APPENDIX A

INTEGRAL ABUTMENTS

Appendix A – Guidelines for Design of Integral Abutments Rev. 1 - September, 2007

These guidelines draw on the experiences and practices from Ontario, the FHWA, various DOT's and the UK Highways Agency. **They provide guidance and outline the issues that need to be considered and should not be interpreted as restrictive on design innovations.**

Introduction

In the past, Alberta Transportation has experienced many maintenance problems related to bridge deck joints and bearings. Even waterproof joints eventually leak, and allow de-icing salt to reach major structural components. Joint hardware can be subject to damage from snowplows and pounding from heavy vehicles. Joints sometimes need to be raised or replaced because of bridge deck overlay installations. Joints and bearings are expensive to buy, install, maintain, repair and replace; and maintenance activities can cause major traffic interruption.

The development of moment distribution analysis and later the computer facilitated the design of bridge decks that are continuous over the piers with no deck joints, but joints and expansion bearings are still common at the abutments. In some instances, these structures behave as if there are no abutment deck joints after the abutments moved forward until they become jammed against the end of the bridge deck.

Later totally jointless integral abutment bridges were developed, and the accommodation of deck thermal movements was shifted away from the bridge deck ends to the structure/road interface at the end of the approach slab, where minor leakage could be readily handled. Today many US State DOTs and MTO (Ontario) routinely use integral abutment designs. Reports of performance over the last 20 years have been excellent, and the length of jointless bridges has grown to over 300 m.

In Alberta, many SCC type bridges with pinned-integral abutments are performing very well over the last ten to fifteen years. These bridges are mostly less than 50 m long, but there are a few up to 75 m. More recently, AT has been designing and building new integral bridges with longer spans and longer total lengths, and also converting many existing bridges into integral bridges in rehabilitation projects. It should be noted that approximately 95% of all bridges in Alberta are shorter than 100 m.

The following is a list of the advantages of integral abutment bridges:
1. Reduced initial cost and long term maintenance.
2. Elimination of deck joints.
3. Elimination of bearings, anchor bolts, grouting etc., resulting in less tolerance restrictions and faster construction.
4. Smoother ride across bridges because there are no joints.
5. Elimination of leakage onto critical structural elements.
6. Reduced number of foundation piles.
7. Elimination of potential for tilting piers.
8. Increased reserve load capacity and load distribution, resulting in more resistance to damaging effects of illegal overloads.
9. Provides resistance to uplift at abutment end.
10. Reduced end span to interior span ratio will allow longer interior spans for underpassing roadways and streams.

Types of integral abutments

1. **Full integral abutment on piles** (Fig. 1 & 2) – full monolithic connection between end of superstructure and abutment. Single line of steel H-piles flex to accommodate thermally induced bridge deck movements. This is the most efficient design in most situations and every effort should be made to achieve full integral construction.
2. **Full integral abutment on spread footings** (Fig. 3) – full monolithic connection between end of superstructure and supporting footing. Suitable for short stiff girders with small end rotation and expansion movements.
3. **Pinned-integral abutment** (Fig. 4) – pinned bearing between superstructure and abutment, where it is desirable to eliminate transfer of moments and rotations between abutment and girder ends.
4. **Semi-integral abutment with sliding bearings** (Fig. 5) – superstructure with no deck joints slides over fixed abutment seat, applicable where superstructure loads are too heavy for small flexible piles, or expansion movements are large, or foundation conditions do not permit flexing of supporting piles.

Cyclic movement control joints

The elimination of bridge deck joints does not eliminate the need for joints to facilitate cyclic thermal movement. Jointures bridges will still expand and contract in response to changes in temperature. However, the magnitude of the movements will be reduced due to passive pressure on abutment end diaphragms, and pier and abutment stiffness. The joints are shifted to the end of the approach slab or roof slab, where minor leakage can be tolerated or handled. The approach slab or roof slab, tied to the ends of the structure, adds to the length of the structure responding to the cyclic temperature variations.

Joint type C1 (Fig. 6) **-** Many short integral abutment bridges have been built with the only evidence of movement showing in the form of a crack at the end of the approach slab. These cracks are of a minor nature and do not appear to present any problem. A simple pavement joint with fibreboard and an approved hot asphaltic sealant should suffice.

