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Transportation

Ontario

Structural Office

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Fisher Mills Creek Bridge Hwy 24N

Integral Abutment Bridges

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

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INTRODUCTION

In 1993, the Ministry of Transportation of Ontario prepared a report (SO-93-01), on Integral Abutment Bridges. The report highlighted some of the important features, rationalized the design method and imposed limitations based on the available information and literature at the time.

In recent years, Integral Abutment Bridges have become very popular due to the economic, functional, and durability advantages of these structures. Many new structures have been constructed by the Ministry and the various municipalities and their use is likely to increase in future.

This report reflects the experience gained by the Ministry since issuing the 1993 report and to serve as a guide for designers. The purpose of the report is to make the users aware of some of the limitations of Integral Abutment Bridges and to provide a basis for the planning and design. This report is not intended to limit the innovation and more refined methods of analysis are encouraged.

The computer program presented in the report was developed in the Design Section of the Structural Office for internal use and is not supported or intended for general use. If required, copies of the program may be obtained by contacting the Manager of the Design Section. No warranty expressed or implied is made by the Ministry of Transportation of Ontario as to the accuracy and functioning of the program, nor shall the fact of distribution constitute any such warranty, and no responsibility is assumed by the Ministry of Transportation in any connection therewith.

INTEGRAL ABUTMENT BRIDGES

"Integral Abutment Bridges" are single or multiple span structures with a continuous concrete deck and approach slabs, integral with abutments supported on flexible foundations. Expansion joints and bearings at the ends of the deck are replaced with isolation joints at the ends of the approach slabs. Fig. 1 shows a typical integral abutment bridge. They differ from rigid frame bridges in the manner of disposition of stresses due to temperature change, prestressing, creep and shrinkage, and restraints provided by abutment foundation and backfill. The effect of the longitudinal forces in the structure is minimized by making the abutment foundations flexible and less resistant to longitudinal movements.

Small span bridges have been designed with integral abutments supported on narrow spread footings capable of providing small rotations as shown in Fig. 2. The behaviour of the structure and its durability is greatly influenced by the movement requirement and detail of the footing. It is therefore restricted to structures of less than 25m in length on secondary highways only. Alternatively, further consideration may be given to details providing a semi-integral arrangement. "Semi -integral bridges" are single span or multiple span continuous deck type bridges with rigid non-integral foundations and a movement system composed primarily of reinforced concrete end diaphragms, approach slabs, movable bearings and horizontal joints at the super-structure and abutment interface as shown in Fig 3. This arrangement should be considered where an integral arrangement cannot be used due to unfavourable foundation conditions.

PLANNING CONSIDERATIONS

The economic and functional advantages, and improved durability of integral abutment bridges, due to the elimination of costly and maintenance prone expansion joints and bearings, are generally recognized by bridge engineers. However, not every site is suitable for this type of bridge and it is necessary to determine the feasibility early in the planning stage.

The feasibility of an integral abutment arrangement is influenced by the following factors:

I) Length of Structure:

It is intended that, for the present, where the overall length of the structure is less than 150m, it shall be considered for design as an integral abutment bridge. Bridges with lengths more than 100m but not exceeding 150m shall be considered for integral abutment design provided that adequate measures are taken to account for the movement and its effects. Such measures should be discussed and approved by the Ministry. In considering the movement requirements, due consideration should be given to the place and type of joints, joint seal, bearings, backfill and approach slab details and construction temperatures. Bridges with length less than 100m shall be constructed with an expansion joint at the end of approach slab as shown in Fig. 4. The limitation placed on the total length of the structure is mainly a function of local soil properties, seasonal temperature variations, resistance of abutment foundations to longitudinal movements and the type of superstructure being considered. In the absence of a rigorous theoretical or experimental study, there are self imposed limitations on lengths by various authorities, resulting from their experience with the performance of their structures.

ii) Type of Superstructure:

Types of superstructure to be used with integral abutments include:
1. Steel girders with concrete deck;
2. CPCI girders with concrete deck;
3. Prestressed box girders with concrete deck.

Cast-in-place post-tensioned deck type structures are not normally used with integral abutments because of the large movements, resulting from shrinkage and creep and elastic shortening due to prestressing forces.

iii) Geometry of Structure:

The geometry of the structure should be considered in deciding the feasibility of integral abutment design. Owing to the non-uniform distribution of loads and difficulties in establishing the movement and its direction, structures with skews greater than 35°or where an angle subtended by a 30m arc along the length of the structure is greater than

5° are not considered suitable for integral abutment designs. Skews greater than 20° but not exceeding 35° may be considered if a rigorous analysis is carried out to account for the skew effects. In carrying out the analysis for skew, effects such as torsion, unequal load distribution, lateral translation, pile deflection in both longitudinal and transverse direction and increase in the length of the abutment exposed to soil pressure shall be considered.

iv) Abutment height & wingwalls:

It is recommended that abutment height and wingwall length shall be limited to 6.0m and 7.0m respectively. The abutment should be kept as short as possible to reduce the soil pressure, however, the minimum penetration required for frost protection should be provided. The frost penetration requirement can be reduced to minimize abutment height by providing insulation at the bottom of the abutment. It is recommended that abutments be of equal height. A difference in abutment heights causes unbalanced lateral load resulting in sidesway, which should be considered in the design. The design procedure requires an iterative process in order to determine a sidesway value such that the corresponding earth pressure on the short leg plus the base shear of the frame would balance the earth pressure on the high leg. Wingwalls parallel to the roadway, carried by the structure, shall be used and their size should be minimized to allow the substructure to move with minimum resistance.

v) Multi-span Structures:

The spans and the articulation at the supports 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 the piers, made fixed in the lateral direction or move laterally, as appropriate. The piers should be flexible and supported on the flexible foundations if made integral with the deck diaphragms.

vi) Sub-soil Conditions:

Sub-soil condition is an important consideration in the feasibility study for the selection of integral abutment arrangement. The primary criteria is the need to support the abutments on relatively flexible piles. Therefore, where load bearing strata is near the surface or where the use of short piles, less than 5.0m in length or caissons is planned, the site is not considered suitable for integral abutment bridges. Where piles are driven in dense and stiff soils, pre-augered holes filled with loose sand shall be provided to reduce resistance to lateral movement. The gradation for the sand shall be as given in Table 1. Where the soil is susceptible to liquefaction, slip failure, sloughing or boiling, the use of integral abutment arrangement should be avoided.

Table 1

MTO Sieve Designation		Percentage Passing Mass
2 mm	#10	100%
600 μm	#30	80% - 100%
425 μm	#40	40% - 80%
250 μm	#60	5% - 25%
150 μm	#100	0% - 6%

DESIGN CONSIDERATIONS

Loads:

Integral abutment bridges shall be designed to resist all the vertical and lateral loads acting on them individually and in combination. The combined load effects on the structure at various stages of construction should be considered in the design. The stages at which the structure is simply supported, then made integral with abutments and backfilled are of primary importance. The vertical loads include dead loads, superimposed dead loads, live loads including dynamic load allowance, and thermal gradients. Horizontal loads include braking force, soil pressure, seismic load as well as the induced loads due to temperature, shrinkage and creep.

Design and Analysis:

The connection between the superstructure and the abutment is normally assumed pinned for girder design and analysis. The girder is designed for dead load and superimposed dead load and live load applied to the composite section, as shown in Fig. 5. This is a conservative design and allows the simplified methods using conventional programs(OMBAS-Standard Structures). It is recognized that in some cases it may be more economical to take advantage of the frame action in the design by assuming some degree of fixity. This, however, requires careful engineering judgement and a sophisticated girder analysis.

If the advantage of frame action is taken in the girder design, a connection detail consistent with the degree of fixity assumed should be provided. Owing to the uncertainty in the degree of fixity, it would be conservative to ignore the beneficial effect of axial compression induced in the girder. However, the girder and deck slab shall be checked for the adverse effect of fixity. A moment connection shall be assumed for the design of the abutment wall and piles, for superimposed dead load, live load, earth pressure, temperature, shrinkage, creep and seismic loads as shown in Fig. 6. Moment connections shall be achieved by providing continuity reinforcing steel.

The force or restraint due to backfill is dependent upon the movement of the abutment and may be considered to develop between full passive and at rest earth pressure. Abutment movement of 60mm to 80mm is required to mobilize full passive pressure. Full passive pressure, however, creates a very large design force that, in all likelihood, would be excessively conservative. It is therefore suggested that the backfill force should be based on a coefficient of earth pressure(Kp) calculated in accordance with the design procedure in Appendix-1 of this report or a method approved by the geotechnical engineer.

Where retained soil systems are used for resisting earth pressure, they should be designed to take the load induced due to the movement of abutment. Alternatively, details as shown in Fig. 7, may be used to allow the piles to move freely without transferring the load to the retained soil system.

The abutment wall shall be supported on a single row of vertical H-piles. The top of piles shall be embedded at least 600mm into the abutment walls and shall be adequately reinforced to transfer the bending forces. The connection between the abutment wall and pile top may be considered as pinned or fixed for the design of piles. For structures where movement and loading requirements are such that piles can be designed within the elastic range, it is suggested that the connection should be considered as fixed and piles should be placed with the strong axis normal to the direction of movement. In such cases due consideration should be given to the stability of the structure in the transverse direction by considering frame action and/or battering of end piles at each abutment in the transverse direction as required.

Where loading and movement requirements are such that pile resistance exceeds the elastic range, the connection may be assumed as pinned. In such cases the piles should be placed with weak axis normal to the direction of movement. It is assumed that the piles would yield and provide sufficient flexibility and rotation. It may be beneficial in some cases to look into both cases to arrive at an economic and safe design.

The structural design of piles may be carried out using the equivalent cantilever method (Abendroth et al. 1989, Greimann et al. 1987); as a column with a fixed base at some distance below the ground surface. More sophisticated methods for the analysis that take into account the soil-pile interaction by assuming a series of springs along the length of the piles may also be used. The piles shall be designed as beam columns. The forces developed due to lateral displacement of the pile head, vertical loads, and soil-pile interaction shall be taken into consideration.

The longitudinal forces induced in the superstructure due to movements, are directly related to the lateral resistance of the integral abutment. In designing the substructure, attention shall be paid to details that provide flexibility and reduce unwanted restraints. Where piles are driven into stiff soils, pre-drilled oversize holes, 600mm dia, filled with loose sand shall be provided to reduce resistance to lateral movements and reduce pile stresses. Where required, pre-drilled holes shall be provided with a CSP to protect the hole from caving in . The depth of such holes below the abutment shall be 3.0 m. The geotechnical engineer shall be consulted to establish the need for pre-drilling and to adjust the geotechnical capacity of friction piles to account for the pre-drilled holes. The end piles at each abutment shall be battered to a minimum of 1:10 in the transverse direction to provide for additional lateral resistance irrespective of their orientation.

SEISMIC DESIGN CONSIDERATIONS

Integral abutment bridges perform better during an earthquake due to the fixity and restraint at the abutments, however caution should be exercised in the design of substructures to minimize damage in the event of an earthquake . The maximum earth pressure acting on the abutment in the longitudinal direction may be assumed to be equal to the maximum longitudinal earthquake force transferred from the superstructure to the abutment. To minimize abutment damage, the abutment should be designed to resist the passive pressure being mobilized by the backfill, which should be greater than the maximum estimated longitudinal earthquake force transferred to the abutment. When longitudinal seismic forces are also resisted by piers or columns, it is necessary to estimate the stiffness of the components in order to compute the proportion of earthquake load transferred to the abutment.

The wingwalls should be treated similarly for transverse seismic forces.

The capacity of piles in both directions should be checked to resist the earthquake forces. It may be necessary in some cases to batter the piles sufficiently in the transverse direction, to adequately transfer the earthquake forces or provide stability in the transverse direction.

CONSTRUCTION CONSIDERATIONS

Construction considerations and sequence shall be given on the drawings to specify the following requirements:

1. The abutments including wingwalls shall be constructed first to bearing seat elevation.
2. The girders shall be placed on a support that allows rotation and deflection of the girders due to self weight and dead weight of the deck.
3. The deck and the portion of the abutment above bearing seat elevation shall be cast integrally with the girders.
4. The deck and the abutment to the bearing seat level, shall be poured in sequence so that the structure becomes integral with no residual stresses. This may require a careful consideration of concrete pouring sequence and use of a retarder. The ends of the deck and the abutments shall be placed last unless concrete can be retarded sufficiently to allow the placement from one end to the other in a single pour.
5. The stability and the integrity of the structure shall be maintained at all stages of construction.
6. Backfill shall not be placed behind the abutments until the deck has reached 75% of its specified strength.
7. Backfill shall be placed simultaneously behind both abutments, keeping the height of the backfill approximately the same. At no time shall the difference in heights of backfill be greater than 500mm.

ABUTMENT CONNECTION DETAILS

The design details used to achieve a rigid connection between the superstructure and the substructure vary for different types of superstructures. In addition, specific considerations may be required to reflect other design aspects such as lateral movements, vibration, frost protection, subsurface soil conditions, backfill requirements etc. These aspects may have a considerable effect on the performance, integrity, and durability of the integral abutment design. Typical details used by the Structural Office for bridge lengths up to 100m are given in Figures 4 and 8 to 12.

RECOMMENDATIONS

Planning:

1. Bridges up to 100m in length should be considered for integral abutment design, with provision of expansion at the end of approach slab as shown in Fig. 4
2. Bridges with lengths more than 100m but not exceeding 150m shall be considered for integral abutment design provided that adequate measures are taken to account for the movement and its effects.
   Any such measures should be discussed with and approved by the Ministry.
3. Bridges with lengths exceeding 150m should not be considered for integral abutment design without prior approval by the Ministry.
4. Cast-in-place post-tensioned deck type structures should not be considered for integral abutment design.
5. Structures with a skew of less than 20° should be considered for integral abutment design.
6. Structures with a skew greater than 20° but not exceeding 35° may be considered if a rigorous analysis is carried out.
7. Structures with a skew exceeding 35° or where the angle subtended by a 30m arc along the length of the structure exceeds 5° , shall not be considered for integral abutment design.
8. Abutments with heights more than 6m should not be considered for integral abutment design, unless it is used in conjunction with the retained soil system.
9. Wingwalls greater than 7m in length or oriented perpendicular to the direction of movement should not be designed as integral with the abutments.
10. Building of the abutment up to the bearing seat level should be considered for future widening.
11. An integral abutment concept should not be considered where the length of the H-piles is less than 5m or where the abutments are supported on rigid foundations, caissons or wooden piles.
12. Where a bridge cannot be considered for an integral abutment design due to unfavourable foundation conditions, a semi-integral arrangement as shown in Fig. 3 can be used. Total length and movement provisions as mentioned above shall apply .
13. Single span bridges on rigid foundations may be designed as integral abutments provided the following conditions are met:

    (a) The bridge is on a secondary highway.
    (b) The span does not exceed 25m.
    (c) A connection detail which allows some rotation is used. An example is shown in Fig. 2
    (d) Ministry approval is obtained.

Design and Analysis:

14. Weak axis of the piles shall be parallel to the movement for bridges not exceeding 50m in length.
15. The orientation of the piles shall be based on the design considerations and economy for bridges longer than 50m but not exceeding 100m in length.
16. Weak axis of the piles shall be perpendicular to the movement for bridges exceeding 100m in length.
17. The connection between the abutment and superstructure should be considered as pinned for the design of the girders unless a reduction in the number or size of girder can be achieved by assuming a degree of fixity.
19. At-rest earth pressure should be used for bridges not exceeding 25m in length.

Construction:

20. Where piles are driven in dense and stiff soils, pre-augered holes filled with loose sand shall be provided to reduce resistance to lateral movements. The geotechnical engineer should be consulted to establish the need for pre-augering.
21. The stability and the integrity of the structure shall be maintained at all stages of construction.
22. Backfill behind the abutment shall not be placed until the deck has reached 75% of the specified concrete strength.
23. Backfill shall be placed simultaneously behind both abutments keeping the height of the backfill approximately the same. At no time shall the difference in the backfill heights be greater than 500mm.

INTEGRAL ABUTMENT DESIGN PROCEDURE

Frame Analysis:

1) Analytical model
   - Use model as shown in Fig.13
   - Assume all joints are moment connections
   - Use soil springs along length of pile based on modulus of subgrade reaction (obtained from geotechnical investigation), or;
   - Use equivalent cantilever method ($l = 10d_p$), where d_p is the diameter of the pile and l is the length of equivalent cantilever, see Fig. 13 (b)

2) Load cases

   Stage I - naked girder - simply supported
   - (a) Dead load (DL) - girder, deck

   Stage II - composite girder, integral abutment

   Load combination 1
   - (a) Dead load (DL)
   - (b) Superimposed dead load (SDL)
   - (c) Live load (LL)
   - (d) Thermal expansion (temp. rise- assume a construction temperature of 15°C unless more reliable information is available)
   - (e) Passive soil pressure* - based on actual rotation of abutment stem -coefficient of passive earth pressure ($K_p = 0.5$ to 3.0)*
   - (f) Seismic Load (Q) , Wind Load (W) , Braking Force (B)

   Load combination 2
   - (a) Dead load (DL)
   - (b) Superimposed dead load (SDL)
   - (c) Live load (LL)
   - (d) Thermal contraction (temp. fall- assume a construction temperature of 15°C unless more reliable information is available.)
   - (e) Creep, shrinkage - converted to equivalent temperature
   - (f) Active soil pressure - coefficient of active earth pressure ($K_a = 0.33$)
   - (g) Seismic Load (Q), Wind Load (W), Braking (B)

* To calculate coefficient of passive earth pressure (K_p):
   - (a) Apply thermal load (temp. rise) to structure model as described in Figure 13.
   - (b) Determine movement at top of abutment (x)
   - (c) Determine rotation of abutment wall (x/h), where h is abutment height above top of pile.
   - (d) determine K_p from OHBDC Commentary clause C6-7.1 -See Appendix-I

* For short structures less than 25m in length, use at-rest earth pressure. It is assumed that

the movement would not be enough to mobilize passive earth pressure.

