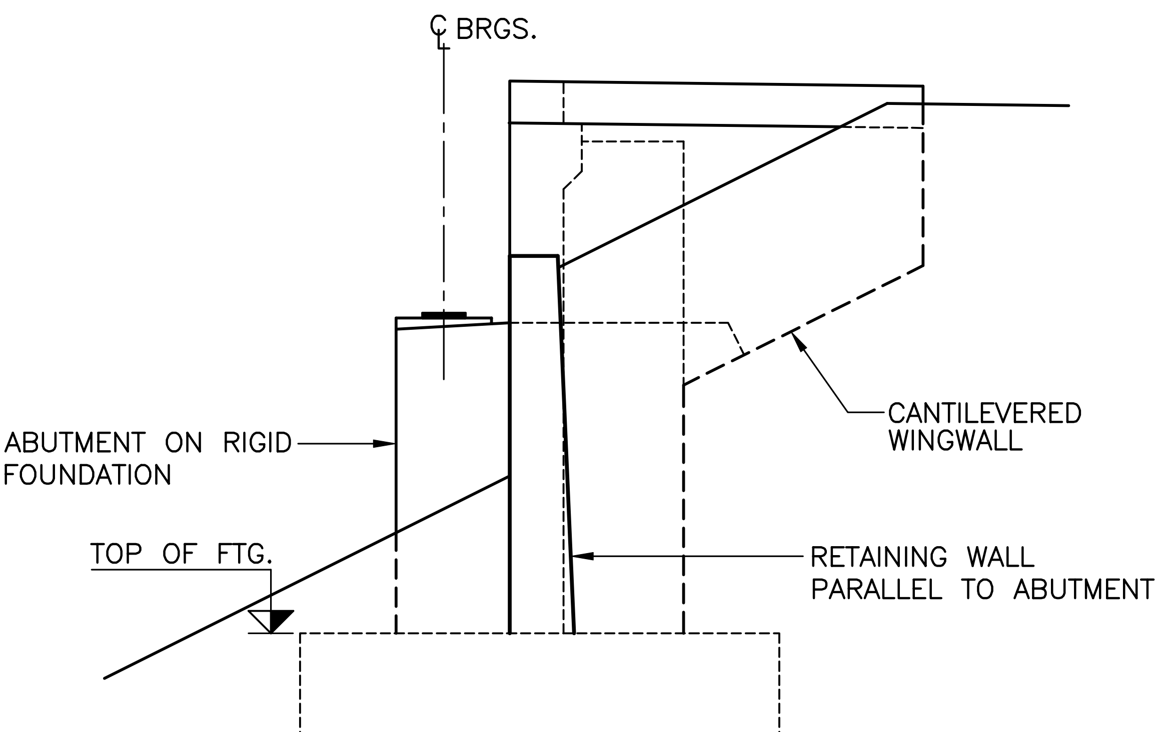


STEEL GIRDER WITH CONCRETE DECK OVERHANGING THE BALLAST WALL

FIG. 11

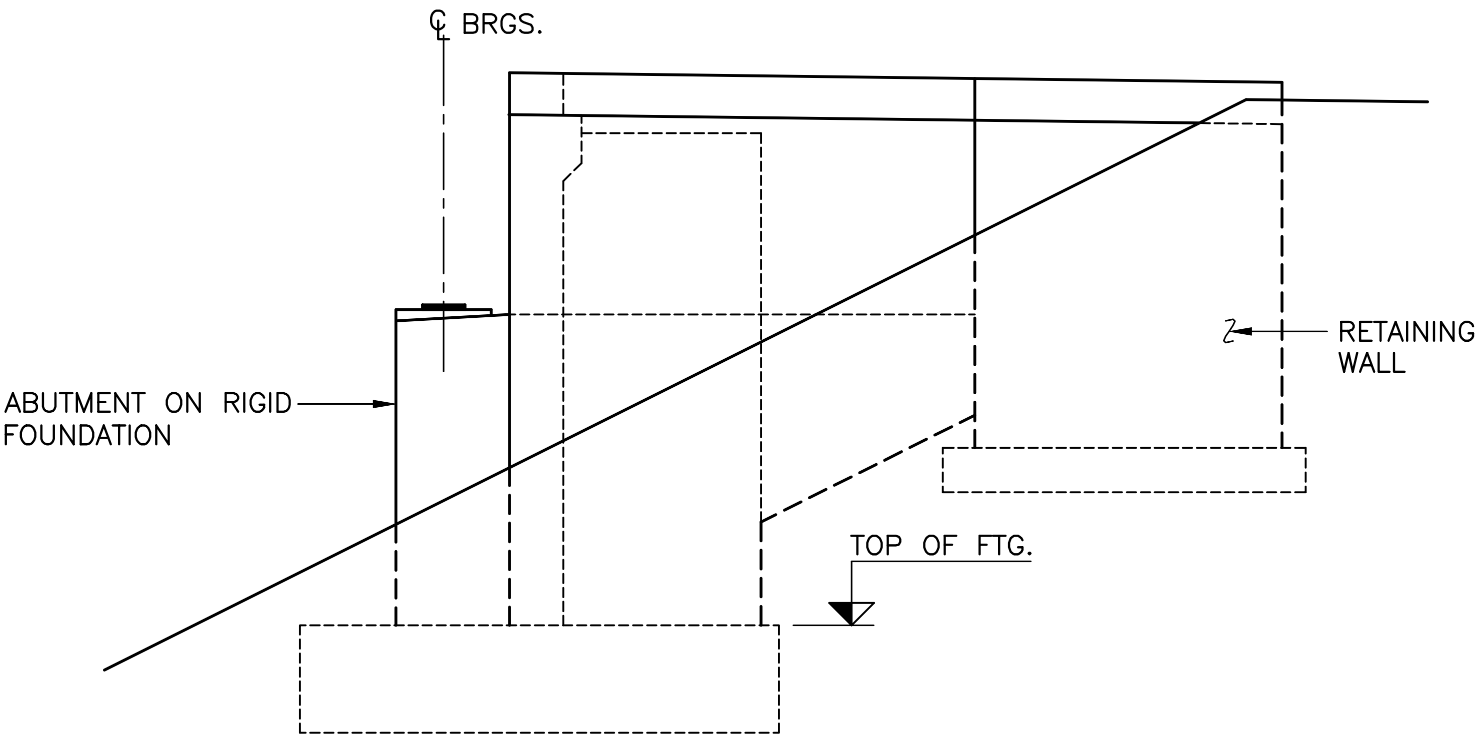


CANTILEVERED WINGWALL