Joint type C2 (Fig. 7) **-** For intermediate length bridges, the joint sealant can debond and the joints can be opened during the contraction cycle. This can allow debris accumulation and roadway drainage to penetrate the joints. To prevent pavement pumping, the subgrade should be protected by providing a sleeper slab under the end of the approach slab, complete with weeping drains to channel any leakage. This design is simple and can be very cost effective for bridge sites with light traffic. The degradation is a somewhat long time process (5 to 10 years), and will eventually cause some local pavement failure and a bump. The bump is a minor problem to fix compared to deck joint maintenance. This joint can be retrofitted with a neoprene compression seal sometime after the head-slope and abutment backfill has settled down and stabilized. Where open joints across sidewalks can become hazardous to pedestrians, sliding cover plates should be provided.

Joint type C3 (Fig. 8) – For intermediate length bridges on main highways, where it is desirable to avoid traffic interruptions due to joint maintenance, a steel armored compression seal can be provided. The compression seal will prevent entry of debris but may allow acceptable minor leakage. Alternatively, an asphalt plug joint may be considered.

Joint type C4 (Fig. 9) **-** For long bridges, a large neoprene strip seal or finger joint may be required. These large joints cannot tolerate settlement and requires structural support from a piled grade beam. A roof slab, tied to the end of the bridge deck and complete with integral curbs to channel drainage, can span from the girder end to the grade beam. An approach slab is then provided beyond the roof slab. This arrangement may also be considered for intermediate length bridges with high traffic volumes.

The following table provides general guidance for joint types for various bridge lengths. The difference in concrete and steel bridge lengths is due to the greater mass of concrete which provides a heat sink, and the greater sensitivity of steel in reacting to temperature changes. The differences in thermal response is reflected in the provisions of CSA-S6-06 in clause 3.9.4 - temperature effects, clause 8.4.1.3 - coefficient of expansion (concrete), and clause 10.4.12 coefficient of expansion (steel). When using this table, engineering judgement with due considerations for site specifics, such as traffic type and volume, is required.

Steel girder bridges	Concrete girder bridges	Joint type	Approx. movement range
< 40 m	< 50 m	C1	< 16 mm
40 m to 75 m	50 m to 100m	C2 or C3	16 < range < 32 mm
> 75 m	> 100 m	C4	> 32 mm

<u>Drainage</u>

To ensure a successful and durable design, good drainage details must be incorporated. The goal should be to minimize the amount of water from the bridge deck (by providing deck drains), or the approach highway that will go over the approach slab, and also to ensure that joints around the approach slab are well sealed to prevent water infiltration. Even the best attempt to seal joints cannot prevent some leakage from time to time between maintenance cycles. It is therefore important to design a secondary system of sub-soil weeping drains to collect, channel and remove the seepage.

<u>Best practice recommendations</u>

1. Use full monolithic integral abutments as far as possible.
2. Effects of skew and potential for twisting of superstructure on plan shall be analyzed and accounted for, especially for skew greater than 20°. Consider semi-integral abutment for high skews.
3. Minimize the amount of structure and earth that have to move with the abutment during thermal movement of the superstructure. Suggest limits for abutment seat height < 1.2 m, and wing wall length < 8 m. Use turned-back wing walls parallel to the roadway designed to cantilever from the end of the superstructure. Where necessary, steepen headslope locally to reduce the length of the wing wall.
4. Avoid high abutment walls except for short spans where anticipated movements are small and can be easily tolerated. When large abutments are required for the design, an independent retaining wall system that does not move with the integral portion (Fig. 10) should be considered.
5. Use single row of steel H-piles and orient piles for weak axis bending wherever possible. For large movements, piles can be installed in permanent steel casings. Due to concerns of compaction of loose sand or earth fill material over time, it is preferable to fill the casing with Styrofoam pellets. Steel casing should be designed to last the same life as the bridge, and an appropriate sacrificial corrosion thickness or galvanizing should be considered. Embed H-piles at least two pile sizes into the abutment seat. Use the smallest pile section permitted for drivability and strength.