3) Girder Design
   - Girders (naked and composite) are designed conservatively assuming no fixity at abutments for DL, LL and SDL using conventional programs such as OMBAS.- Standard Section
   - The connection between deck and abutment can be considered to be somewhere between fixed and pinned. This would require engineering judgement and sophisticated girder design.
   - The beneficial effects of axial compression induced in the girders due to earth pressure should not be included in the design of the girders.
   - When the girders are designed as pinned at the abutments, the effect on the deck and girders shall be checked, assuming fixity at the abutments.

4) Abutment Design
   - Load combination 1 is critical for negative moment reinforcement at the corner of abutment and deck.
   - The maximum bending moment obtained from frame analysis should be assumed to act at the corner of the idealized frame.
   - The distribution of moments from wingwalls to the abutments should be considered in the design of horizontal reinforcement of abutments.

5) Pile Design
   - Single row of piles shall be used at abutments.
   - Piles may be designed elastically for axial force and bending moment or assuming a plastic hinge at the underside of abutment wall and pile top.
   - Piles may be orientated with bending to occur about the strong or weak axis. (relative stiffness between abutment and piles is so large that piles attract little moment regardless of orientation.)
   - The orientation of piles shall be consistent with the design assumptions.
   - In stiff soils, where recommended by the geotechnical engineer, piles shall be placed in 600 mm diameter, 3m deep pre-augered holes filled with loose sand.

6) Multi-span structures:
   - Pier shafts with elastomeric bearings can be modelled as equivalent springs.

<u>Details:</u>

1) Bearings at abutment
   - Provide 20 mm plain natural rubber pad supported on 150 mm high concrete pedestal; size of the bearing to be same as that of pedestal.

- Rubber pad allows for rotation of girder end (under dead load) without damage to girder.
- Pedestal allows for placement of reinforcement and proper consolidation of concrete underneath girders.

2) Detail at end of approach slab (Fig. 4)
   - Provide 20-40 mm (based on anticipated movements) asphalt impregnated fibre board.

3) Pile embedment into abutment stem (Fig. 8-11)
   - Embed pile 600 mm and reinforce as shown

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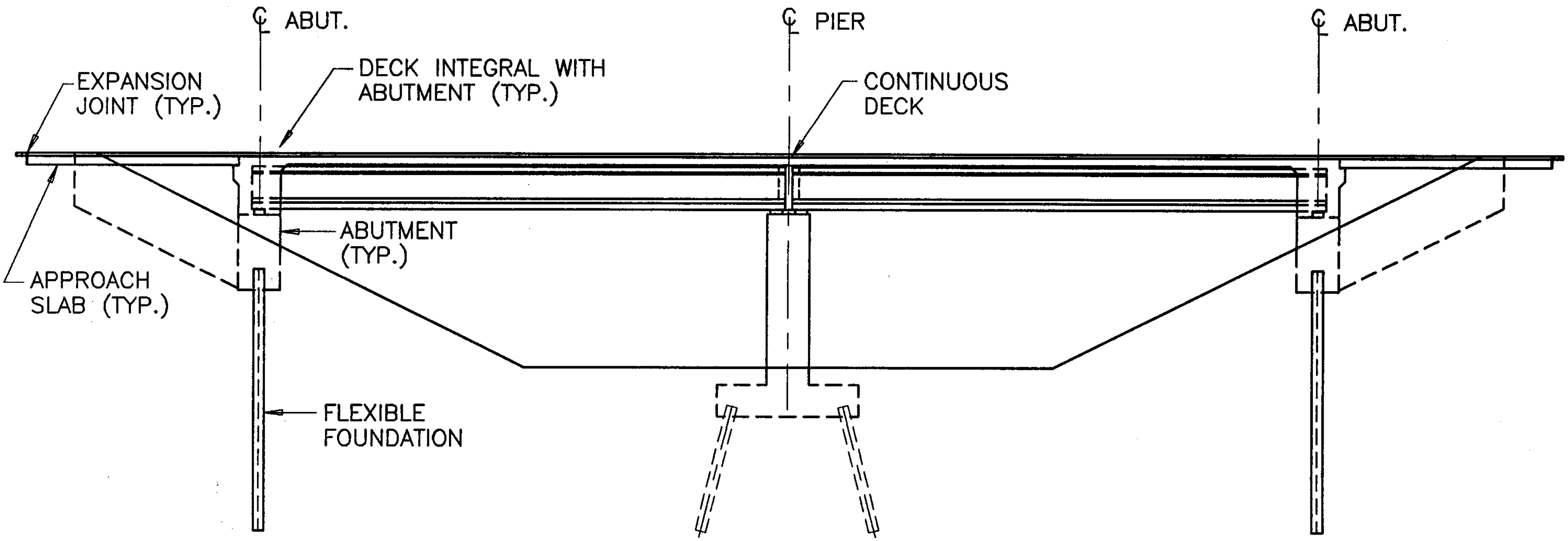
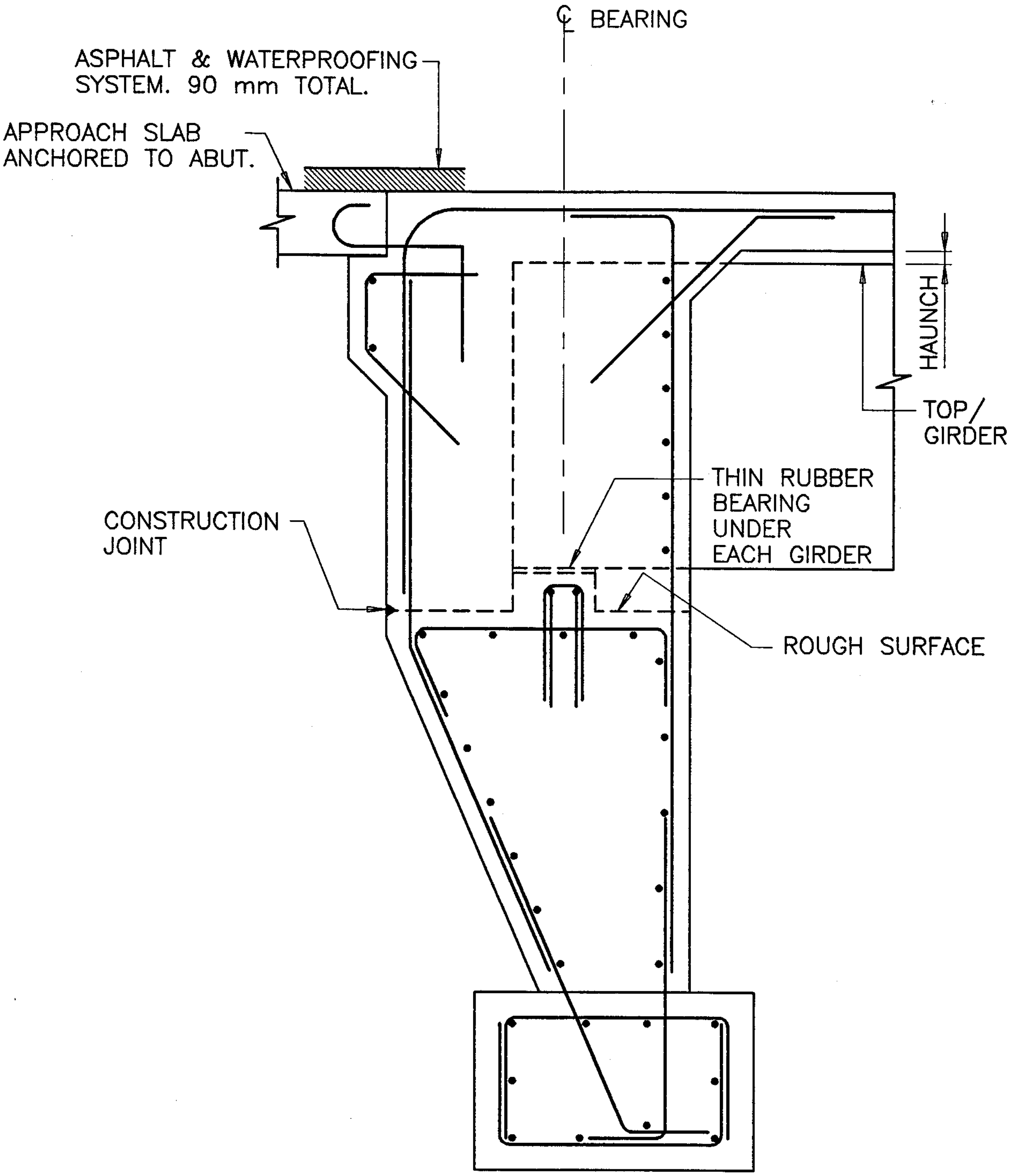
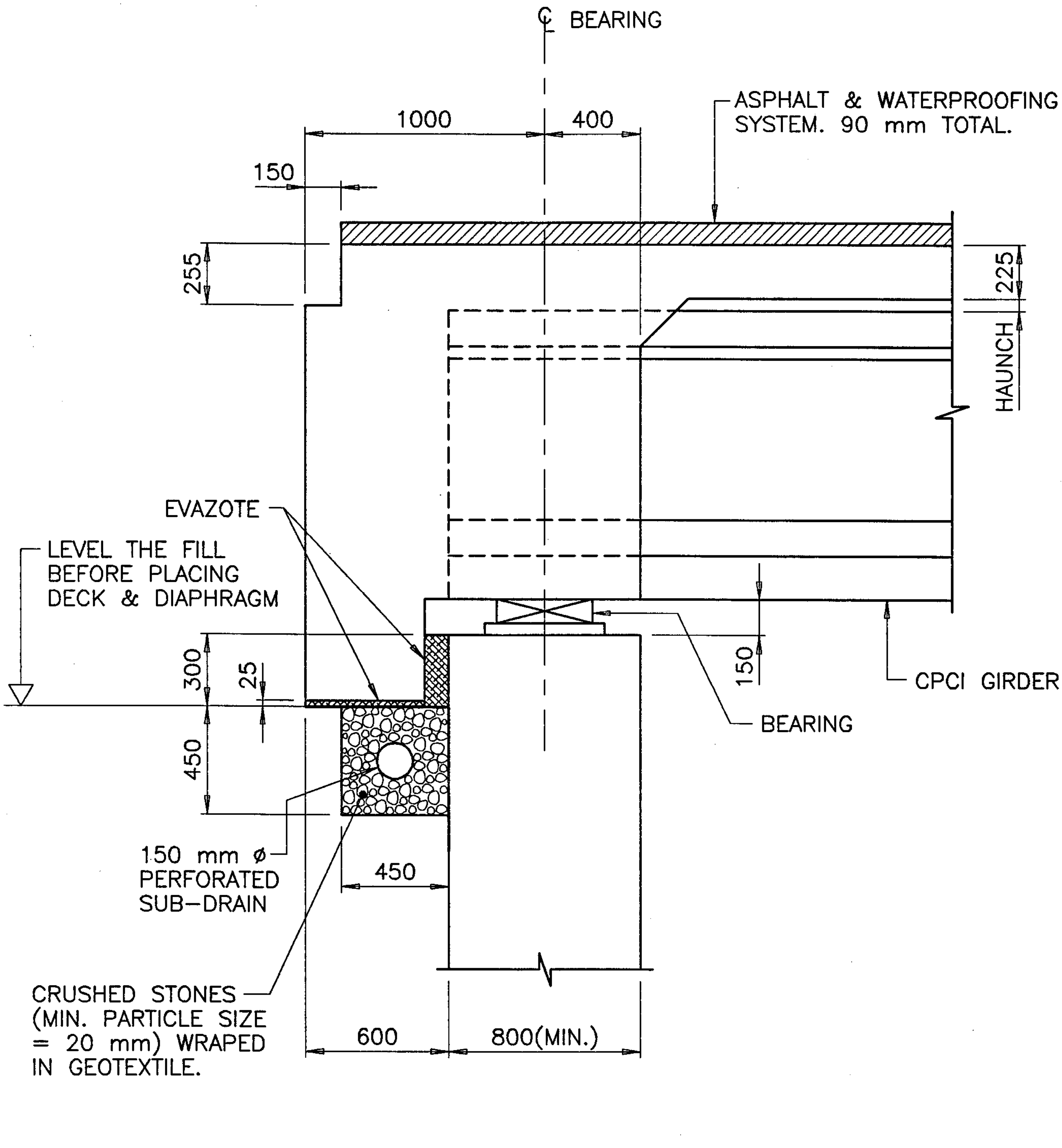