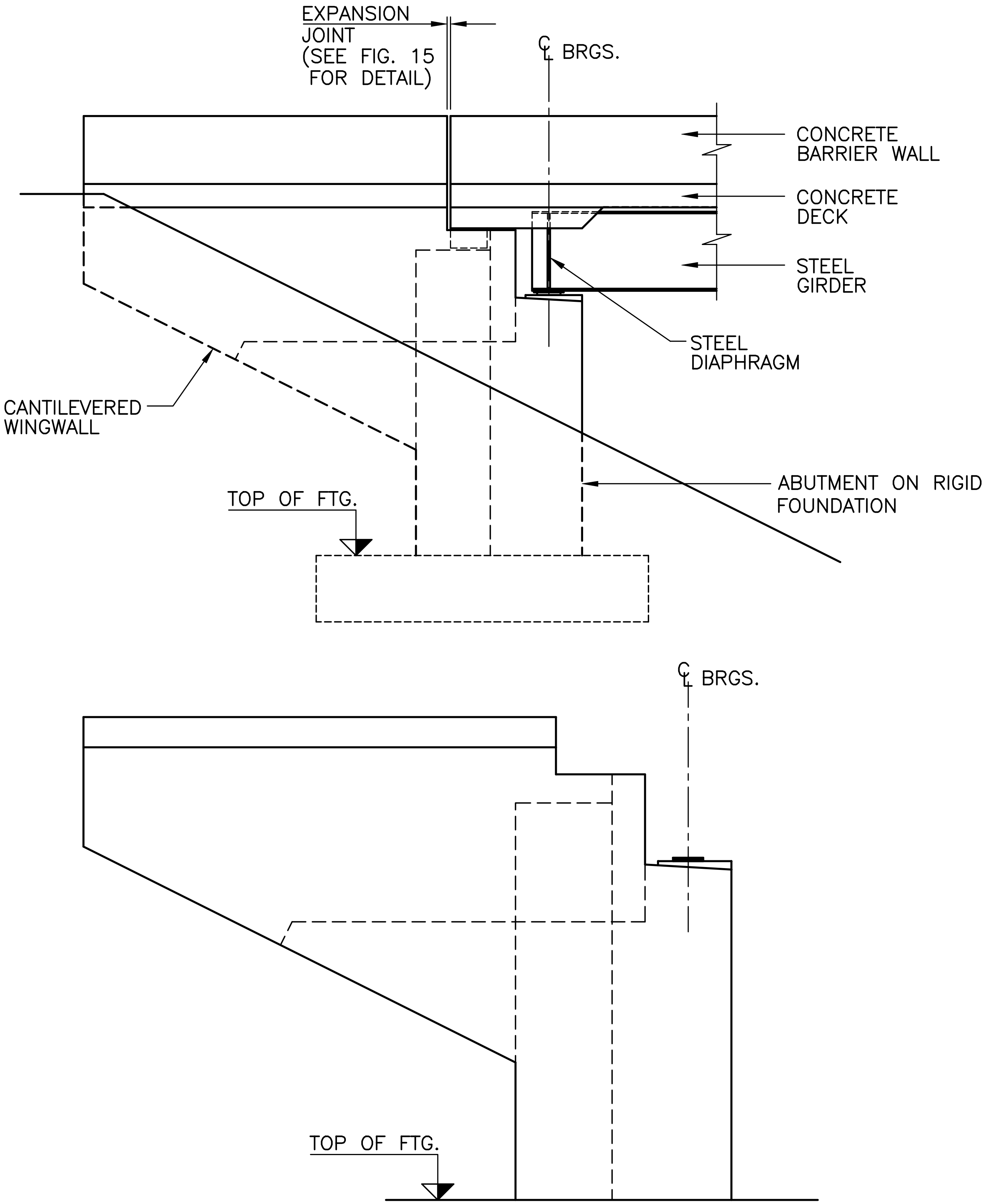
CANTILEVERED WINGWALL WITH RETAINING WALL PARALLEL TO ABUTMENT

FIG. 12



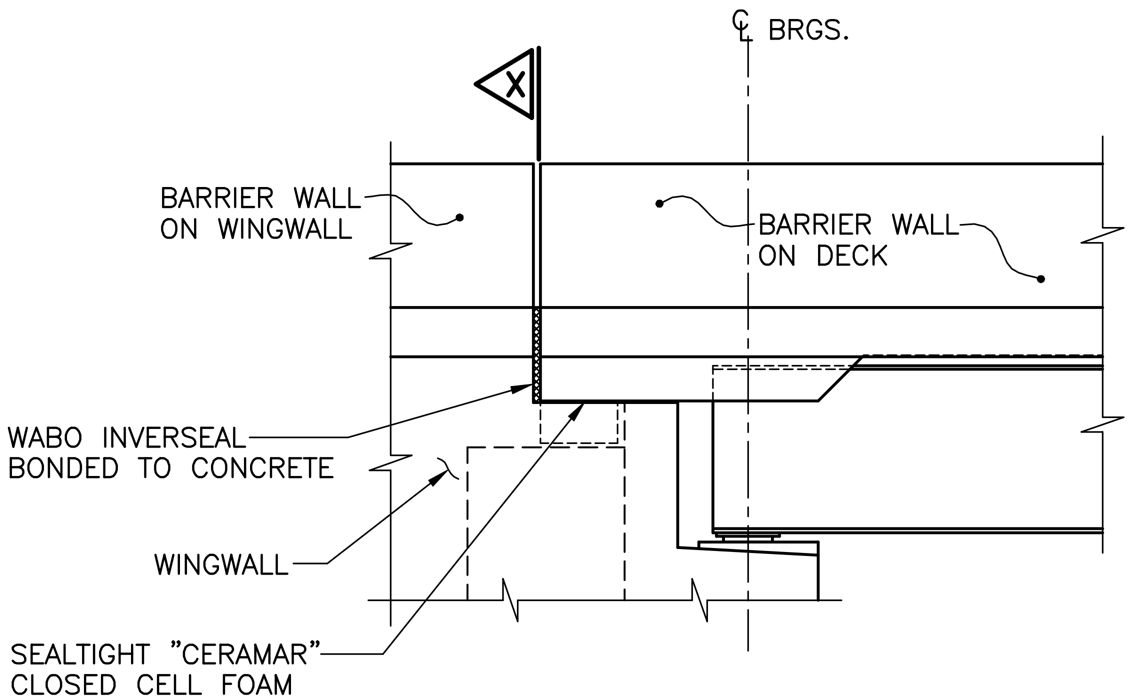
CANTILEVERED WINGWALL WITH RETAINING WALL