6. Use steel H-piles for maximum ductility and flexibility in cyclical bending. Stiffer steel pipe or concrete piles are not recommended.
7. The approach slab should preferably extend 0.5 m longer than the wing walls such that the cycle control joint is located beyond the end of the wing walls. Settlement due to sub-soil conditions should be reduced or eliminated by surcharging or pre-building the headslope. Where necessary, considerations should be given to increasing the length of the approach slab to account for anticipated settlement. A rule of thumb is a grade change of 0.5% to 0.8 % after settlement has occurred.
8. Soil/structure interaction caused by thermal movements will generate passive pressures behind the abutment end diaphragms. Abutment movements of 60 mm to 80 mm are required to mobilize full passive pressure in the granular backfill. Compressive stresses generated by passive pressure against the end of the superstructure are structurally beneficial and will reduce cyclical movements at the end of the approach slab. Girder stresses due to earth pressure are generally low but should be included in the girder design. Girders generally have no problems with pushing against and compressing the backfill.
9. Passive pressures at the bridge ends can be utilized to resist longitudinal forces on the superstructure. For this purpose, a minimum end diaphragm depth of 1.2 m is recommended. Long term shrinkage and creep of prestressed girders is a single gradual movement while the backfill is disturbed on a daily basis. Shortening of the deck will therefore not cause a gap to form between the backfill and the back face of the abutment.
10. The effects of installing expansion foam material behind integral abutments for the purpose of relieving earth pressure are questionable. Such foam material is unnecessary and not recommended. The soft material can get compressed or punctured by backfill compaction during construction. In the longer run, cyclical movements may cause progressive plastic compression, and it is unlikely that the expansion material can expand against the backfill. This may also promote unequal movements at the two abutments, resulting in a net shift to one side for the whole structure.
11. Water penetration can be especially serious when the bridge and approach slabs are provided with curbs, as accumulated drainage from the bridge deck can be channeled along the curbs into the cycle control joints. Do not slide approach slabs in and out between stationary and parallel non-integral wing walls. This type of movement will make it impossible to seal the parallel joints and the approach slab may also be prone to jamming between the wing walls. Provide Sheet wall drain spot-glued to the earth face of the abutment and wing walls to intercept and channel seepage into a perforated weeping drain that will be day-lighted on the headslope.
12. Use ‘Designation 2 Class 25’ granular backfill compacted to 95 % Proctor density behind integral abutments, complete with perforated weeping drains under the abutment seat and wing walls.
13. Effects of construction sequence should be duly considered. Provide extra re-bar in the deck in the vicinity of the abutment end diaphragm, for forces and reactions from deck end rotation, crack control, any differential shrinkage due to pretress, and the effects of the concrete pour sequence. Provide temporary sliding mechanism for post-tensioning shortening where necessary..
14. Provide two layers of polyethylene sheet or a fabric under the approach slab to minimize friction against horizontal movement. Provide generously sized anchor dowels for tying the approach slab to the end of the superstructure. Dowels should be located to provide free hinge rotation without causing restraining moments.
15. Movement on guardrail transition posts attached to the end of bridgerails can generally be accommodated by soil deformation for bridge lengths less than 100 m. For longer bridges, consideration may be given to providing short expansion slotted holes in the terminal

connection. Such slotted holes should be kept very short such as not to excessively weaken the crash tested guardrail transition.

Structural analysis and design

Detailed structural analysis can be handled by many computer programs and is not covered in these guidelines. Guidance for frame analysis and soil/structure interaction can be found in references 1 & 2.

References

1. ‘Integral Abutment Bridges’ Report SO-96-01, Ministry of Transportation of Ontario.
2. ‘Integral Bridges’ Imperial College & Highways Agency (Publisher - Thomas Telford Ltd.)
3. ‘Performance of Integral Abutment Bridges’ Report BO-99-04, Ministry of Transportation of Ontario.