INTEGRAL ABUTMENT BRIDGE
FIG. 1



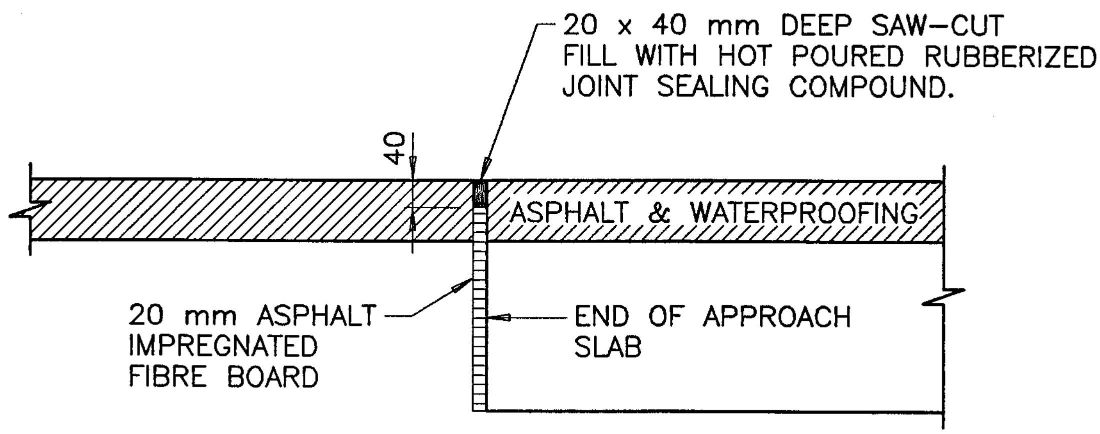
HINGED CONNECTION DETAILS

FIG. 2



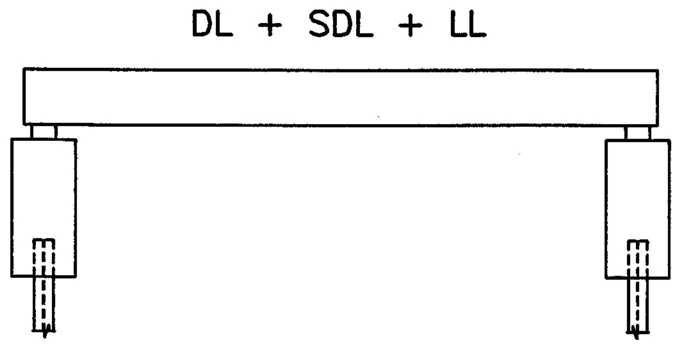
SEMI-INTEGRAL ARRANGEMENT

FIG. 3



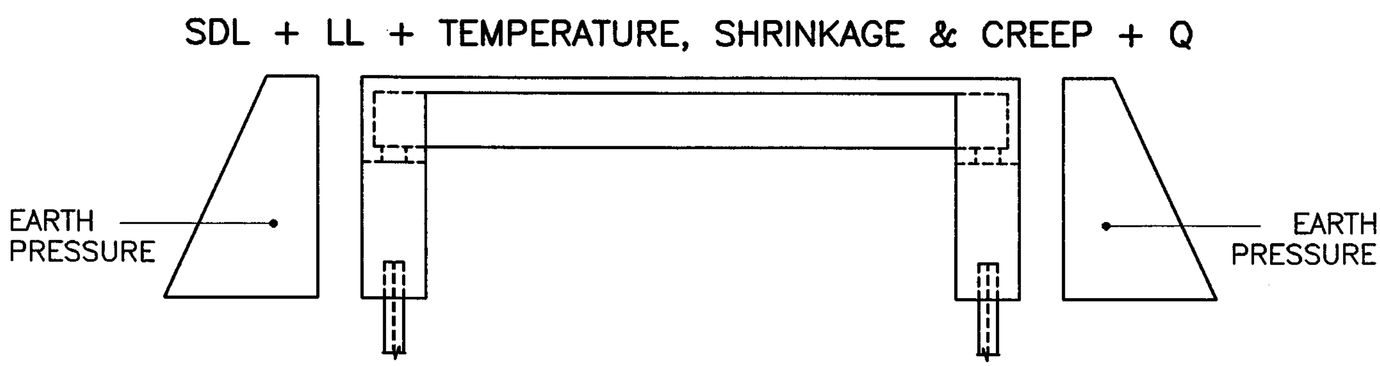
EXPANSION JOINT AT END OF APPROACH SLAB

FIG. 4



DESIGN OF GIRDER

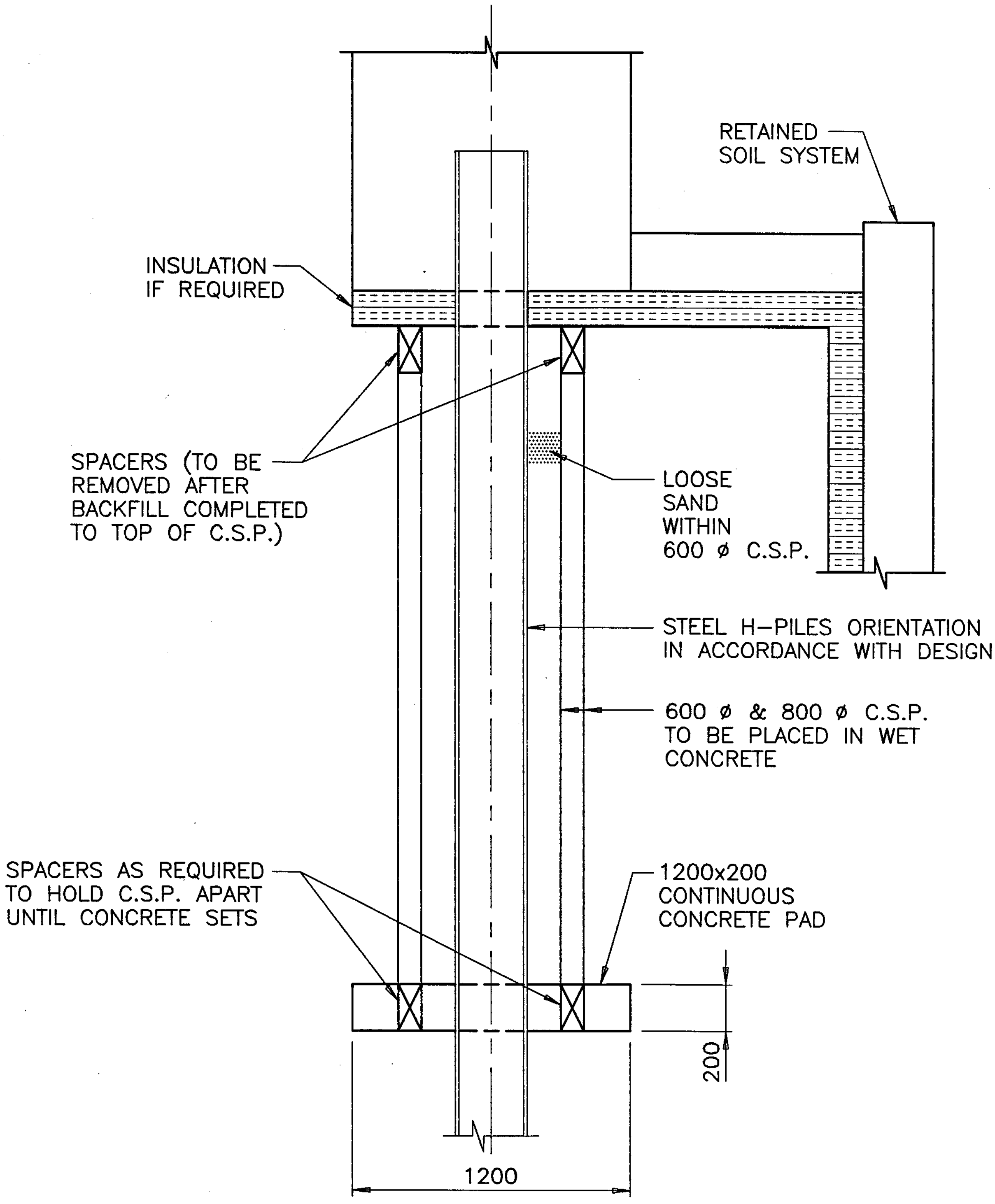
FIG. 5



DESIGN OF ABUTMENT WALL

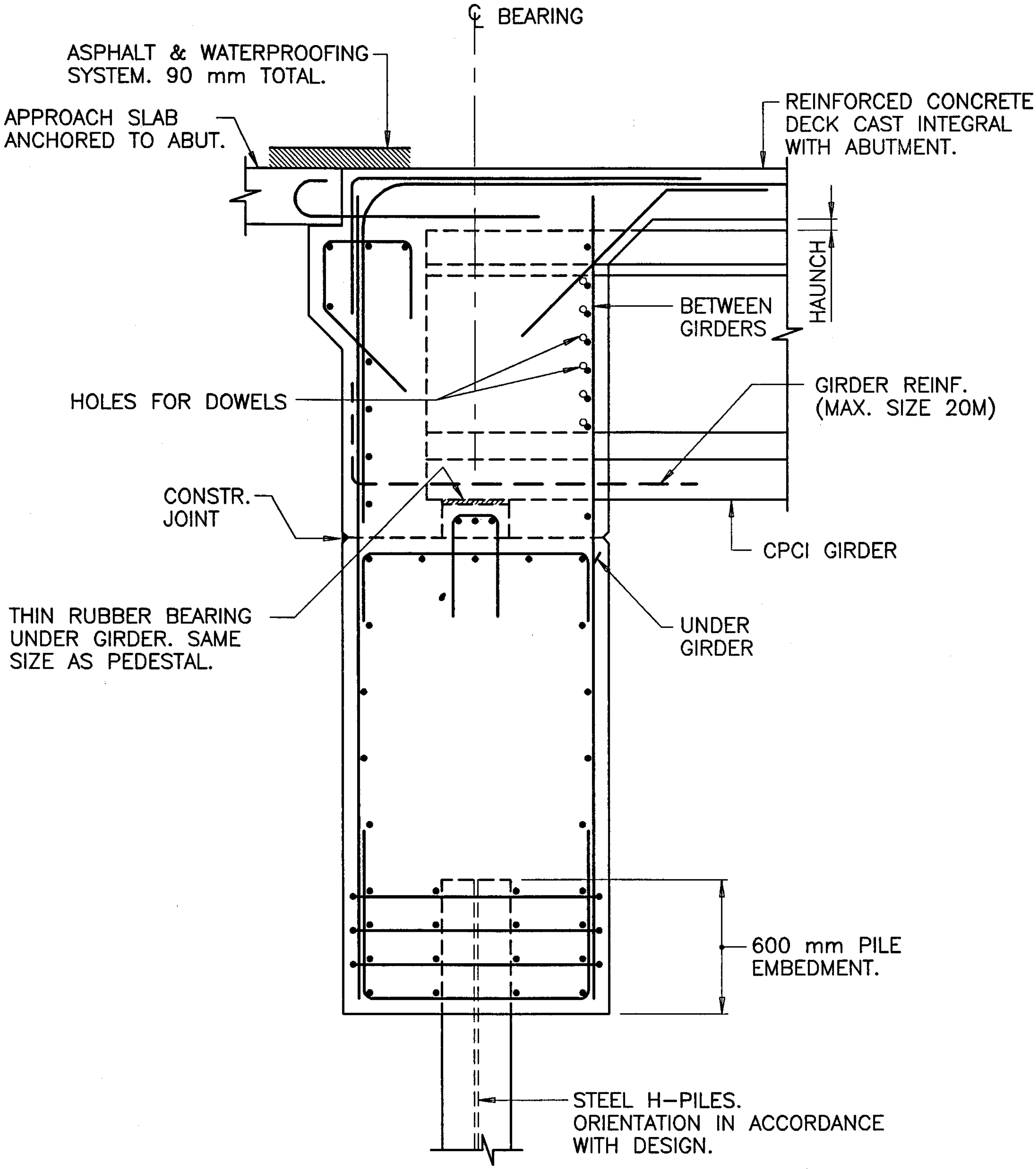
FIG. 6

DESIGN LOADS



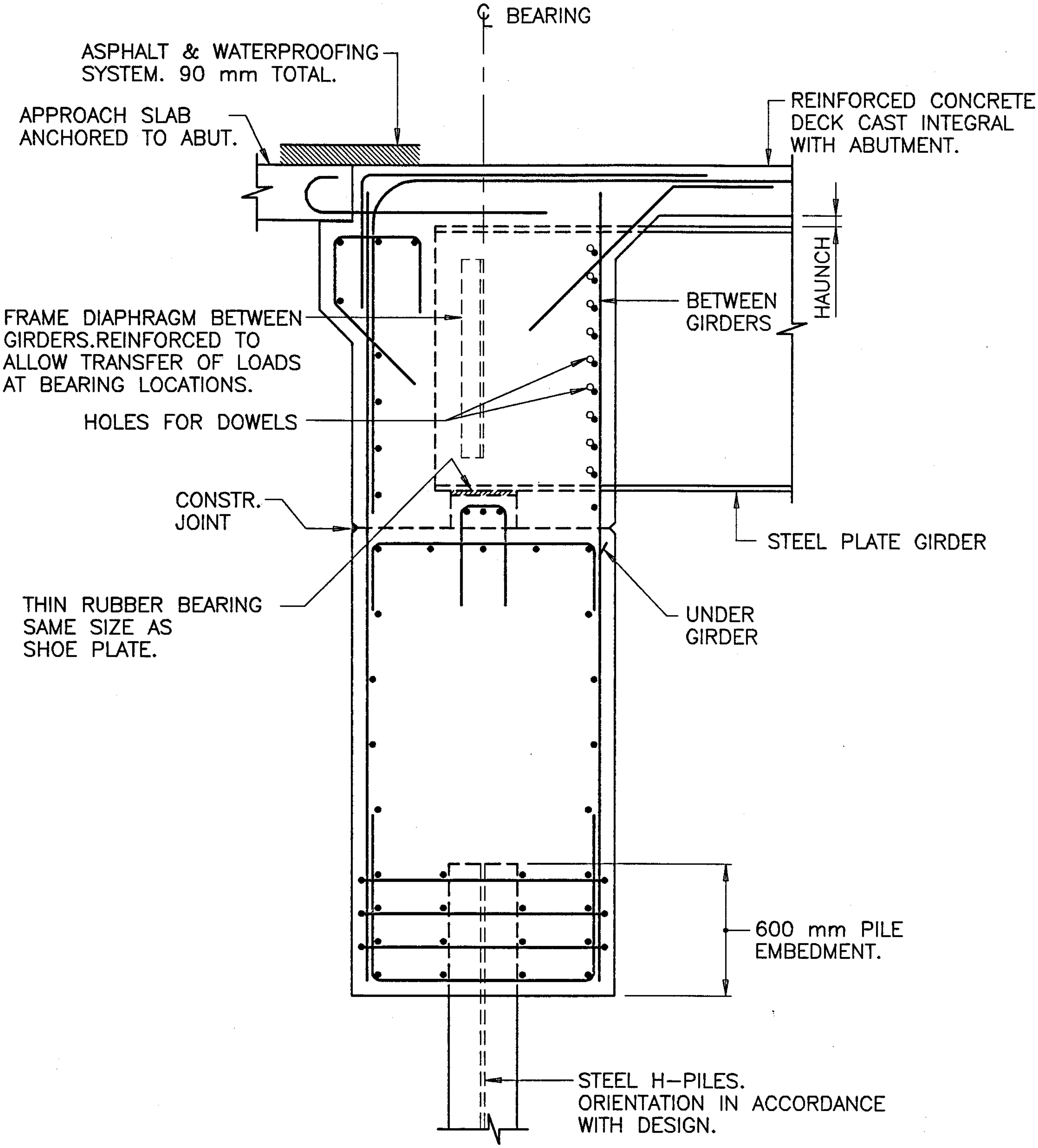
INTEGRAL ABUTMENT WITH RETAINED SOIL SYSTEM