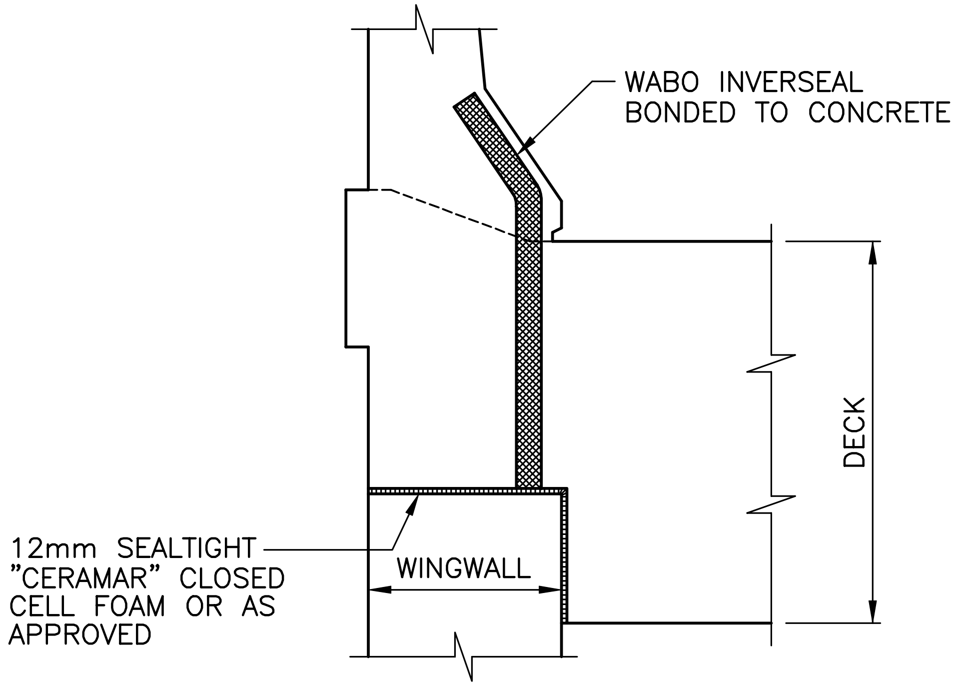
FIG. 13



WINGWALL DETAIL FOR DECK OVERHANGING THE BALLAST WALL

FIG. 14