List of figures

Contact

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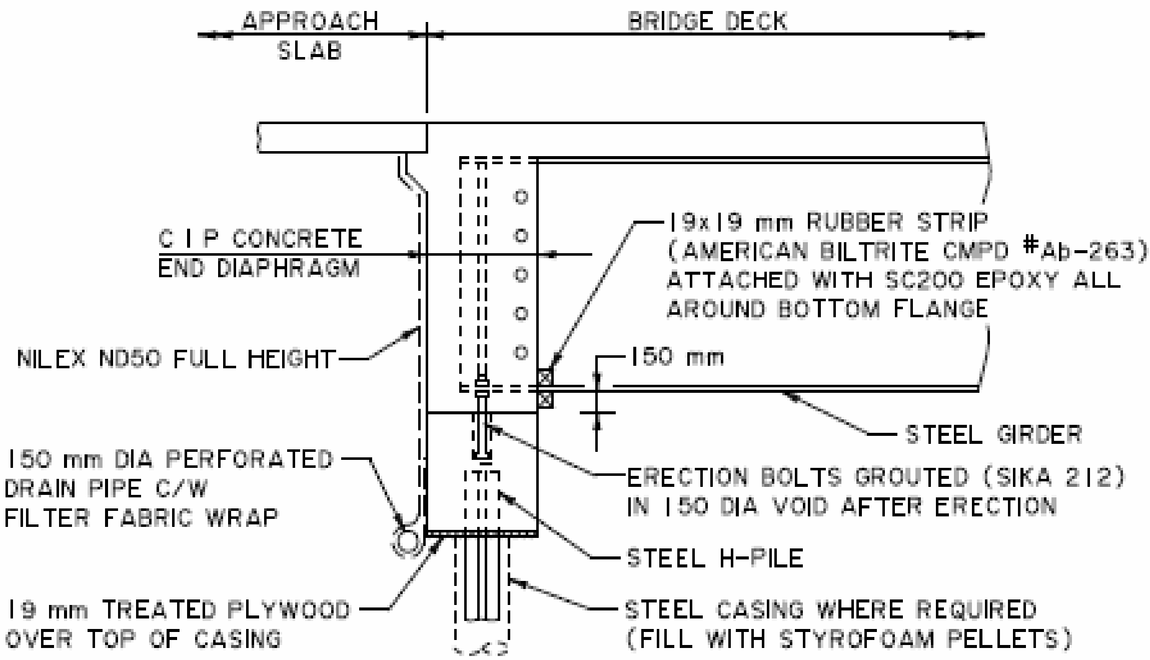