FIG. 7



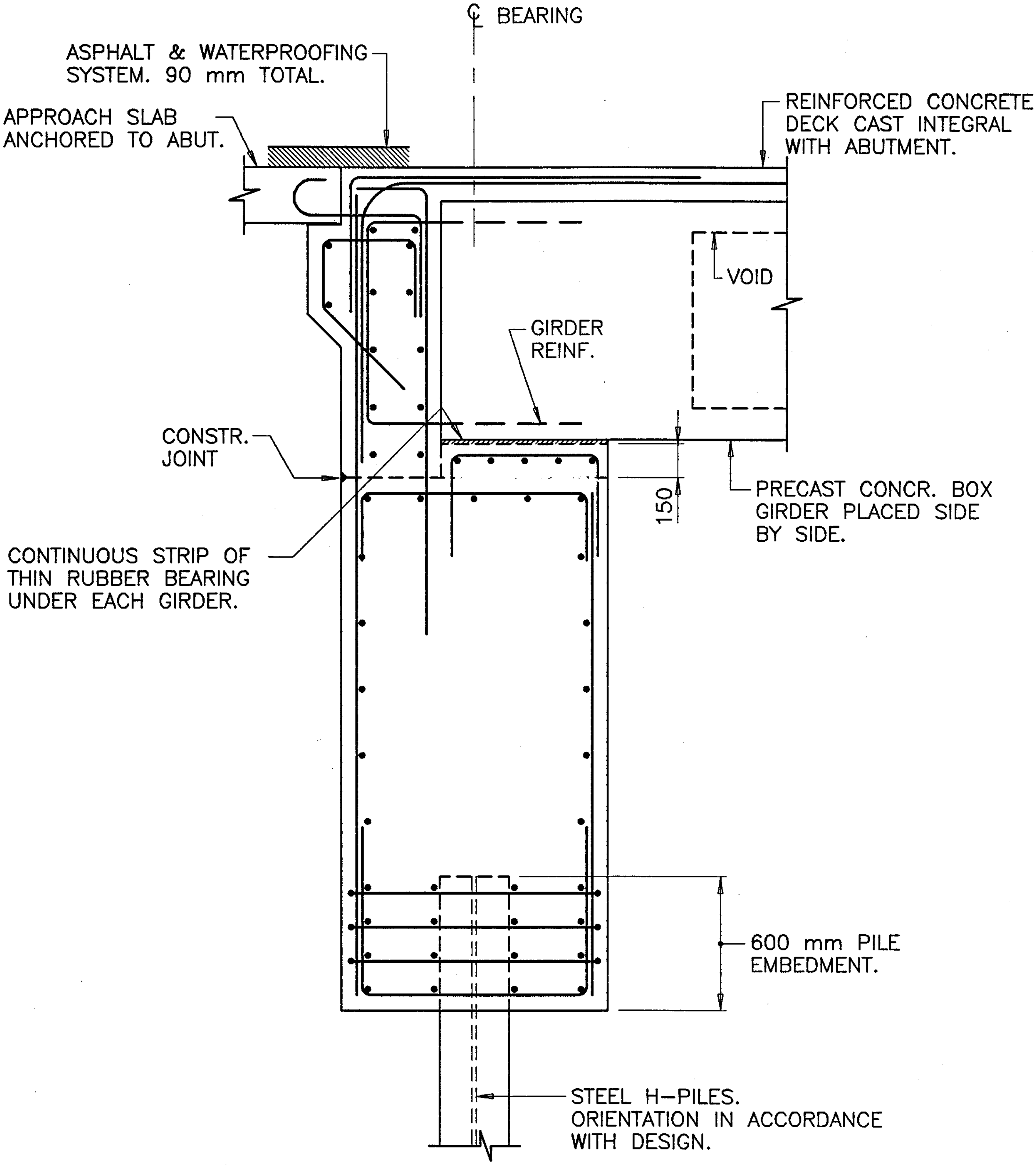
CPCI GIRDER WITH CONCRETE DECK

FIG. 8



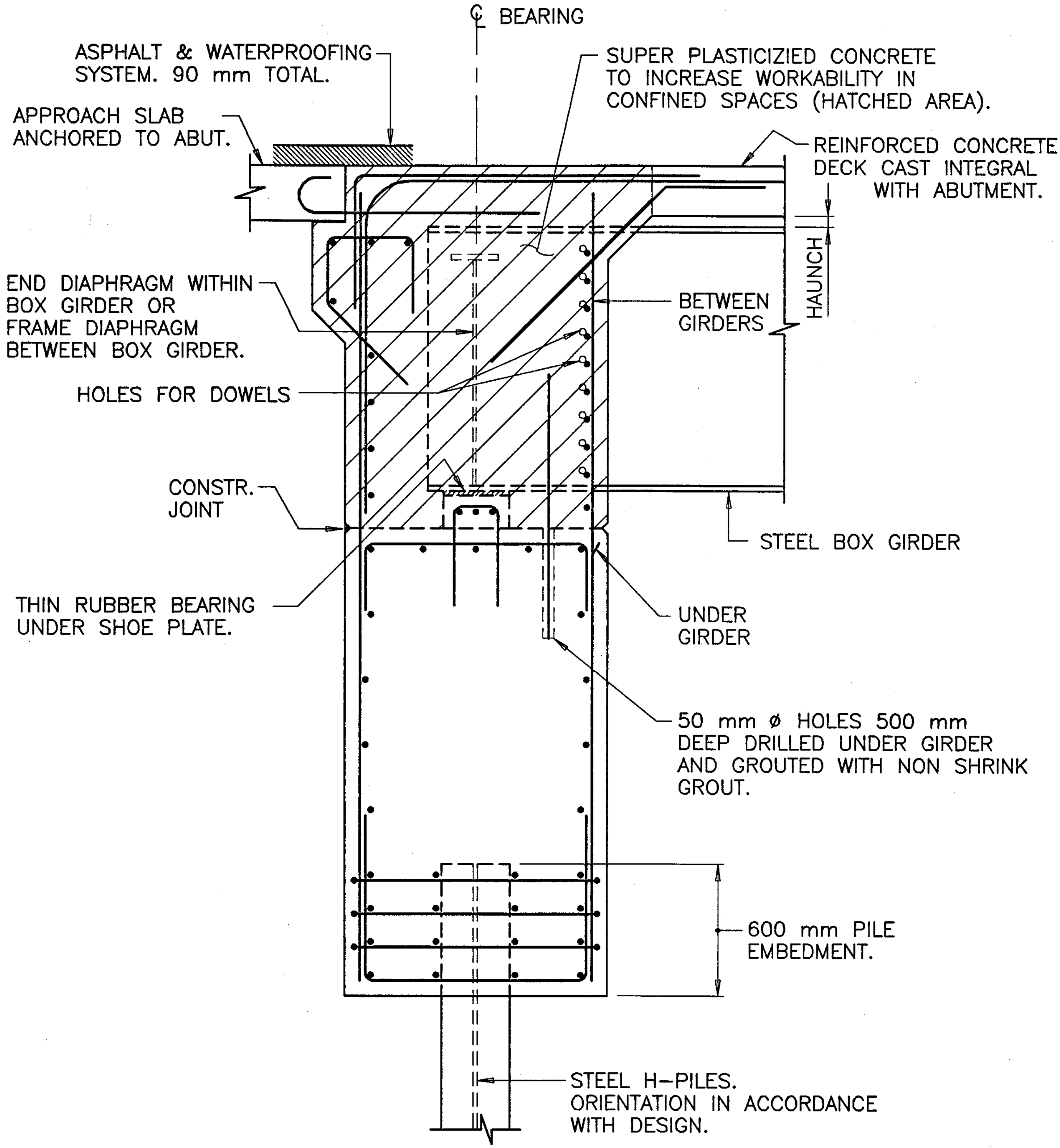
STEEL GIRDER WITH CONCRETE DECK

FIG. 9



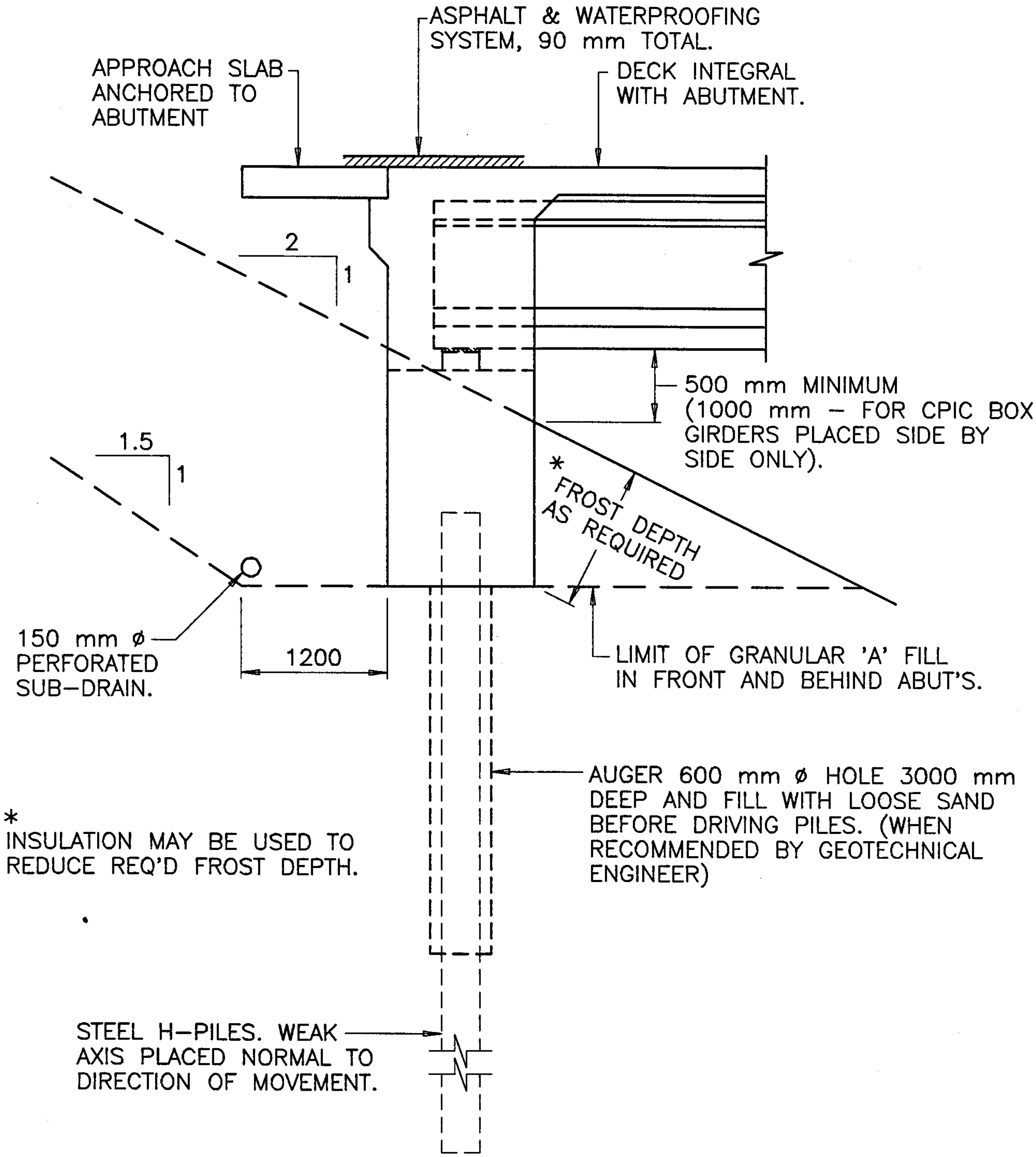
SIDE BY SIDE PLACED PRECAST CONCRETE BOX GIRDER WITH CONCRETE DECK

FIG. 10



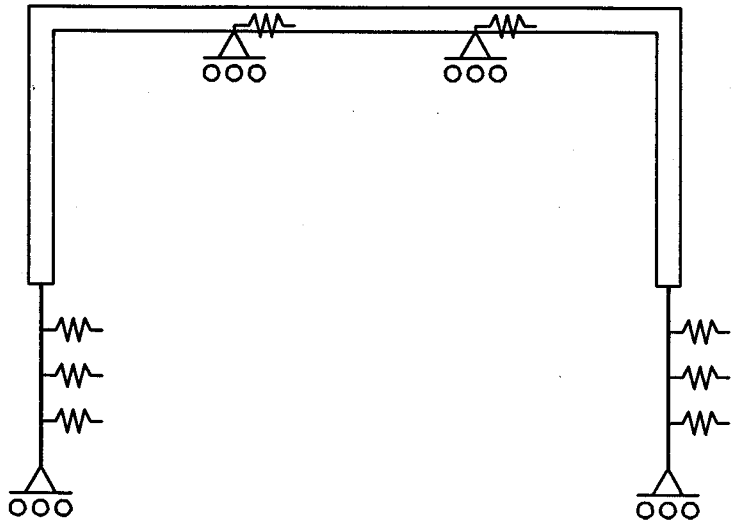
STEEL BOX GIRDER WITH CONCRETE DECK

FIG. 11

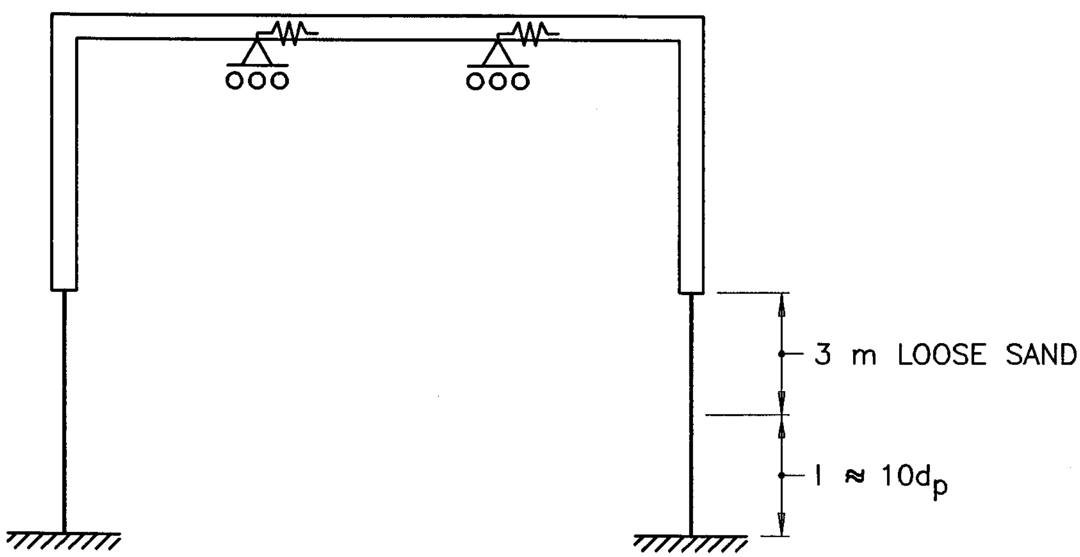


BACK FILL AND SUB–SURFACE SOIL CONSIDERATIONS

FIG. 12



(a) SOIL SPRING METHOD



(b) EQUIVALENT CANTILEVER METHOD

ANALYTICAL MODEL
FIG. 13

Appendix -1

Earth Pressure Calculation

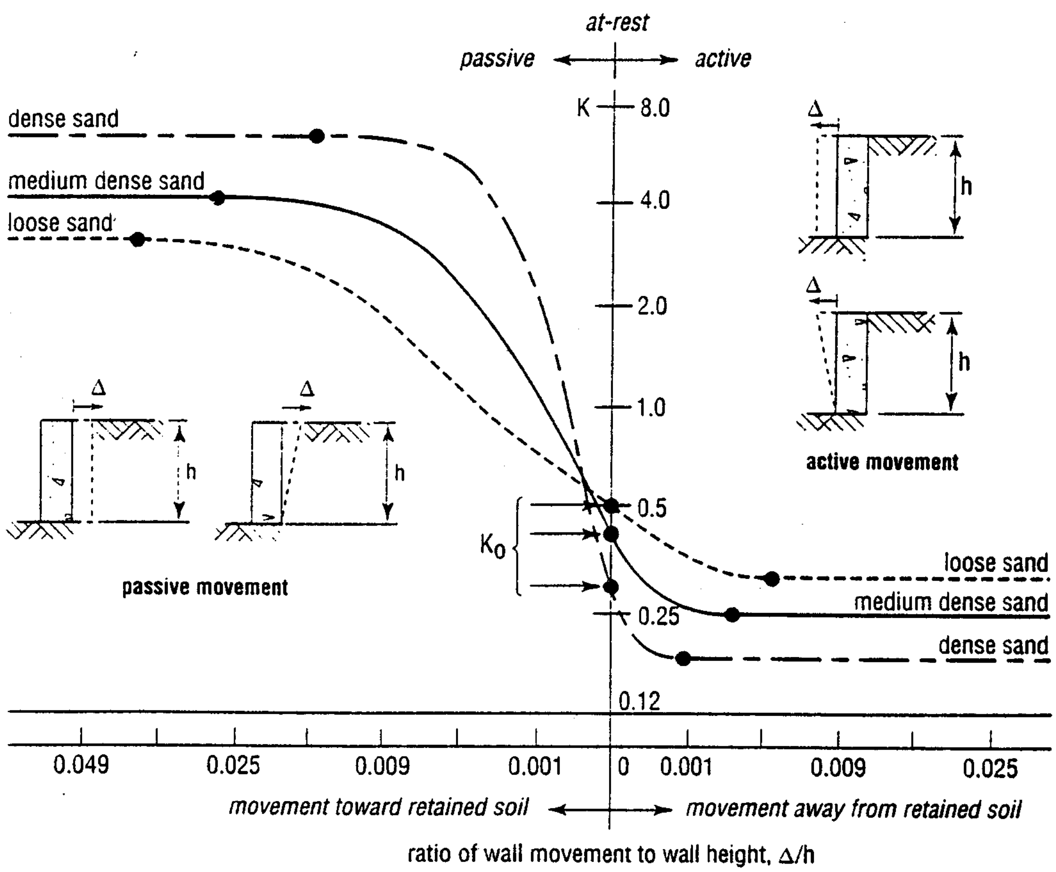
The earth pressure acting on a retaining structure may range from an active pressure to a passive pressure or passive resistance, depending on the displacement characteristics of the structure relative to the soil. Active pressure is the minimum value of the lateral earth pressure which a soil mass can exert against an unrestrained structure, as shown in the figure below. This figure applies to soil placed naturally or to engineered fill. The initial value of the horizontal deflection of the wall is then taken to zero. Passive pressure or resistance is the maximum value of the lateral earth pressure or resistance which can be mobilized by a structure moving against a soil mass. Table below indicates the order of magnitude of wall movement required to achieve various pressure conditions in cohesionless soils. For geotechnical design, in general, an at-rest earth pressure would be assumed for restrained structures with little or no movement against the soil mass. In all other cases a coefficient of passive earth resistance can be obtained for the required movement from below.

Movements required to mobilize various conditions

Movement to Mobilize			
Active Pressure		Passive Pressure	
Displacement, Δ	Rotation, Δ/h	Displacement, Δ	Rotation, Δ/h
$0.001h$	0.002 (about bottom of wall)	$0.050h$	0.100 (about bottom of wall 0.020 (about top of wall)

Notes: *1) Displacements are considered to take place without rotation.*
2) h is the height of retaining wall.
3) Rotation is considered to take place about a fixed point at either the top or the bottom of the wall.

Various earth pressures



Appendix - 2

Computer Analysis

Integral Abutment Bridges

By:

Andrew Burgess P.Eng.

What is "Integral.wk4" ?

"Integral. wk4" is a lotus spreadsheet utilizing cell calculation in combination with macros. The spreadsheet analyzes bridge frames for various loads. The basic bridge models are shown in examples 1,2,3. By varying member stiffness the user can modify the basic model to simulate the bridge design.

General Input

All input **must be** calculated based on a meter width of structure.

- Thermal Coefficient of Expansion

This value is used when calculating the thermal effects on the deck only.

- Temperature Change

A positive value refers to a rise in temperature and a negative value refers to a decrease in temperature. Only one value can be inputed therefore if the user wishes to analysis a temperature rise and fall two runs would be required.

- Number of Span

A maximum of 3 spans can be analyzed. Input titles change depending on the number of spans.

- Modulus of Elasticity

This value is used in the formation of the stiffness matrix. If the bridge is comprised of more than one material all materials have to be converted into an equivalent stiffness (using the modular ratio).

- Uniformly Distributed Load

This uniform load is applied to the bridge deck.

- % of Truck Per Meter Width

The user shall determine this value based on the live load distribution characteristics of the bridge. "Integral.wk4" multiplies the responses from the inputed truck by this value.

- Dynamic Load Allowance Truck

This factor is applied to the input truck load to account for the dynamic effect of the moving truck
.

- Dynamic Load Allowance Lane

This factor is applied to the lane load to account for the dynamic effect.

Basic Model

The basic model is comprised of 8 vertical members with variable bending inertia and length and three horizontal members with variable bending inertia, length and cross-sectional area. The model has three fixed supports and all members have fixed end restraint.

Creating a Specific Bridge Model

By inputing a relatively weak member stiffness (inertia/length ratio) the user can effectively eliminate the effect of that member thereby modifying the basic model. To ensure appropriate model action the user can view the non-moving load reactions after running "non-moving load analysis". If satisfied with the modified model, a "moving load analysis" can then be performed. Examples of different bridge models are given in this appendix. Member lengths should be based on neutral axis distances.

Location of Critical Sections

These sections are in addition to sections located at the tenth locations. The labels within brackets (ie. x1) indicate the general location as shown in appendix-1. In vertical members this distance is measured down from the top of the member. In horizontal members two distances are required, one from the left end and the other from the right end of the member. Responses at critical sections given in "Unfactored responses" are in bold text.

Live Load Data

A maximum of five axles can be input. Two live load conditions are calculated, the first being the truck axles alone, and the second the truck axles multiplied by the "truck fraction" and combined with the "lane load".

Analysis Method

The stiffness method is used in the analysis.

Thermal

The thermal movement of the bridge is calculated based on the change in temperature of the deck members and the stiffness of the model.

Soil Pressure

The soil pressure coefficients are based on the thermal movement of the model. These coefficients vary with abutment rotation as described in appendix-1. It should be noted that when the two abutments have different heights an unbalanced force results and the bridge model shows relatively large lateral displacements. The effect of this unbalanced load shall be taken into consideration as discussed in the report , under planning considerations.

Live Load

Influence lines are generated at tenths spots on the span using the stiffness matrix of the bridge model. The inputed truck is then passed over the influence lines to generate live load responses. A quadratic is used to interpolate between calculated influences.

If an axle or a section of the lane loading benefits the section being maximized then the effect of that axle or portion of lane load is ignored.

The truck is passed over the bridge in one direction from left to right. To obtain results for the truck passing in the other direction a further run has to be done with truck axles reversed.

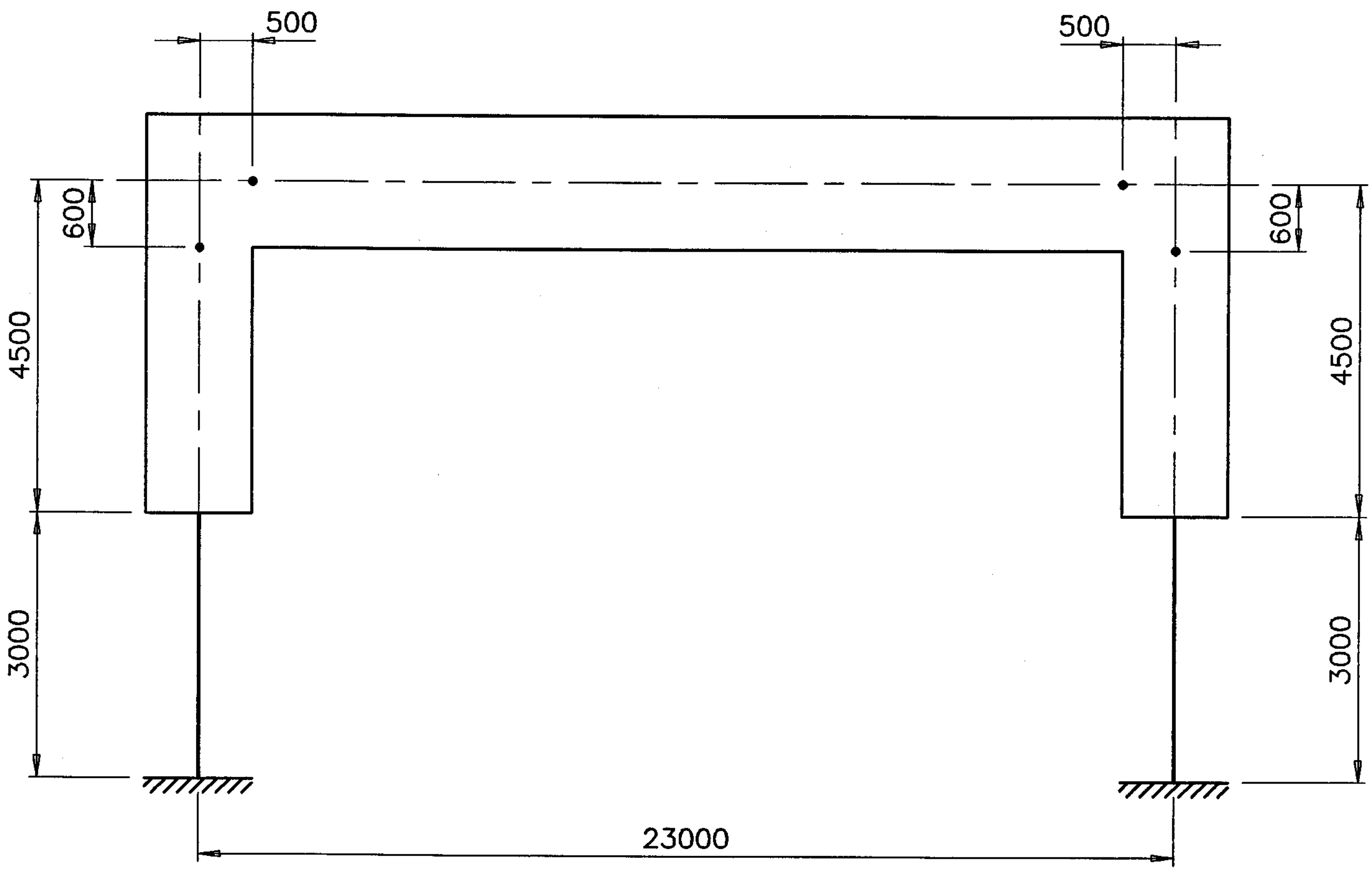
Running "Integral.wk4"

There are two types of runs that can be completed. The non-live load analysis does not run the influence module and therefor is very fast. This run can be done, as stated in Creating a specific Bridge Model to view non-moving load responses to ensure that the model as inputl is appropriate.