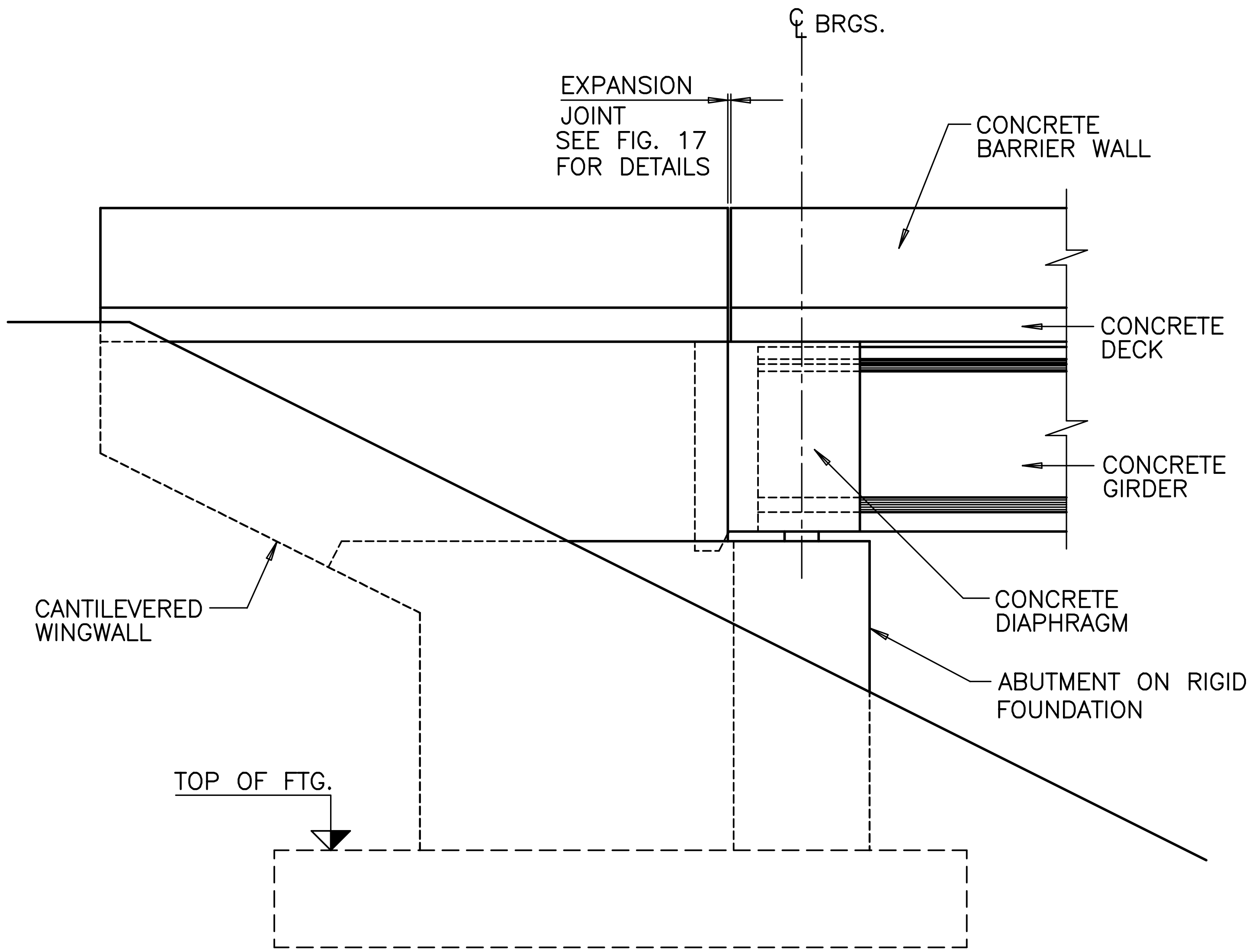




X

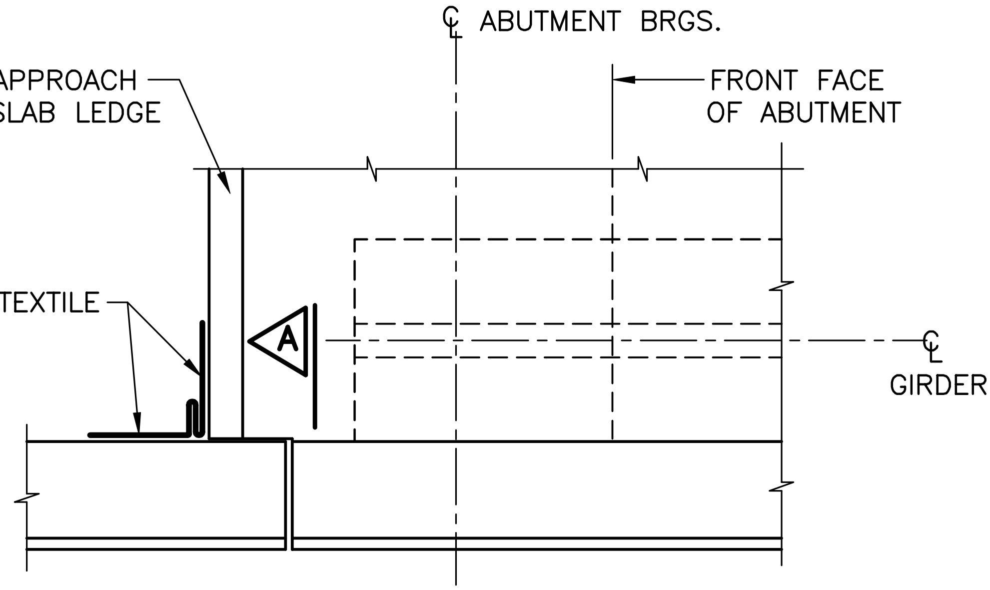
EXPANSION JOINT DETAILS (FIG. 14)