FIG 1 FULL INTEGRAL ABUTMENT ON PILES - STEEL GIRDER

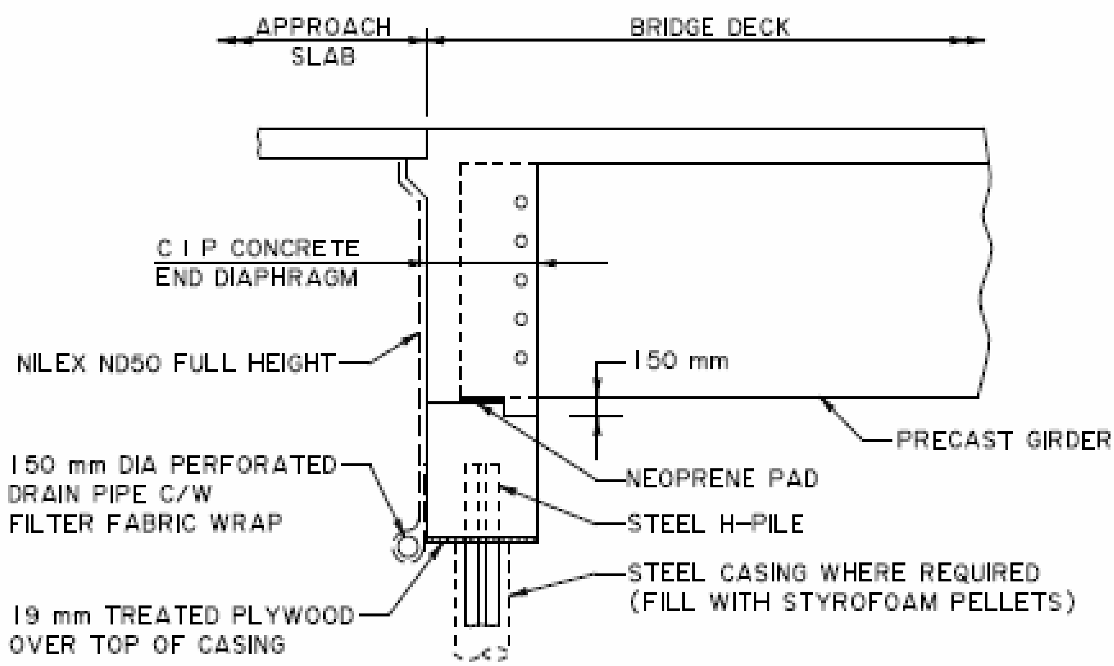

FIG 2 FULL INTEGRAL ABUTMENT ON PILES - PRECAST GIRDER

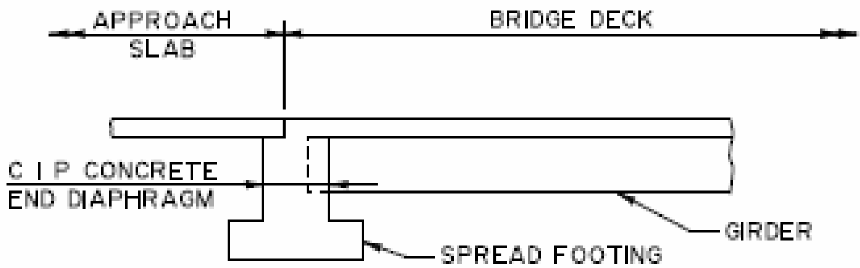