The live load analysis can then be run once the user is satisfied with non-moving load responses. The status of the analysis is displayed throughout the run.

Results

Unfactored responses are given in both tabular and graphical form for each bridge component. Results are per meter width of bridge. The user can combine these responses as required.



NOTE:

• DENOTES LOCATION OF CRITICAL SECTION.

EXAMPLE – 1 SPAN

BRIDGE ANALYSIS SPREADSHEET

12/29/95

Bridge Location: Example, One Span
District : XX
wp # : XX/XXXX
Site # : XX-XXXX
Designer : XXXXXXXXX

1 - GENERAL...

Thermal Coefficient of Expansion.....	1E-05	/°C
Temperature change.........................	20	°C
# of Spans...	1	
Modulus of Elasticity..........................	27400	Mpa
Superimposed Dead Load................	2.50	kN/m²
% of Truck per meter.........................	25%	truck/m
Dynamic Load Allowance Truck.......	0.25	
Dynamic Load Allowance Lane.........	0.10	

2- BASIC MODEL PARAMETERS...

	length, mm	Inertia, mm	Area, mm²
Spans			
1st	23000	8.8E+10	1000000
weak	100000	1	1
weak	100000	1	1
Abutments/Piers			
left abutment	4500	6.1E+10	
right abutment	4500	6.1E+10	
weak	10000	1	
weak	10000	1	
Piles			
left abutment	3000	3.9E+08	
right abutment	3000	3.9E+08	
weak	10000	1	
weak	10000	1	

3 - LOCATION OF CRITICAL SECTIONS...

12/29/95

Spans	Left	Right
1st (x1, x2)	500	500
N/A	0	0
N/A	0	0

Abutments/Piers	
left abutment (y1)	600
right abutment(y2)	600
N/A	0
N/A	0

4 - Live Load...

Axle#	Axle Load (kN)	Spacing (m)
1	60	-
2	160	3.6
3	160	1.2
4	200	6
5	160	7.2

Lane Load 2.50 Kn/m²

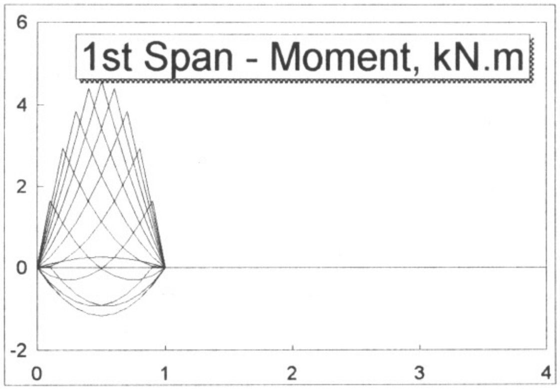
Truck Fraction 0.7

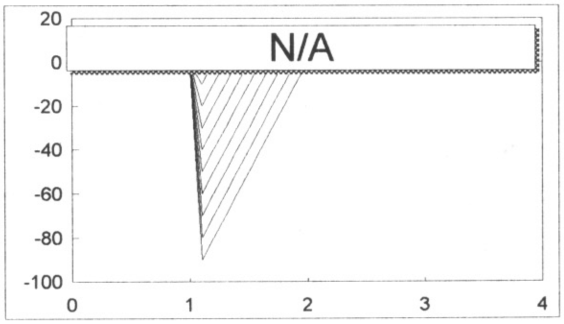
5-ANALYZE...

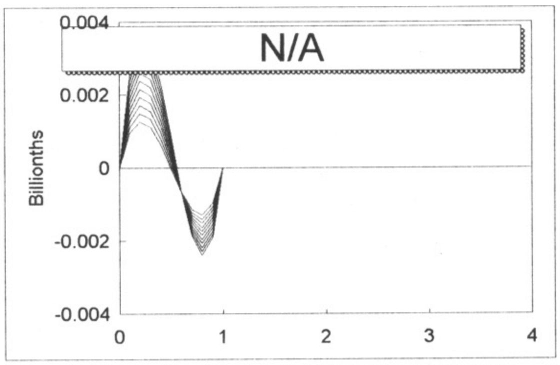
.... Analysis Status.............. 100.0%

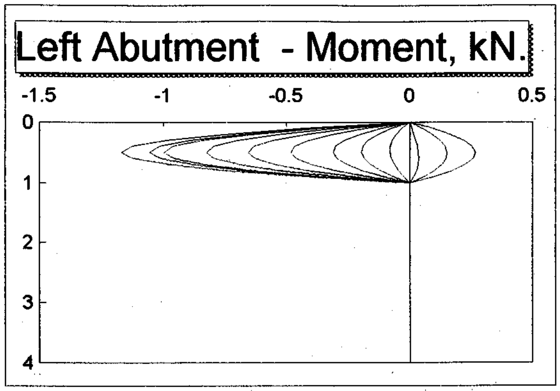
12/29/95

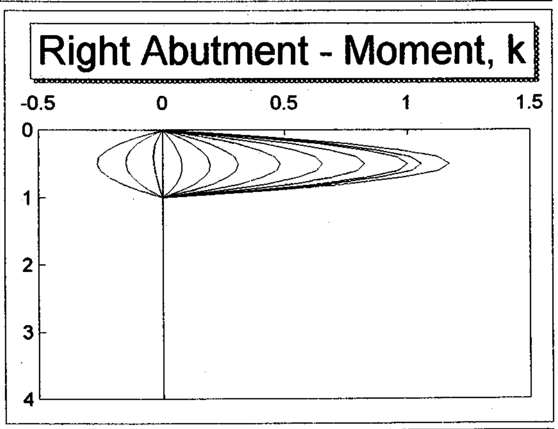
6 - INFLUENCE LINES

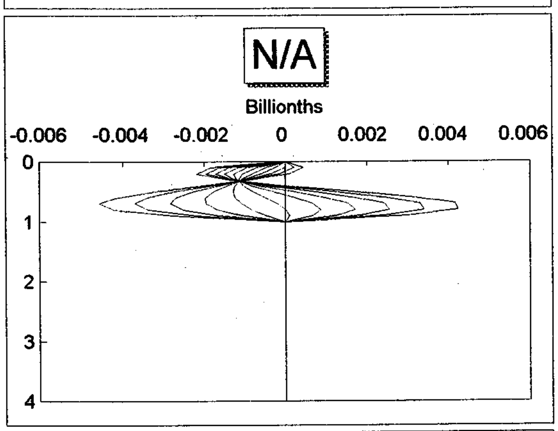


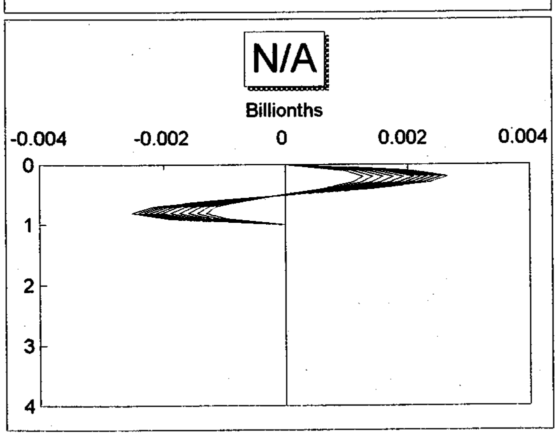





Left Abutment - Moment, kN.
-1.5
-1
-0.5
0
0.5
0
1
2
3
4


Right Abutment - Moment, k
-0.5
0
0.5
1
1.5
0
1
2
3
4


N/A
Billionths
-0.006
-0.004
-0.002
0
0.002
0.004
0.006
0
1
2
3
4


N/A
Billionths
-0.004
-0.002
0
0.002
0.004
0
1
2
3
4

7 - UNFACTORED RESPONSES...

Soil Pressures

Left Abutment

thermal movement (<-- +ve)	2.3	mm
pressure coefficent	0.65	
soil pressure (at abut. bot.)	59	kN/m²

Right Abutment

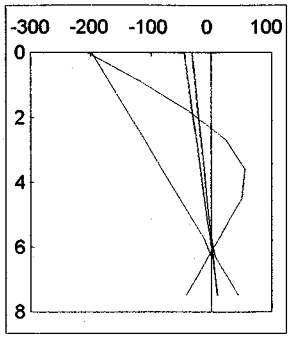
thermal movement (--> +ve)	2.3	mm
pressure coefficent	0.65	
soil pressure (at abut. bot.)	59	kN/m²

Reactions (kN & m)

Load	Support #	Rxx (+)	Ryy (+)	Mzz (+)
sdl	left abut	-7	29	-10
	right abut	7	29	10
	N/A	-0	-0	-0
	N/A	0	0	0
Thermal	left abut	-5	0	-9
	right abut	5	-0	9
	N/A	0	-0	0
	N/A	0	0	0
Soil	left abut	31	0	43
	right abut	-31	-0	-43
	N/A	0	0	0
	N/A	-0	-0	-0
Live load Maximum	left abut	0	138	45
	right abut	31	132	0
	N/A	0	0	0
	N/A	0	0	0
Live load Minimum	left abut	-31	0	0
	right abut	-0	0	-45
	N/A	-0	-0	-0
	N/A	-8	-0	-0

12/29/95

Left Abutment - Moment, kN.m



Location	sdl	Thermal	Soil Pressure	Live load Maximum	Minimum
0.600	**-40**	**-29**	**-146**	**0**	**-179**
0.000	-45	-32	-206	0	-198
0.900	-38	-27	-117	0	-169
1.800	-32	-22	-37	0	-140
2.700	-25	-17	24	0	-111
3.600	-18	-12	56	0	-81
4.500	-12	-7	50	0	-52
5.100	-7	-4	32	0	-33
5.700	-3	-1	13	0	-13
6.300	1	2	-5	6	0
6.900	6	6	-24	26	0
7.500	10	9	-43	45	0

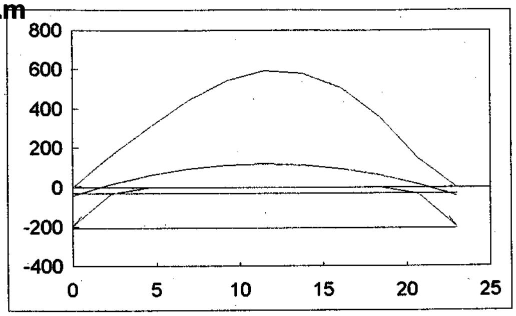
Left abutment - Axial, kN

Location	sdl	Thermal	Soil Pressure	Live load Maximum	Minimum
full wall	29	-0	-0	0	-138

Left Abutment - Shear, kN

Location	sdl	Thermal	Soil Pressure	Live load Maximum	Minimum
0.600	**-7**	**-5**	**-98**	**0**	**-31**
0.000	-7	-5	-101	0	-31
0.900	-7	-5	-95	0	-31
1.800	-7	-5	-80	0	-31
2.700	-7	-5	-53	0	-31
3.600	-7	-5	-17	0	-31
4.500	-7	-5	31	0	-31
5.100	-7	-5	31	0	-31
5.700	-7	-5	31	0	-31
6.300	-7	-5	31	0	-31
6.900	-7	-5	31	0	-31
7.500	-7	-5	31	0	-31

1 st Span - Moment, kN.m



Location	sdl	Thermal	Soil Pressure	Live load Maximum	Minimum
0.500	**-31**	**-32**	**-206**	**5**	**-147**
0.000	-45	-32	-206	0	-198
2.300	15	-32	-206	162	-33
4.600	61	-32	-206	309	0
6.900	94	-32	-206	440	0
9.200	114	-32	-206	544	0
11.500	120	-32	-206	595	0
13.800	114	-32	-206	581	0
16.100	94	-32	-206	508	0
18.400	61	-32	-206	356	0
20.700	15	-32	-206	146	-33
23.000	-45	-32	-206	0	-199
22.500	**-31**	**-32**	**-206**	**1**	**-147**

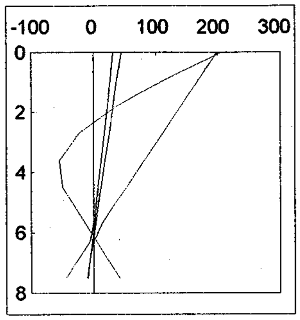
1 st Span - Axial, kN

Location	sdl	Thermal	Soil Pressure	Live load Maximum	Minimum
full span	-7	-5	-101	0	0

1 st Span - Shear, kN

Location	sdl	Thermal	Soil Pressure	Live load Maximum	Minimum
0.500	**27**	**0**	**0**	**134**	**0**
0.000	29	0	0	147	0
2.300	23	0	0	134	0
4.600	17	0	0	111	-6
6.900	11	0	0	93	-16
9.200	6	0	0	79	-25
11.500	-0	0	0	56	-36
13.800	-6	0	0	40	-57
16.100	-12	0	0	25	-74
18.400	-17	0	0	15	-85
20.700	-23	0	0	6	-106
23.000	-29	0	0	0	-123
22.500	**-28**	**0**	**0**	**0**	**-123**

Right Abutment - Moment, kN.m



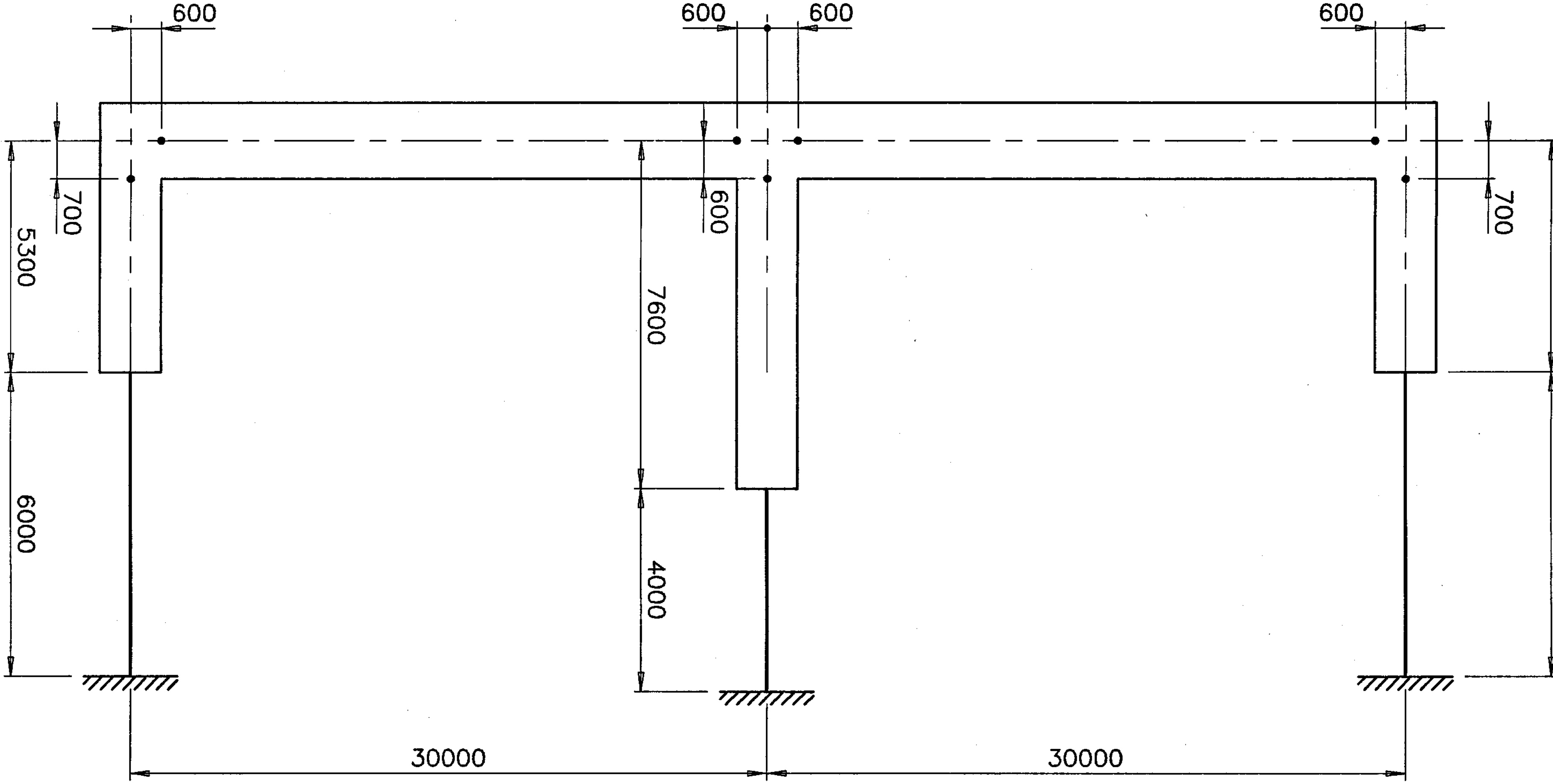
Location	sdl	Thermal	Soil Pressure	Live load Maximum	Minimum
0.600	40	29	146	179	0
0.000	45	32	206	199	0
0.900	38	27	117	170	0
1.800	32	22	37	140	0
2.700	25	17	-24	111	0
3.600	18	12	-56	82	0
4.500	12	7	-50	53	0
5.100	7	4	-32	33	0
5.700	3	1	-13	14	0
6.300	-1	-2	5	0	-6
6.900	-6	-6	24	0	-25
7.500	-10	-9	43	0	-45

Right Abutment - Axial, kN

Location	sdl	Thermal	Soil Pressure	Live load Maximum	Minimum
full pier	-29	-0	-0	0	-132

Right Abutment - Shear, kN

Location	sdl	Thermal	Soil Pressure	Live load Maximum	Minimum
0.600	7	5	-31	31	-0
0.000	7	5	-31	31	-0
0.900	7	5	-31	31	-0
1.800	7	5	-31	31	-0
2.700	7	5	-31	31	-0
3.600	7	5	-31	31	-0
4.500	7	5	-31	31	-0
5.100	7	5	-31	31	-0
5.700	7	5	-31	31	-0
6.300	7	5	-31	31	-0
6.900	7	5	-31	31	-0
7.500	7	5	-31	31	-0



NOTE:

- DENOTES LOCATION OF CRITICAL SECTION.