FIG. 15

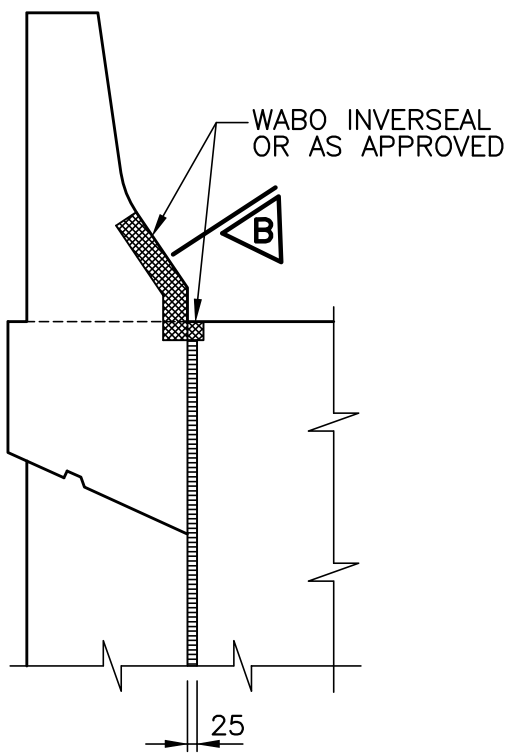


WINGWALL DETAIL FOR DECK OVERHANGING THE STUB ABUTMENT

FIG. 16



PLAN AT ABUTMENT DIAPHRAGM



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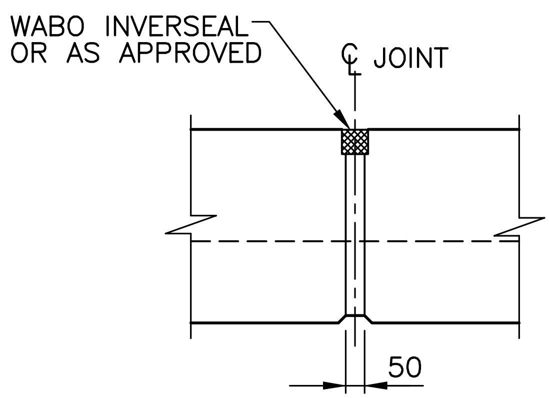
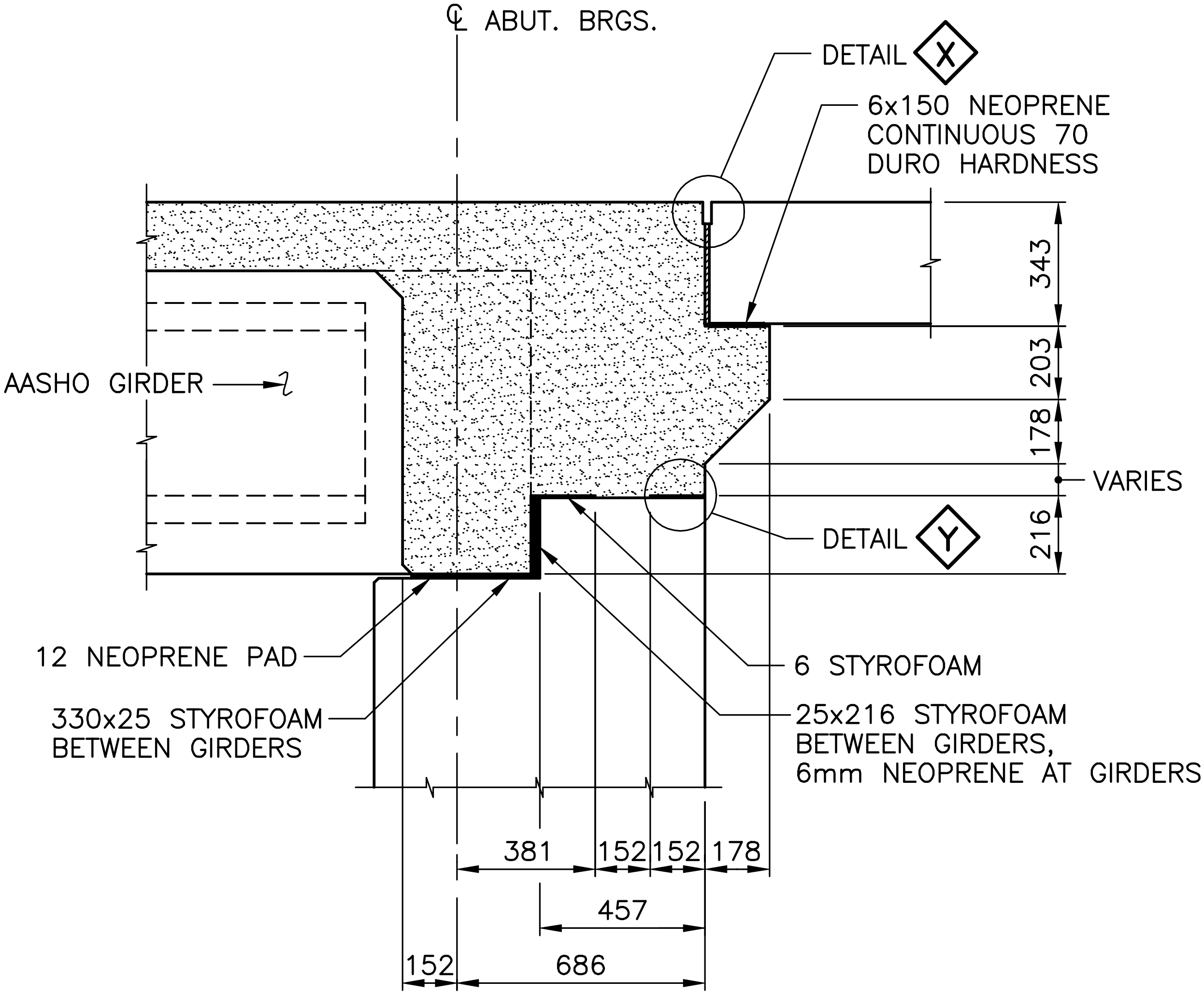