FIG 3 FULL INTEGRAL ABUTMENT ON SPREAD FOOTING

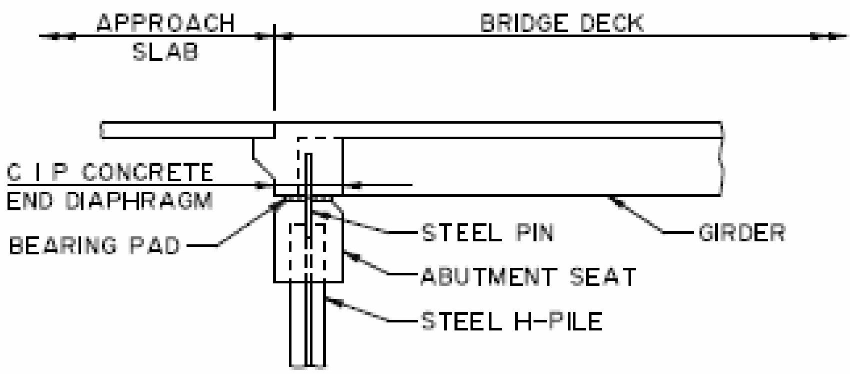

FIG 4 PINNED - INTEGRAL ABUTMENT

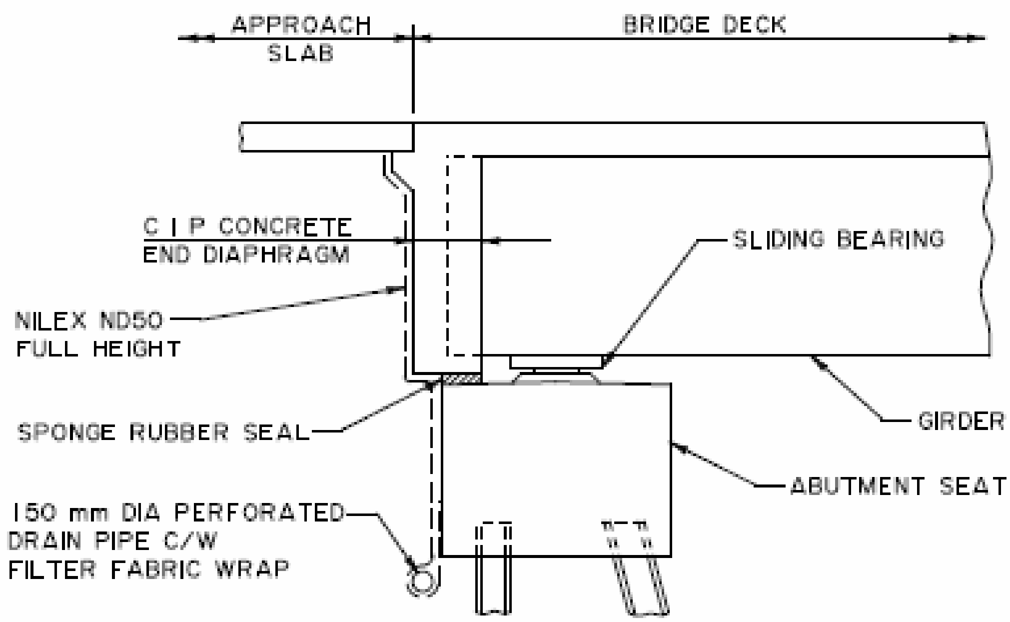

FIG 5 SEMI - INTEGRAL ABUTMENT ON SLIDING BEARING