EXAMPLE – 2 SPAN, INTEGRAL PIERS

BRIDGE ANALYSIS SPREADSHEET

Bridge Location: Two Span - Integral Abutments & Pier
District : XX
wp # : XX/XXXX
Site # : XX-XXXX
Designer : XXXXXXXXX

1 - GENERAL...

Thermal Coefficient of Expansion.....	1E-05	/°C
Temperature change.........................	20	°C
# of Spans...	2	
Modulus of Elasticity..........................	27400	Mpa
Superimposed Dead Load................	2.50	kN/m²
% of Truck per meter.........................	25%	truck/m
Dynamic Load Allowance Truck.......	0.25	
Dynamic Load Allowance Lane.........	0.10	

2- BASIC MODEL PARAMETERS...

	length, mm	Inertia, mm	Area, mm²
Spans			
1st	30000	1.4E+11	445000
2nd	30000	1.4E+11	445000
weak	100000	1	1
Abutments/Piers			
left abutment	5300	1.6E+11	
pier	7600	6.8E+10	
right abutment	5300	1.6E+11	
weak	100000	1	
Piles			
left abutment	6000	8.6E+08	
pier	4000	4.0E+08	
right abutment	6000	8.6E+08	
weak	100000	1	

3 - LOCATION OF CRITICAL SECTIONS..

Spans	Left	Right
1st (x1, x2)	600	600
2nd (x3, x4)	600	600
N/A	0	0

Abutments/Piers	
left abutment (y1)	700
pier (y2)	600
right abutment (y3)	700
N/A	0

4 - LIVE LOAD...

Axle#	Axle Load (kN)	Spacing (m)
1	60	-
2	160	3.6
3	160	1.2
4	200	6
5	160	7.2

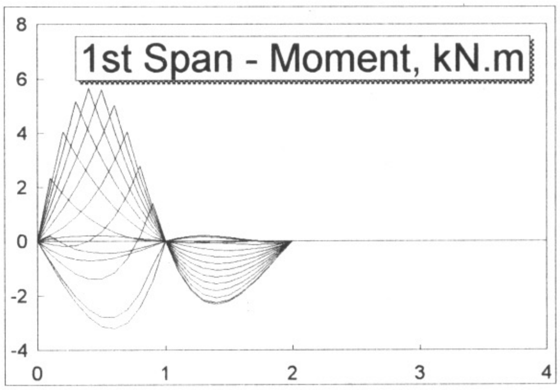
Lane Load 2.50 Kn/m²

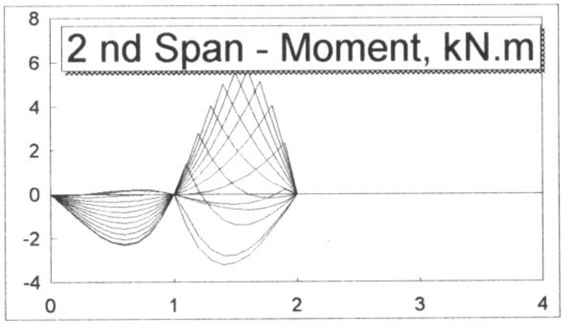
Truck Fraction 0.7

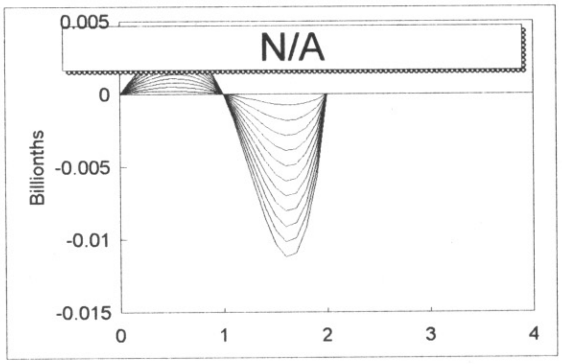
5-ANALYZE...

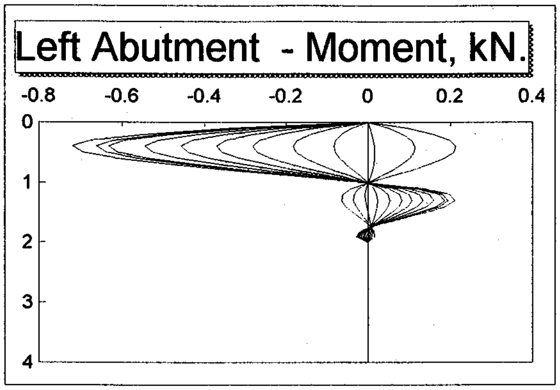
.... Analysis Status.............. 100.0%

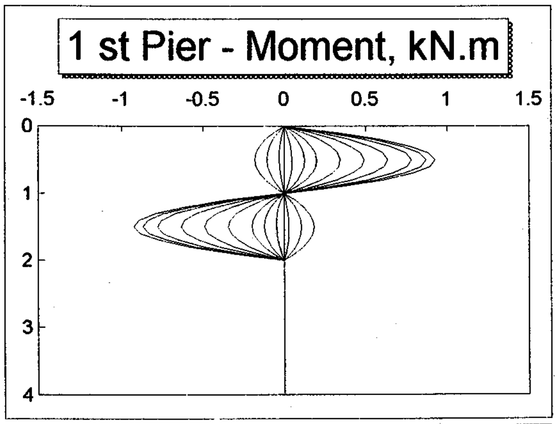
6 - INFLUENCE LINES

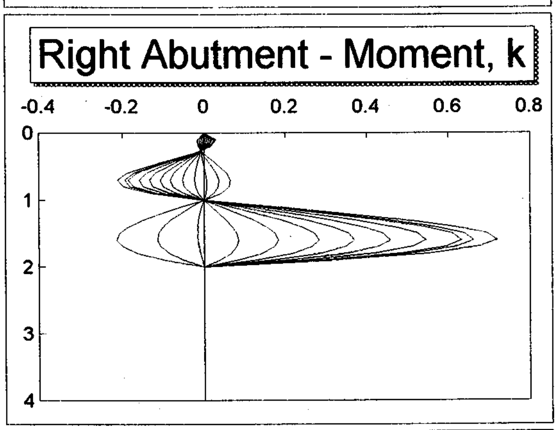


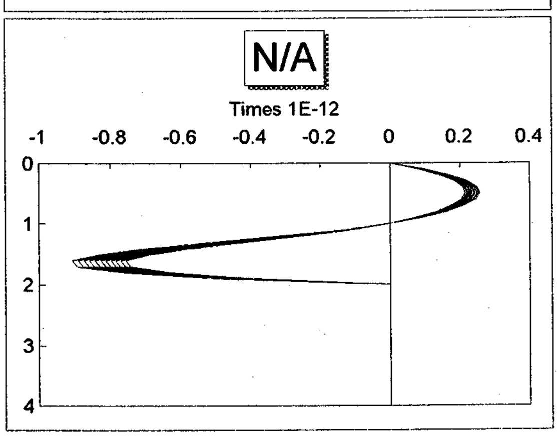





Left Abutment - Moment, kN.
-0.8
-0.6
-0.4
-0.2
0
0.2
0.4
0
1
2
3
4


1 st Pier - Moment, kN.m
-1.5
-1
-0.5
0
0.5
1
1.5
0
1
2
3
4


Right Abutment - Moment, k
-0.4
-0.2
0
0.2
0.4
0.6
0.8
0
1
2
3
4


N/A
Times 1E-12
-1
-0.8
-0.6
-0.4
-0.2
0
0.2
0.4
0
1
2
3
4

7 - UNFACTORED RESPONSES...

Soil Pressures

Left Abutment

thermal movement (<-- +ve)	6.0	mm
pressure coefficent	1.10	
soil pressure (at abut. bot.)	117	kN/m²

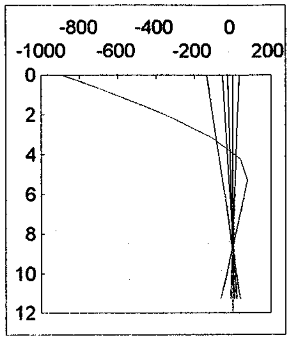
Right Abutment

thermal movement (--> +ve)	6.0	mm
pressure coefficent	1.10	
soil pressure (at abut. bot.)	117	kN/m²

Reactions (kN & m)

Load	Support #	Rxx (← +)	Ryy (↑ +)	Mzz (↷ +)
sdl	left abut	-3	30	-8
	pier	0	91	0
	right abut	3	30	8
	N/A	-0	-0	-0
Thermal	left abut	-6	3	-20
	pier	-0	-5	-0
	right abut	6	3	20
	N/A	0	0	0
Soil	left abut	23	45	61
	pier	-0	-89	-0
	right abut	-23	45	-61
	N/A	0	0	0
Live load Maximum	left abut	4	139	40
	pier	16	177	36
	right abut	4	140	41
	N/A	5	0	0
Live load Minimum	left abut	-14	-14	-10
	pier	-16	0	-36
	right abut	-14	-14	-10
	N/A	-5	-0	-0

Left Abutment - Moment, kN.m



Location	sdl	Thermal	Soil Pressure	Live load Maximum	Minimum
0.700	-25	-48	-694	30	-124
0.000	-28	-52	-893	33	-135
1.060	-24	-46	-594	29	-118
2.120	-21	-39	-321	25	-102
3.180	-18	-32	-101	21	-85
4.240	-14	-25	40	17	-69
5.300	-11	-19	77	13	-53
6.500	-7	-11	50	8	-34
7.700	-3	-3	22	4	-16
8.900	1	4	-6	3	-1
10.100	5	12	-33	21	-5
11.300	8	20	-61	40	-10

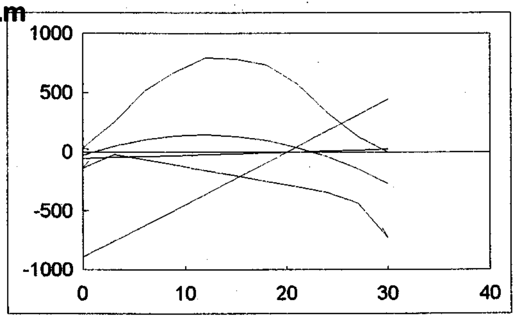
Left abutment - Axial, kN

Location	sdl	Thermal	Soil Pressure	Live load Maximum	Minimum
full wall	30	-3	-45	14	-139

Left Abutment - Shear, kN

Location	sdl	Thermal	Soil Pressure	Live load Maximum	Minimum
0.700	-3	-6	-281	4	-14
0.000	-3	-6	-286	4	-14
1.060	-3	-6	-274	4	-14
2.120	-3	-6	-237	4	-14
3.180	-3	-6	-175	4	-14
4.240	-3	-6	-88	4	-14
5.300	-3	-6	23	4	-14
6.500	-3	-6	23	4	-14
7.700	-3	-6	23	4	-14
8.900	-3	-6	23	4	-14
10.100	-3	-6	23	4	-14
11.300	-3	-6	23	4	-14

1 st Span - Moment, kN.m



Location	sdl	Thermal	Soil Pressure	Live load Maximum	Minimum
0.600	**-10**	**-51**	**-866**	**25**	**-75**
0.000	-28	-52	-893	33	-135
3.000	50	-45	-759	253	-22
6.000	104	-37	-625	518	-65
9.000	137	-29	-491	674	-109
12.000	146	-21	-357	792	-154
15.000	134	-13	-223	786	-201
18.000	98	-5	-89	734	-247
21.000	41	3	45	579	-293
24.000	-39	10	179	333	-339
27.000	-142	18	312	131	-436
30.000	-267	26	446	0	-727
29.400	**-241**	**25**	**419**	**3**	**-643**

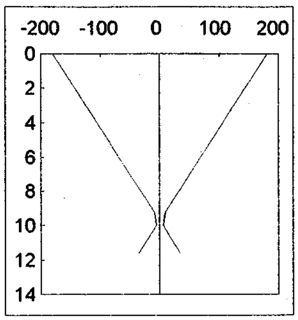
1 st Span - Axial, kN

Location	sdl	Thermal	Soil Pressure	Live load Maximum	Minimum
full span	-3	-6	-286	0	0

1 st Span - Shear, kN

Location	sdl	Thermal	Soil Pressure	Live load Maximum	Minimum
0.600	**28**	**3**	**45**	**128**	**-14**
0.000	30	3	45	149	-14
3.000	22	3	45	128	-14
6.000	15	3	45	107	-15
9.000	7	3	45	86	-24
12.000	-0	3	45	67	-43
15.000	-8	3	45	49	-62
18.000	-15	3	45	34	-80
21.000	-23	3	45	23	-98
24.000	-30	3	45	13	-115
27.000	-38	3	45	6	-130
30.000	-45	3	45	0	-147
29.400	**-44**	**3**	**45**	**46**	**-144**

1 st Pier - Moment, kN.m



Location	sdl	Thermal	Soil Pressure	Live load Maximum	Minimum
0.600	0	-0	-0	170	-169
0.000	0	-0	-0	181	-180
1.520	0	-0	-0	153	-152
3.040	0	-0	-0	124	-124
4.560	0	-0	-0	96	-96
6.080	0	-0	-0	68	-67
7.600	0	-0	-0	39	-39
8.400	0	-0	-0	24	-24
9.200	0	-0	-0	9	-9
10.000	-0	0	0	6	-6
10.800	-0	0	0	21	-21
11.600	-0	0	0	36	-36

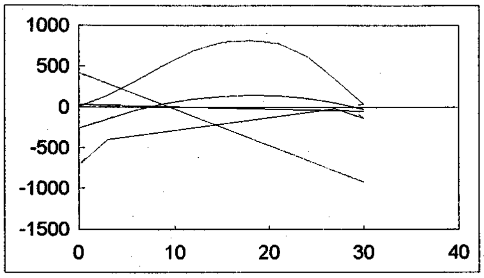
1 st Pier - Axial, kN

Location	sdl	Thermal	Soil Pressure	Live load Maximum	Minimum
full pier	-91	-5	-89	0	-177

1 st Pier - Shear, kN

Location	sdl	Thermal	Soil Pressure	Live load Maximum	Minimum
0.600	0	-0	-0	16	-16
0.000	0	-0	-0	16	-16
1.520	0	-0	-0	16	-16
3.040	0	-0	-0	16	-16
4.560	0	-0	-0	16	-16
6.080	0	-0	-0	16	-16
7.600	0	-0	-0	16	-16
8.400	0	-0	-0	16	-16
9.200	0	-0	-0	16	-16
10.000	0	-0	-0	16	-16
10.800	0	-0	-0	16	-16
11.600	0	-0	-0	16	-16

2 nd Span - Moment, kN.m



Location	sdl	Thermal	Soil Pressure	Live load Maximum	Minimum
0.600	**-241**	**25**	**393**	**0**	**-631**
0.000	-267	26	419	4	-715
3.000	-142	18	286	146	-394
6.000	-39	10	152	331	-347
9.000	41	3	18	524	-300
12.000	98	-5	-116	688	-253
15.000	134	-13	-250	793	-206
18.000	146	-21	-384	814	-159
21.000	137	-29	-518	777	-111
24.000	104	-37	-652	621	-64
27.000	50	-45	-785	343	-20
30.000	-28	-52	-919	34	-138
29.400	**-10**	**-51**	**-893**	**25**	**-79**

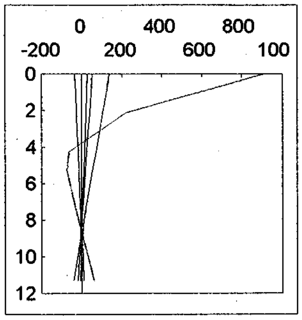
2 nd Span - Axial, kN

Location	sdl	Thermal	Soil Pressure	Live load Maximum	Minimum
full span	-3	-6	-286	0	0

2 nd Span - Shear, kN

Location	sdl	Thermal	Soil Pressure	Live load Maximum	Minimum
0.600	**45**	**-3**	**-45**	**148**	**0**
0.000	47	-3	-45	162	0
3.000	39	-3	-45	148	-0
6.000	32	-3	-45	132	-7
9.000	24	-3	-45	94	-25
12.000	17	-3	-45	74	-39
15.000	9	-3	-45	74	-39
18.000	2	-3	-45	53	-55
21.000	-6	-3	-45	37	-76
24.000	-13	-3	-45	15	-110
27.000	-21	-3	-45	14	-110
30.000	-28	-3	-45	14	-129
29.400	**-27**	**-3**	**-45**	**0**	**-0**

Right Abutment - Moment, kN.m



Location	sdl	Thermal	Soil Pressure	Live load Maximum	Minimum
0.700	**25**	**48**	**677**	**127**	**-32**
0.000	28	52	909	138	-34
1.060	24	46	569	121	-30
2.120	21	39	218	104	-26
3.180	18	32	77	88	-22
4.240	14	25	-65	71	-18
5.300	11	19	-74	54	-14
6.500	7	11	-50	35	-9
7.700	3	3	-22	16	-4
8.900	-1	-4	6	1	-3
10.100	-5	-12	33	5	-22
11.300	-8	-20	61	10	-41