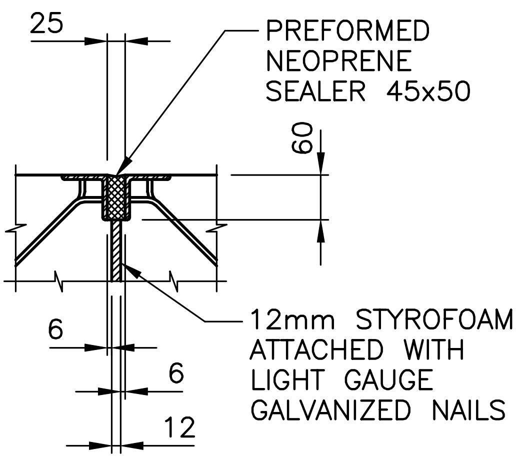
B

EXPANSION JOINT DETAILS (FIG. 16)

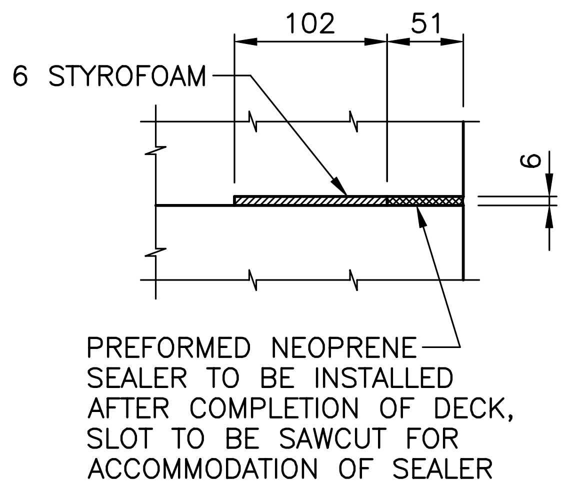
FIG. 17

Appendix





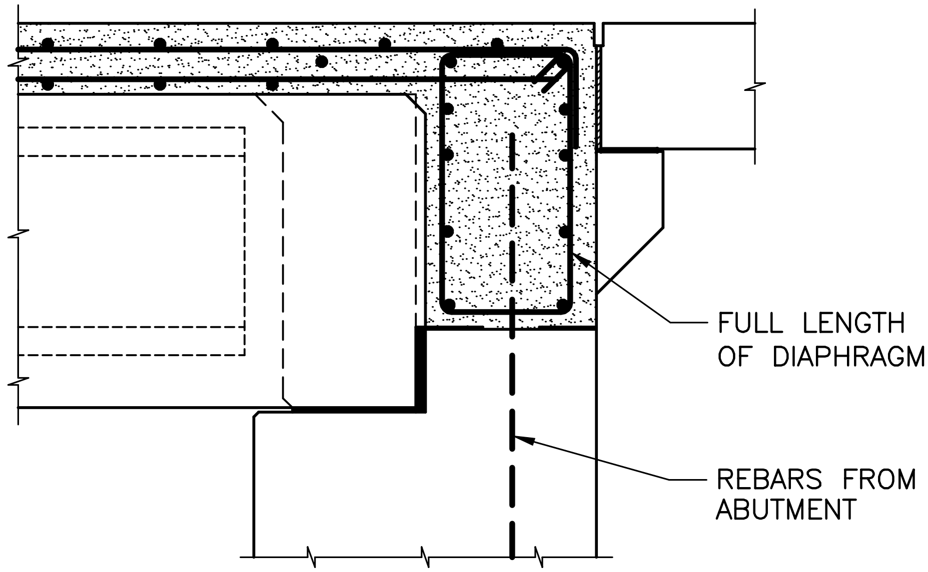
DETAIL X



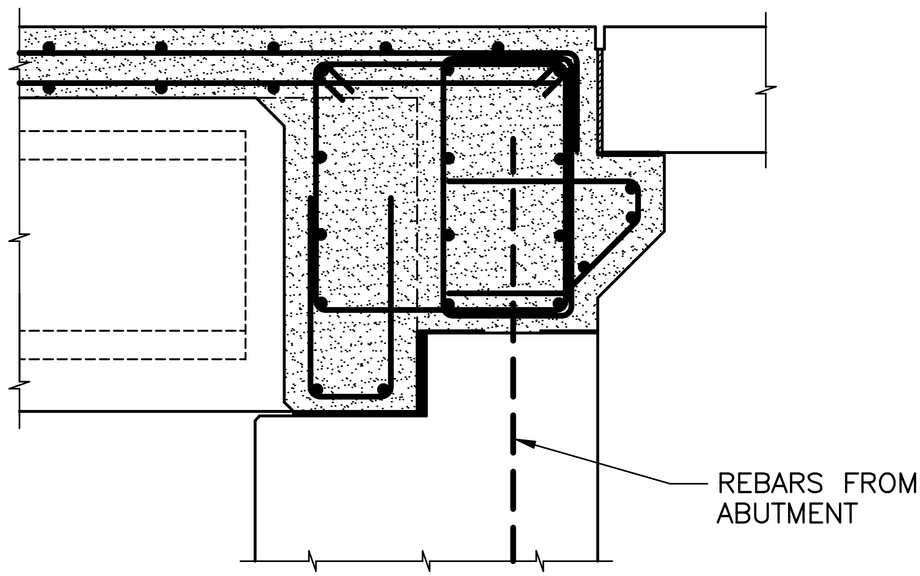
DETAIL Y