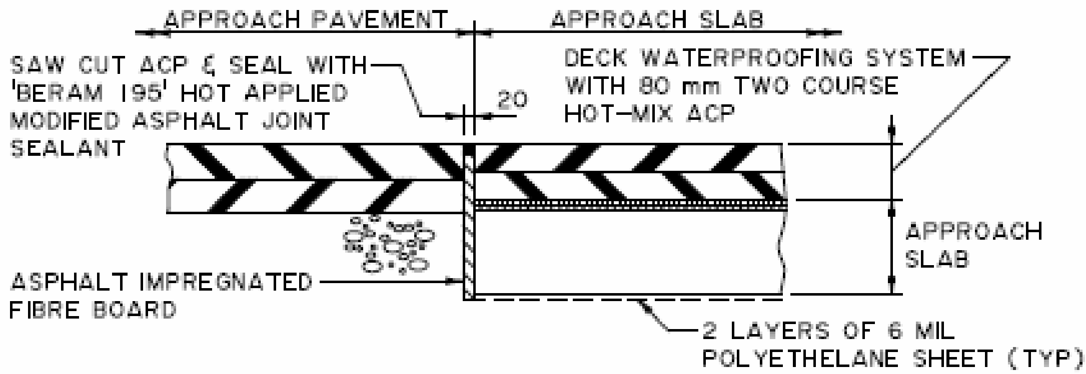

FIG 6 CYCLE CONTROL JOINT TYPE 1

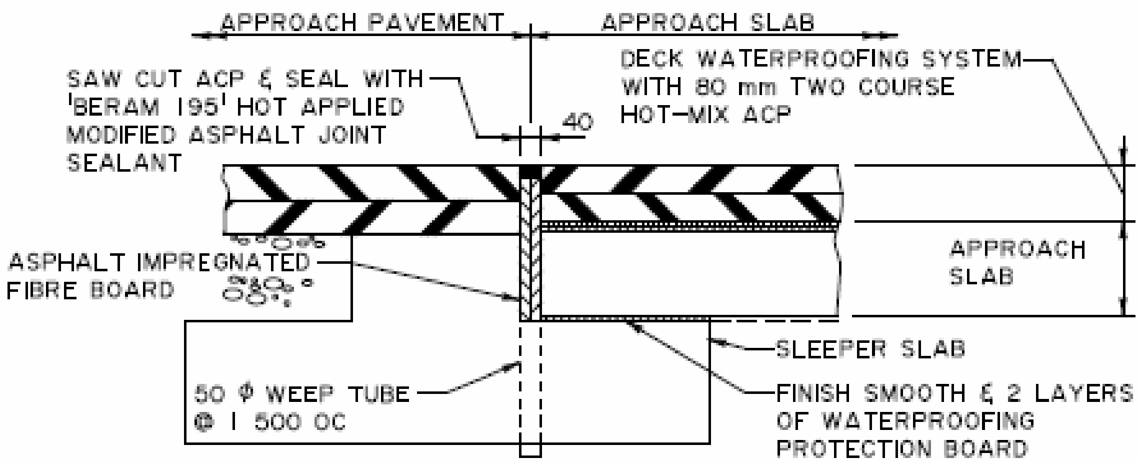

FIG 7 CYCLE CONTROL JOINT TYPE 2

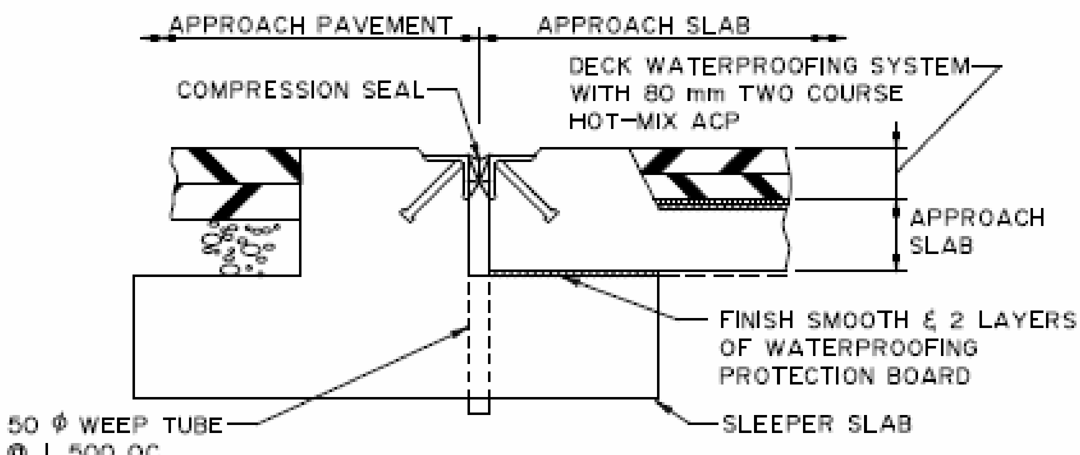