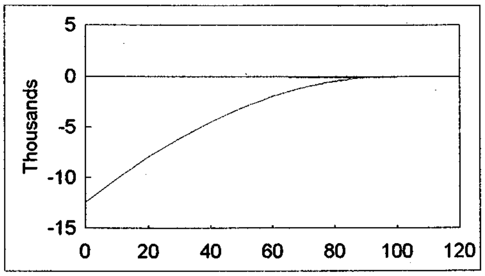
Right Abutment - Axial, kN

Location	sdl	Thermal	Soil Pressure	Live load Maximum	Minimum
full wall	-30	-3	-45	14	-140

Right Abutment - Shear, kN

Location	sdl	Thermal	Soil Pressure	Live load Maximum	Minimum
0.700	**3**	**6**	**281**	**14**	**-4**
0.000	3	6	286	14	-4
1.060	3	6	274	14	-4
2.120	3	6	237	14	-4
3.180	3	6	175	14	-4
4.240	3	6	88	14	-4
5.300	3	6	-23	14	-4
6.500	3	6	-23	14	-4
7.700	3	6	-23	14	-4
8.900	3	6	-23	14	-4
10.100	3	6	-23	14	-4
11.300	3	6	-23	14	-4

N/A



Location	sdl	Thermal	Soil Pressure	Live load Maximum	Minimum
0.000	**-12500**	**0**	**0**	**0**	**-21**
0.000	-12500	0	0	0	-0
10.000	-10125	-10	0	0	-0
20.000	-8000	-20	0	0	-0
30.000	-6125	-30	0	0	-0
40.000	-4500	-40	0	0	-0
50.000	-3125	-50	0	0	-0
60.000	-2000	-60	0	0	-0
70.000	-1125	-70	0	0	-0
80.000	-500	-80	0	0	-0
90.000	-125	-90	-0	0	-0
100.000	0	-100	-0	0	-0
100.000	**0**	**-100**	**-0**	**0**	**-0**

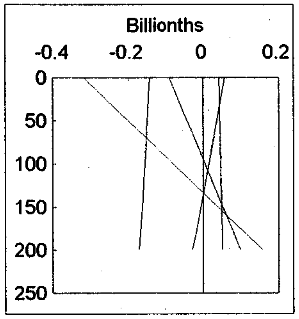
N/A

Location	sdl	Thermal	Soil Pressure	Live load Maximum	Minimum
full span	0	-0	-0	0	-0

N/A

Location	sdl	Thermal	Soil Pressure	Live load Maximum	Minimum
0.000	**250**	**-0**	**-0**	**0**	**-0**
0.000	250	-0	-0	0	-0
10.000	225	-0	-0	0	-0
20.000	200	-0	-0	0	-0
30.000	175	-0	-0	0	-0
40.000	150	-0	-0	0	-0
50.000	125	-0	-0	0	-0
60.000	100	-0	-0	0	-0
70.000	75	-0	-0	0	-0
80.000	50	-0	-0	0	-0
90.000	25	-0	-0	0	-0
100.000	0	-0	-0	0	-0
100.000	**0**	**-0**	**-0**	**0**	**-0**

N/A



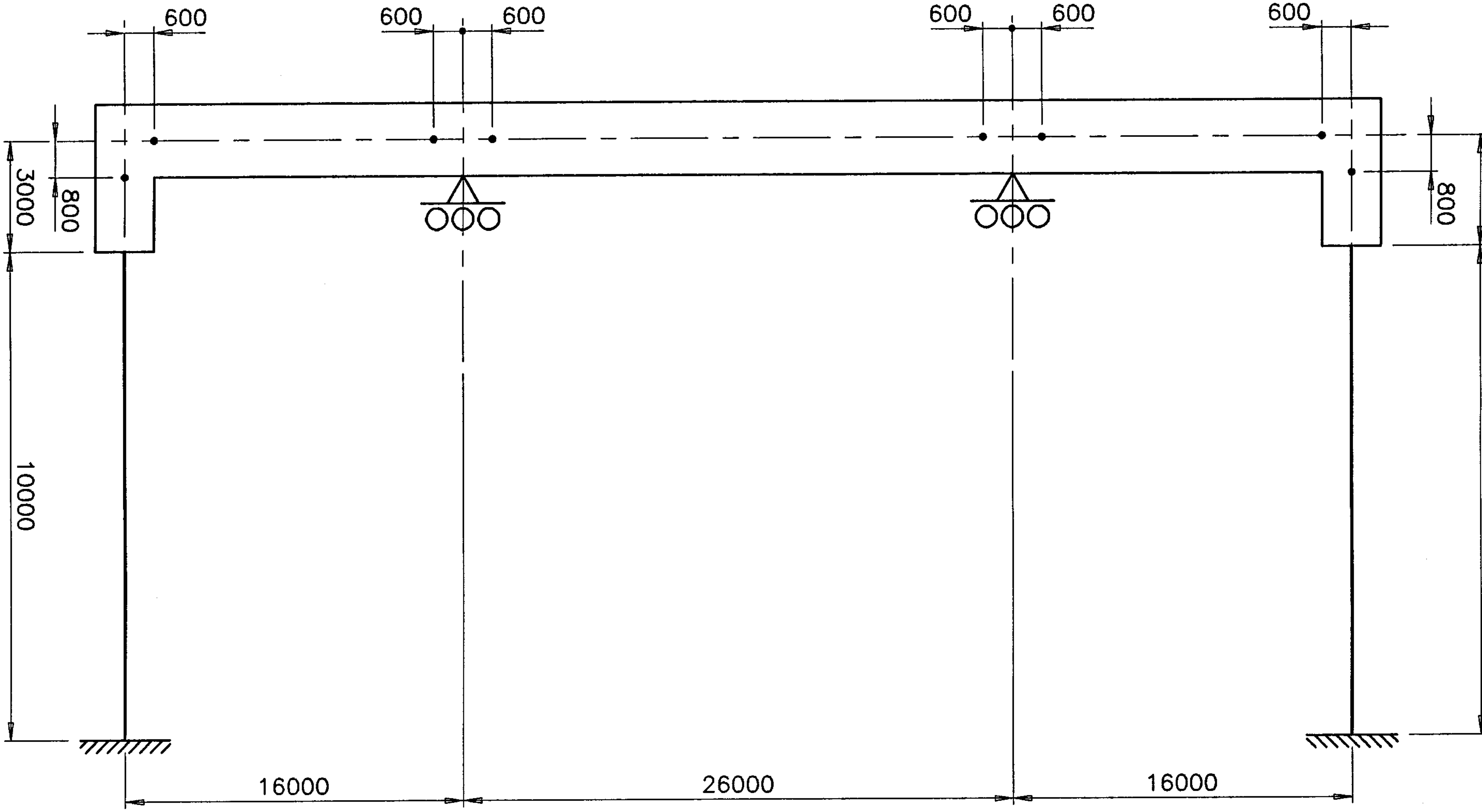
Location	sdl	Thermal	Soil Pressure	Live load Maximum	Minimum
0.000	0	-0	-0	0	-0
0.000	0	-0	-0	0	-0
20.000	0	-0	-0	0	-0
40.000	0	-0	-0	0	-0
60.000	0	-0	-0	0	-0
80.000	0	-0	-0	0	-0
100.000	0	0	-0	0	-0
120.000	0	0	-0	0	-0
140.000	-0	0	0	0	-0
160.000	-0	0	0	0	-0
180.000	-0	0	0	0	-0
200.000	-0	0	0	0	-0

N/A

Location	sdl	Thermal	Soil Pressure	Live load Maximum	Minimum
full wall	0	-0	-0	0	-0

N/A

Location	sdl	Thermal	Soil Pressure	Live load Maximum	Minimum
0.000	-0	0	0	5	-5
0.000	-0	0	0	5	-5
20.000	-0	0	0	5	-5
40.000	-0	0	0	5	-5
60.000	-0	0	0	5	-5
80.000	-0	0	0	5	-5
100.000	-0	0	0	5	-5
120.000	-0	0	0	5	-5
140.000	-0	0	0	5	-5
160.000	-0	0	0	5	-5
180.000	-0	0	0	5	-5
200.000	-0	0	0	5	-5



NOTE:

• DENOTES LOCATION OF CRITICAL SECTION.

EXAMPLE – 3 SPAN, NON-INTEGRAL PIERS

BRIDGE ANALYSIS SPREADSHEET

Bridge Location:	Three Span - Integral Abutments & Simple Piers
District :	XX
wp # :	XX/XXXX
Site # :	XX-XXXX
Designer :	XXXXXXXXX

1 - GENERAL...

Thermal Coefficient of Expansion.....	1E-05	/°C
Temperature change........................	20	°C
# of Spans...	3	
Modulus of Elasticity..........................	27400	Mpa
Superimposed Dead Load................	2.50	kN/m²
% of Truck per meter.........................	25%	truck/m
Dynamic Load Allowance Truck.......	0.25	
Dynamic Load Allowance Lane.........	0.10	

2- BASIC MODEL PARAMETERS...

	length, mm	Inertia, mm	Area, mm²
Spans			
1st	16000	1.8E+11	650000
2nd	26000	2.0E+11	850000
3rd	16000	1.8E+11	650000
Abutments/Piers			
left abutment	3000	4.3E+11	
1 st pier	5000	1	
2 nd pier	5000	1	
right abutment	3000	4.3E+11	
Piles			
left abutment	10000	2.1E+09	
1 st pier	10000	1	
2nd pier	10000	1	
right abutment	10000	2.1E+09	

3 - LOCATION OF CRITICAL SECTIONS...

Spans	Left	Right
1st (x1, x2)	600	600
2nd (x3, x4)	600	600
3rd (x5, x6)	600	600

Abutments/Piers	
left abutment (y1)	800
1 st pier (y2)	700
2 nd pier (y3)	700
right abutment (y4)	800

4 - LIVE LOAD...

Axle#	Axle Load (kN)	Spacing (m)
1	60	-
2	160	3.6
3	160	1.2
4	200	6
5	160	7.2

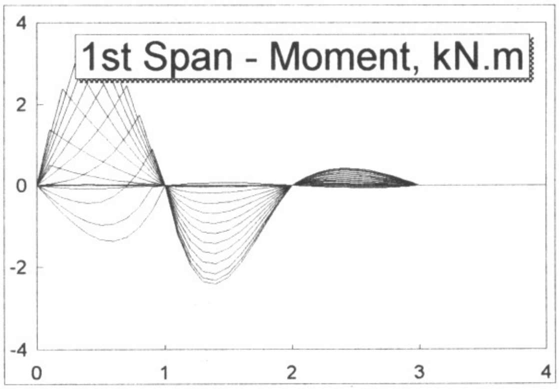
Lane Load 2.50 Kn/m²

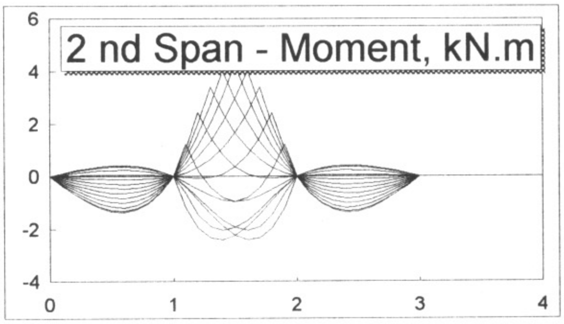
Truck Fraction 0.7

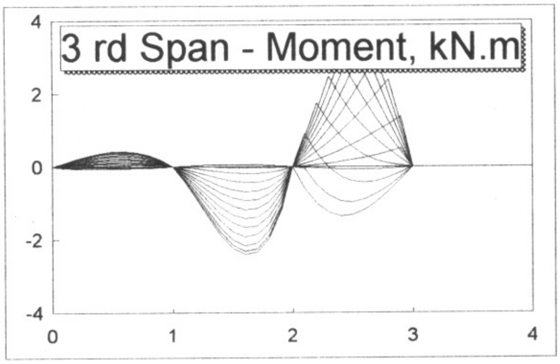
5-ANALYZE...

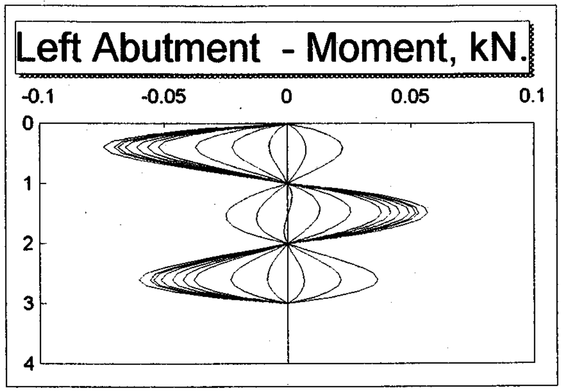
.... Analysis Status............... 100.0%

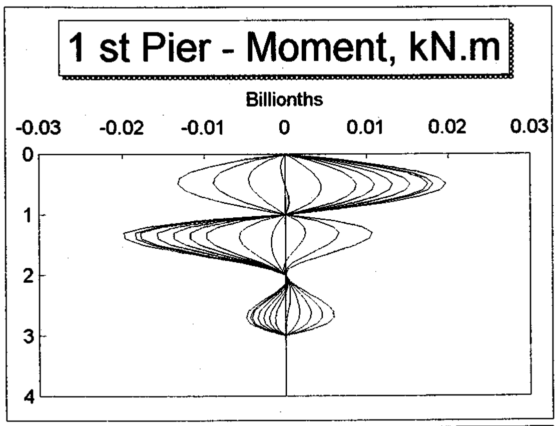
5 - INFLUENCE LINES:

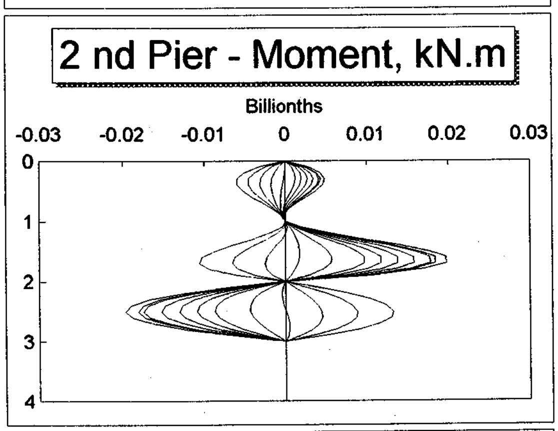


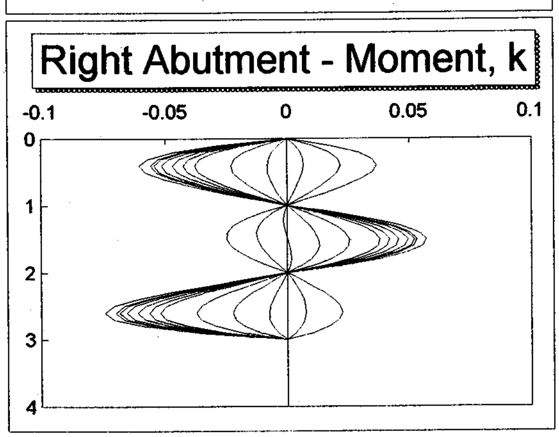





Left Abutment - Moment, kN.
-0.1
-0.05
0
0.05
0.1
0
1
2
3
4


1 st Pier - Moment, kN.m
Billionths
-0.03
-0.02
-0.01
0
0.01
0.02
0.03
0
1
2
3
4


2 nd Pier - Moment, kN.m
Billionths
-0.03
-0.02
-0.01
0
0.01
0.02
0.03
0
1
2
3
4


Right Abutment - Moment, k
-0.1
-0.05
0
0.05
0.1
0
1
2
3
4

7 - UNFACTORED RESPONSES...