EARLIER SEMI-INTEGRAL ABUTMENT DETAILS

FIG. A1



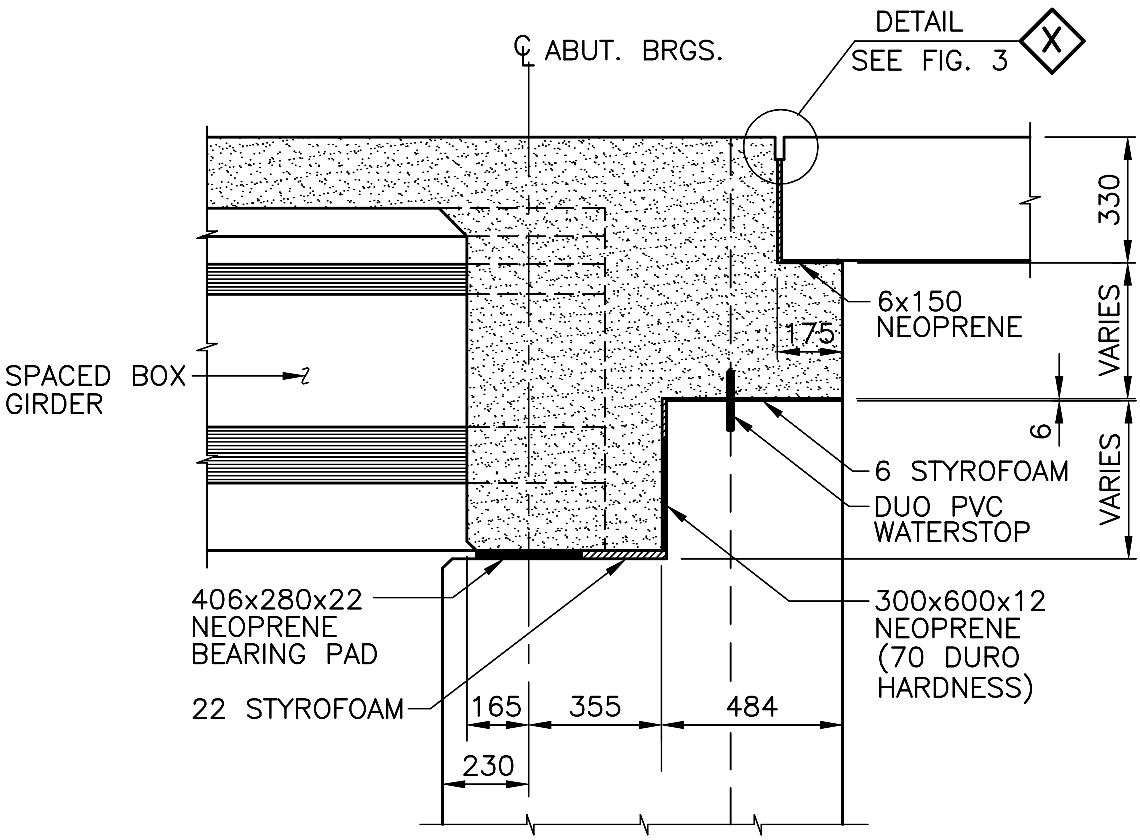
CROSS–SECTION AT GIRDER LOCATION



CROSS–SECTION THROUGH DIAPHRAGM

EARLIER SEMI–INTEGRAL ABUTMENT REINFORCING STEEL DETAILS

FIG. A2