FIG 8 CYCLE CONTROL JOINT TYPE 3

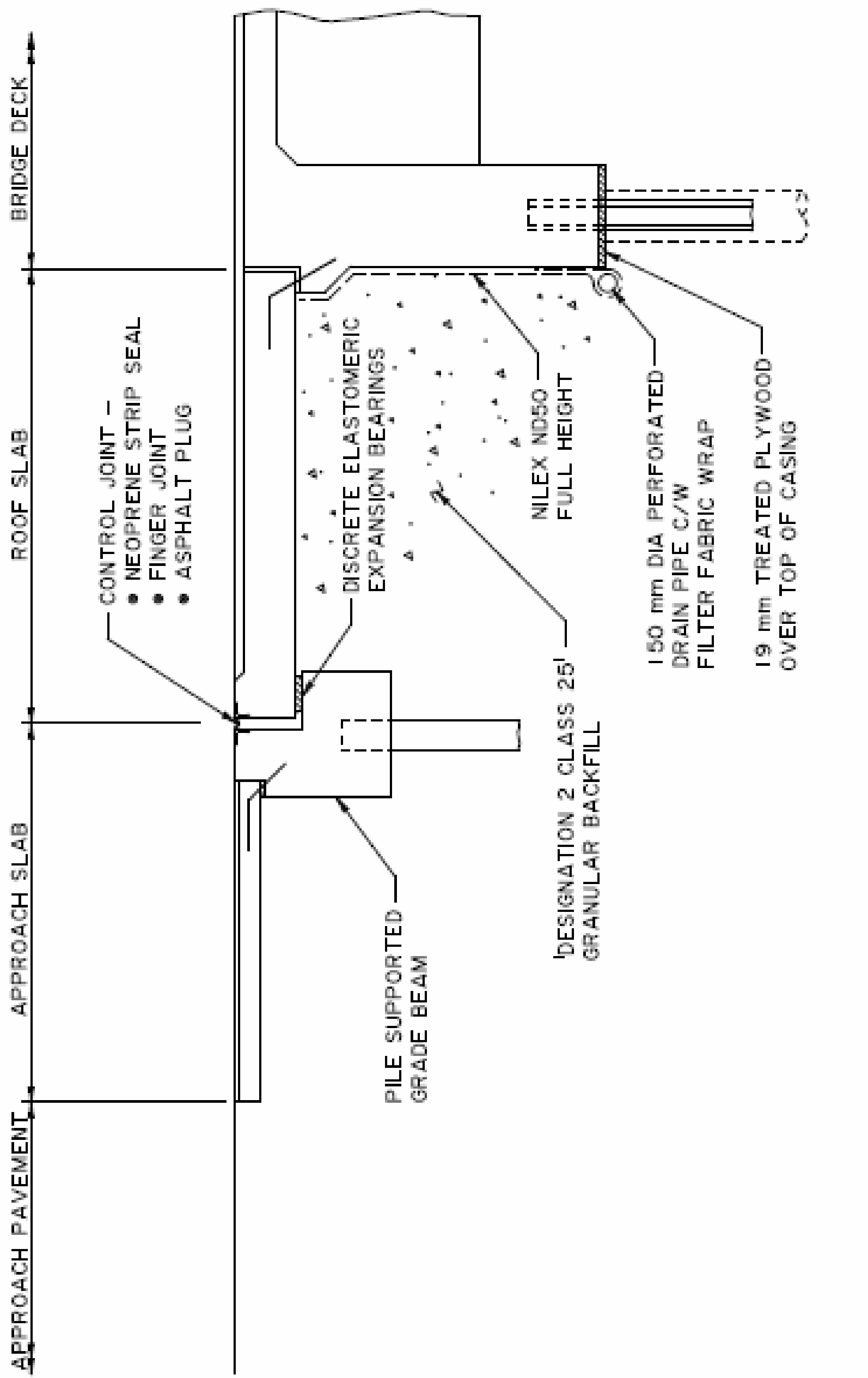

FIG 9 CYCLE CONTROL TYPE 4

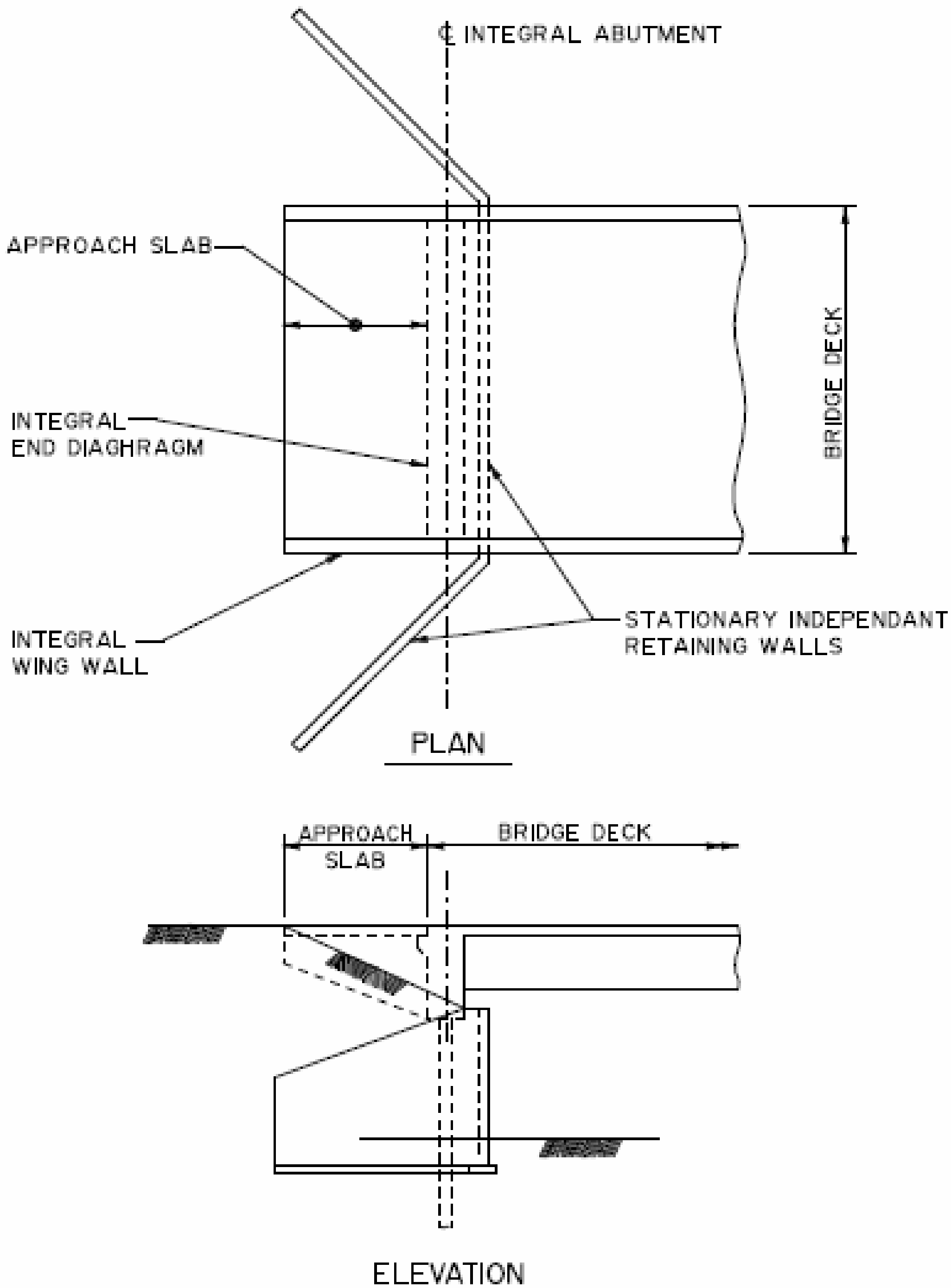

FIG 10 INTEGRAL ABUTMENT AND
INDEPENDANT RETAINING WALL COMBINATION