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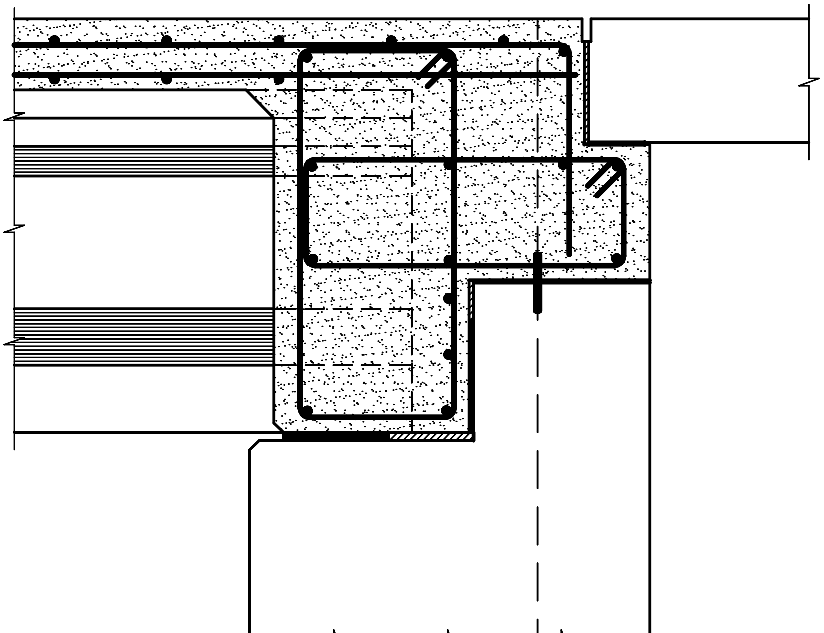
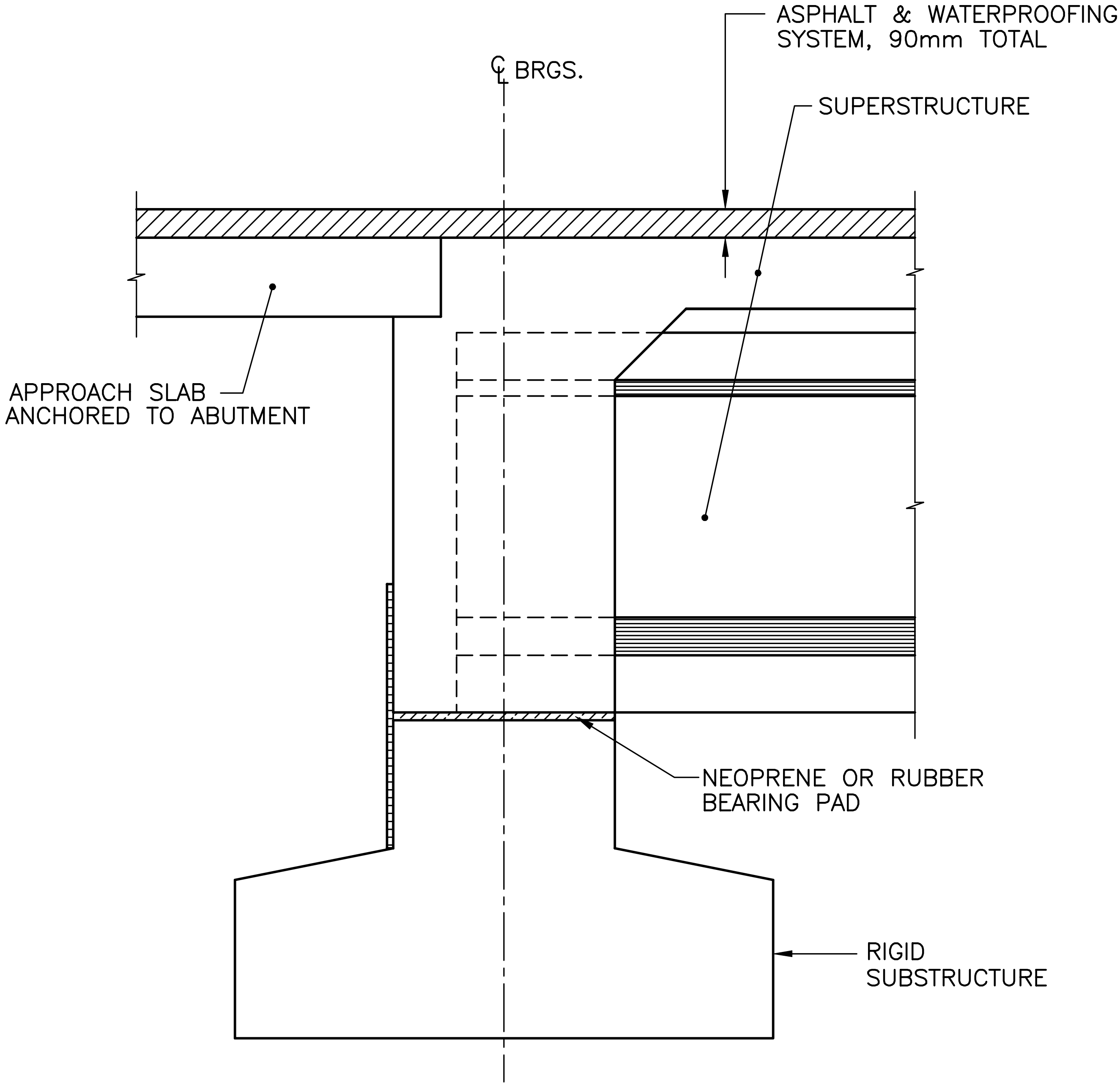


REINFORCEMENT

CROSS-SECTION THROUGH DIAPHRAGM

EARLIER SEMI-INTEGRAL ABUTMENT DETAIL

FIG. A3



SEMI-INTEGRAL ABUTMENT

FIG. A4