Soil Pressures

Left Abutment

thermal movement (<-- +ve) 5.8 mm

pressure coefficent 1.25

soil pressure (at abut. bot.) 75 kN/m²

Right Abutment

thermal movement (--> +ve) 5.8 mm

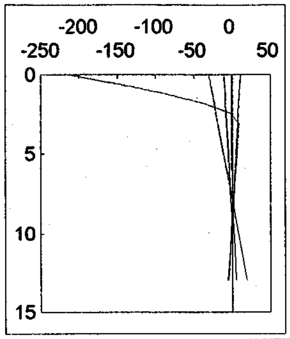
pressure coefficent 1.25

soil pressure (at abut. bot.) 75 kN/m²

Reactions (kN & m)

Load	Support #	Rxx (← +)	Ryy (↑ +)	Mzz (↷ +)
sdl	left abut	-0	12	-0
	1st pier	-0	60	-0
	2nd pier	0	60	0
	right abut	0	12	0
Thermal	left abut	-4	2	-19
	1st pier	-0	-2	-0
	2nd pier	0	-2	0
	right abut	4	2	19
Soil	left abut	1	15	6
	1st pier	-0	-15	-0
	2nd pier	0	-15	0
	right abut	-1	15	-6
Live load Maximum	left abut	1	114	5
	1st pier	0	173	0
	2nd pier	0	176	0
	right abut	1	121	5
Live load Minimum	left abut	-1	-27	-5
	1st pier	-0	-13	-0
	2nd pier	-0	-14	-0
	right abut	-1	-26	-5

Left Abutment - Moment, kN.m



Location	sdl	Thermal	Soil Pressure	Live load Maximum	Minimum
0.800	**-1**	**-27**	**-126**	**10**	**-10**
0.000	-1	-30	-213	11	-11
0.600	-1	-28	-147	10	-10
1.200	-1	-26	-87	9	-9
1.800	-1	-23	-37	9	-9
2.400	-1	-21	-4	8	-8
3.000	-1	-19	8	7	-7
5.000	-0	-11	5	5	-5
7.000	-0	-4	3	2	-3
9.000	-0	4	-0	1	-1
11.000	0	12	-3	3	-2
13.000	0	19	-6	5	-5

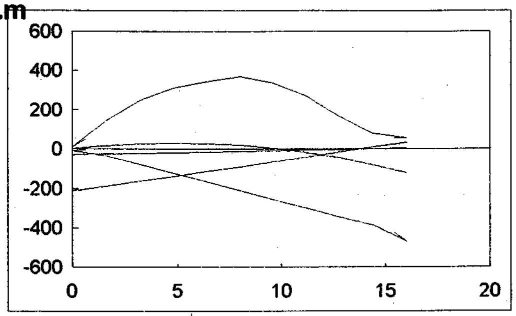
Left abutment - Axial, kN

Location	sdl	Thermal	Soil Pressure	Live load Maximum	Minimum
full wall	12	-2	-15	27	-114

Left Abutment - Shear, kN

Location	sdl	Thermal	Soil Pressure	Live load Maximum	Minimum
0.800	**-0**	**-4**	**-103**	**1**	**-1**
0.000	-0	-4	-111	1	-1
0.600	-0	-4	-107	1	-1
1.200	-0	-4	-93	1	-1
1.800	-0	-4	-71	1	-1
2.400	-0	-4	-39	1	-1
3.000	-0	-4	1	1	-1
5.000	-0	-4	1	1	-1
7.000	-0	-4	1	1	-1
9.000	-0	-4	1	1	-1
11.000	-0	-4	1	1	-1
13.000	-0	-4	1	1	-1

1 st Span - Moment, kN.m



Location	sdl	Thermal	Soil Pressure	Live load Maximum	Minimum
0.600	**6**	**-29**	**-203**	**50**	**-7**
0.000	-1	-30	-213	11	-11
1.600	16	-27	-188	144	-34
3.200	26	-23	-163	247	-78
4.800	30	-20	-139	309	-122
6.400	28	-16	-114	344	-167
8.000	19	-13	-90	367	-211
9.600	3	-9	-65	337	-256
11.200	-18	-6	-40	268	-300
12.800	-46	-2	-16	164	-344
14.400	-81	1	9	78	-389
16.000	-122	5	33	57	-470
15.400	**-106**	**3**	**24**	**54**	**-423**

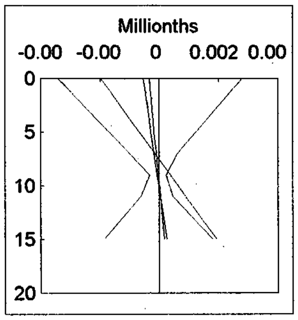
1 st Span - Axial, kN

Location	sdl	Thermal	Soil Pressure	Live load Maximum	Minimum
full span	-0	-4	-111	0	0

1 st Span - Shear, kN

Location	sdl	Thermal	Soil Pressure	Live load Maximum	Minimum
0.600	**11**	**2**	**15**	**100**	**-23**
0.000	12	2	15	120	-23
1.600	8	2	15	100	-23
3.200	4	2	15	84	-23
4.800	0	2	15	70	-25
6.400	-4	2	15	57	-36
8.000	-8	2	15	45	-47
9.600	-12	2	15	33	-65
11.200	-16	2	15	22	-83
12.800	-20	2	15	10	-100
14.400	-24	2	15	4	-100
16.000	-28	2	15	4	-121
15.400	**-26**	**2**	**15**	**37**	**-121**

1 st Pier - Moment, kN.m



Location	sdl	Thermal	Soil Pressure	Live load Maximum	Minimum
0.700	-0	-0	-0	0	-0
0.000	-0	-0	-0	0	-0
1.000	-0	-0	-0	0	-0
2.000	-0	-0	-0	0	-0
3.000	-0	-0	-0	0	-0
4.000	-0	-0	-0	0	-0
5.000	-0	-0	-0	0	-0
7.000	-0	-0	-0	0	-0
9.000	-0	0	-0	0	-0
11.000	0	0	0	0	-0
13.000	0	0	0	0	-0
15.000	0	0	0	0	-0

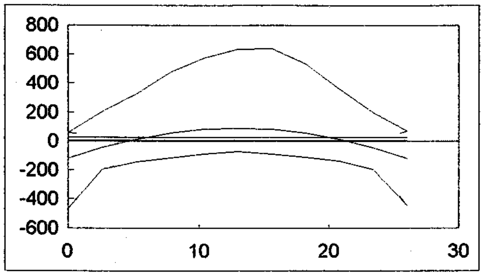
1 st Pier - Axial, kN

Location	sdl	Thermal	Soil Pressure	Live load Maximum	Minimum
full pier	-60	-2	-15	13	-173

1 st Pier - Shear, kN

Location	sdl	Thermal	Soil Pressure	Live load Maximum	Minimum
0.700	-0	-0	-0	0	-0
0.000	-0	-0	-0	0	-0
1.000	-0	-0	-0	0	-0
2.000	-0	-0	-0	0	-0
3.000	-0	-0	-0	0	-0
4.000	-0	-0	-0	0	-0
5.000	-0	-0	-0	0	-0
7.000	-0	-0	-0	0	-0
9.000	-0	-0	-0	0	-0
11.000	-0	-0	-0	0	-0
13.000	-0	-0	-0	0	-0
15.000	-0	-0	-0	0	-0

2 nd Span - Moment, kN.m



Location	sdl	Thermal	Soil Pressure	Live load Maximum	Minimum
0.600	**-103**	**5**	**24**	**51**	**-400**
0.000	-122	5	24	57	-470
2.600	-46	5	24	204	-196
5.200	14	5	24	325	-141
7.800	56	5	24	475	-116
10.400	81	5	24	575	-91
13.000	90	5	24	636	-72
15.600	81	5	24	640	-89
18.200	56	5	24	534	-113
20.800	14	5	24	362	-137
23.400	-46	5	24	197	-193
26.000	-122	5	24	72	-448
25.400	**-103**	**5**	**24**	**53**	**-377**

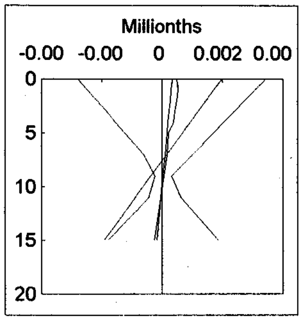
2 nd Span - Axial, kN

Location	sdl	Thermal	Soil Pressure	Live load Maximum	Minimum
full span	-0	-4	-111	0	0

2 nd Span - Shear, kN

Location	sdl	Thermal	Soil Pressure	Live load Maximum	Minimum
0.600	**33**	**-0**	**-0**	**127**	**-9**
0.000	34	-0	-0	145	-9
2.600	28	-0	-0	127	-9
5.200	21	-0	-0	87	-12
7.800	15	-0	-0	69	-27
10.400	8	-0	-0	55	-42
13.000	2	-0	-0	55	-42
15.600	-5	-0	-0	41	-54
18.200	-12	-0	-0	28	-82
20.800	-18	-0	-0	10	-115
23.400	-25	-0	-0	10	-115
26.000	-31	-0	-0	28	-140
25.400	**-30**	**-0**	**-0**	**91**	**-14**

2 nd Pier - Moment, kN.m



Location	sdl	Thermal	Soil Pressure	Live load Maximum	Minimum
0.700	0	0	0	0	-0
0.000	0	0	0	0	-0
1.000	0	0	0	0	-0
2.000	0	0	0	0	-0
3.000	0	0	0	0	-0
4.000	0	0	0	0	-0
5.000	0	0	0	0	-0
7.000	0	0	0	0	-0
9.000	0	-0	0	0	-0
11.000	-0	-0	-0	0	-0
13.000	-0	-0	-0	0	-0
15.000	-0	-0	-0	0	-0

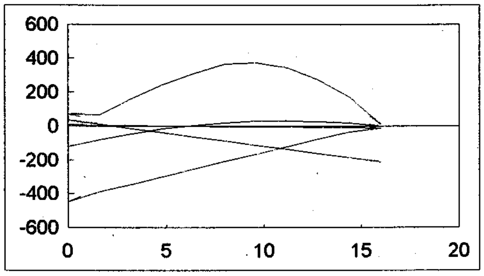
2 nd Pier - Axial, kN

Location	sdl	Thermal	Soil Pressure	Live load Maximum	Minimum
full wall	-60	2	15	14	-176

2 nd Pier - Shear, kN

Location	sdl	Thermal	Soil Pressure	Live load Maximum	Minimum
0.700	0	0	0	0	-0
0.000	0	0	0	0	-0
1.000	0	0	0	0	-0
2.000	0	0	0	0	-0
3.000	0	0	0	0	-0
4.000	0	0	0	0	-0
5.000	0	0	0	0	-0
7.000	0	0	0	0	-0
9.000	0	0	0	0	-0
11.000	0	0	0	0	-0
13.000	0	0	0	0	-0
15.000	0	0	0	0	-0

3 rd Span - Moment, kN.m



Location	sdl	Thermal	Soil Pressure	Live load Maximum	Minimum
0.600	**-106**	**4**	**24**	**56**	**-416**
0.000	-122	5	33	72	-448
1.600	-81	3	9	68	-389
3.200	-46	2	-16	164	-344
4.800	-18	-0	-40	245	-300
6.400	3	-2	-65	310	-256
8.000	19	-3	-90	365	-211
9.600	28	-5	-114	376	-167
11.200	30	-6	-139	342	-122
12.800	26	-8	-163	270	-78
14.400	16	-10	-188	170	-34
16.000	-1	-11	-213	11	-11
15.400	**7**	**-11**	**-203**	**58**	**-7**

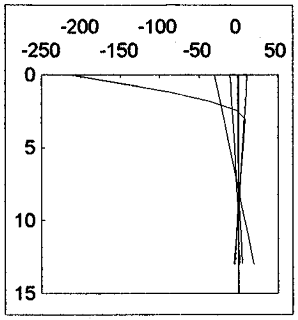
3 rd Span - Axial, kN

Location	sdl	Thermal	Soil Pressure	Live load Maximum	Minimum
full span	-0	-4	-111	1	-1

3 rd Span - Shear, kN

Location	sdl	Thermal	Soil Pressure	Live load Maximum	Minimum
0.600	**26**	**-2**	**-15**	**91**	**-14**
0.000	28	-2	-15	105	-6
1.600	24	-2	-15	91	-14
3.200	20	-2	-15	75	-22
4.800	16	-2	-15	62	-32
6.400	12	-2	-15	49	-46
8.000	8	-2	-15	49	-46
9.600	4	-2	-15	36	-62
11.200	-0	-2	-15	24	-78
12.800	-4	-2	-15	24	-96
14.400	-8	-2	-15	24	-114
16.000	-12	-2	-15	24	-114
15.400	**-11**	**-2**	**-15**	**24**	**-114**

Right Abutment - Moment, kN.m



Location	sdl	Thermal	Soil Pressure	Live load Maximum	Minimum
0.800	**-1**	**-27**	**-126**	**10**	**-10**
0.000	-1	-30	-213	11	-11
0.600	-1	-28	-147	10	-10
1.200	-1	-26	-87	9	-10
1.800	-1	-23	-37	9	-9
2.400	-1	-21	-4	8	-8
3.000	-1	-19	8	7	-8
5.000	-0	-11	5	5	-5
7.000	-0	-4	3	2	-3
9.000	-0	4	-0	1	-1
11.000	0	12	-3	3	-2
13.000	0	19	-6	5	-5

Right Abutment - Axial, kN

Location	sdl	Thermal	Soil Pressure	Live load Maximum	Minimum
full wall	-12	-2	-15	26	-121

Right Abutment - Shear, kN

Location	sdl	Thermal	Soil Pressure	Live load Maximum	Minimum
0.800	**0**	**4**	**103**	**1**	**-1**
0.000	0	4	111	1	-1
0.600	0	4	107	1	-1
1.200	0	4	93	1	-1
1.800	0	4	71	1	-1
2.400	0	4	39	1	-1
3.000	0	4	-1	1	-1
5.000	0	4	-1	1	-1
7.000	0	4	-1	1	-1
9.000	0	4	-1	1	-1
11.000	0	4	-1	1	-1
13.000	0	4	-1	1	-1

Appendix - 3

Simplified analysis of a Single Span

Integral Abutment Bridge

By:

Andrew Burgess P.Eng.

Darshan Bhatia P.Eng.

SIMPLIFIED ANALYSIS OF A SINGLE SPAN INTEGRAL ABUTMENT BRIDGE

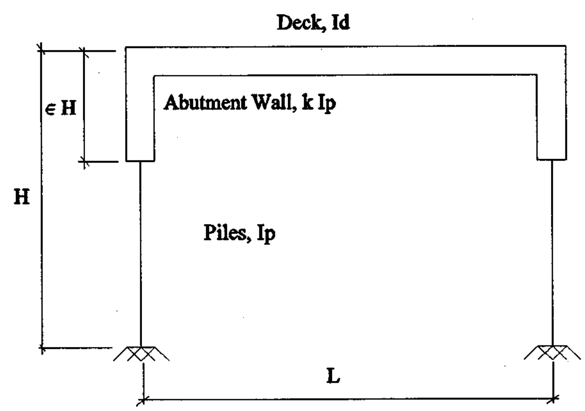
INTRODUCTION

The use of integral abutment bridges has dramatically increased in recent years. The analysis of an integral bridge is more complex than a simply supported bridge. This report develops a simplified method of analysis of a single span integral abutment bridge under gravity loads.

MODEL ASSUMPTIONS

The following were assumed in the analytical model:

- Piles are fixed at the base. With soil interaction the piles become effectively fixed at some depth (cantilever method). This depth to effective fixity is dependent on soil properties to be determined by the designer.
- All member end connections are assumed fixed in transferring shear and moment.
- All members are prismatic.
- Single span bridge.
- Bridge is symmetrical about the mid-span.



Integral Abutment Bridge Model

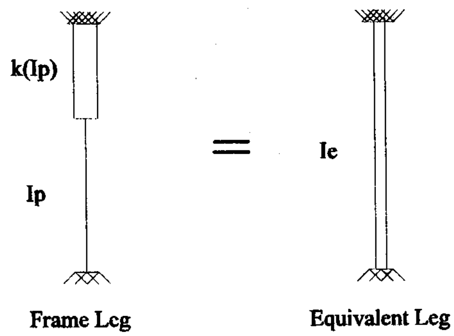
Design Parameters:

H = total length of frame leg (effective pile length + abutment wall length)
I_d = moment of inertia of deck
I_p = moment of inertia of piles
k = ratio of abutment wall inertia to Ia
L = span
ϵ = ratio of abutment wall length to H

Note: all interias must be converted to one material type using the modular ratio and based on a constant deck width.

EFFECTIVE ABUTMENT STIFFNESS

The leg of the frame is comprised of two members with different stiffness. In order to simplify the analysis the leg was reduced to a single member of equivalent stiffness, I_e. This equivalent leg stiffness is referred to as the 'effective abutment stiffness'.



STIFFNESS RATIO

The relative stiffness of the frame components dictates the distribution of forces and moments, as in any frame structure. The ratio of the deck stiffness to the effective abutment stiffness, R, is an important characteristic of the frame.

$$R = \frac{I_d}{I_p} \cdot \frac{H}{L} \cdot \frac{(4\, k_1\, k_2 - 3\, k_3^2)}{4\, k_4}$$

Where :

$$k_1 = (1-\epsilon)^3 + \frac{\epsilon}{k}(3 - 3\epsilon + \epsilon^2)$$

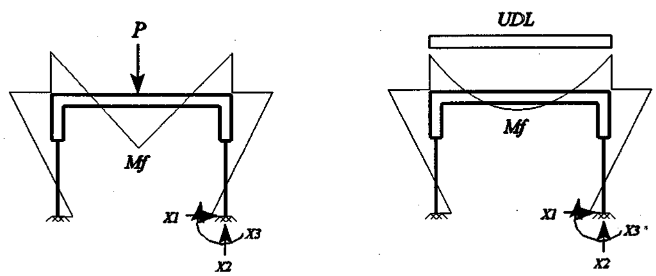
$$k_2 = (1-\epsilon) + \frac{\epsilon}{k}$$

$$k_3 = (1-\epsilon)^2 + \frac{\epsilon}{k}(2-\epsilon)$$

$$k_4 = (1-\epsilon^3) + \frac{\epsilon^3}{k}$$

SIMPLE MOMENT FRACTION

Using the flexibility method the frame was solved for two different load cases, a uniformly distributed load and a point load anywhere on the span. The solution is given in the appendix in the form of X_1, X_2 and X_3.



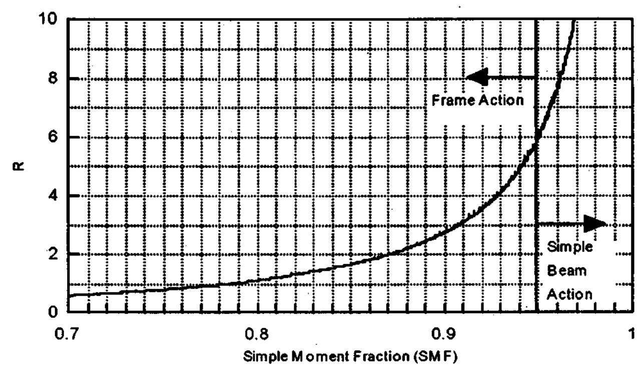
Frame Solution

The positive moment at the mid-span is reduced because of the frame action. The ratio of the mid-span moment, considering frame action, to the moment when considered as a simple span, is refered to as a 'simple moment fraction' or 'SMF', and is defined as:

$$SMF = \frac{M_f}{M_s}$$

Clearly, in the absence of any frame action, when the stiffness of the supporting legs is very small, there is no reduction in the mid-span moment and no negative moment in the corners. SMF approaches the value of unity in this case. On the other hand, when the vertical legs are very stiff, a large negative moment is developed in the corners and the midspan moment is reduced. In the limiting case, the corner moments will approach the negative moments for a fully fixed case with the mid-span positive moment approaching the smallest value.

Generating a large number of solutions a curve was plotted showing the relationship between R and SMF. It is seen that the relative distribution of forces and moments is not affected by load type which makes this curve applicable to any gravity load.



This curve eliminates the need for a frame analysis under gravity loads. Using the SMF a simple beam analysis is modified to account for frame action.

$$+M_f\ (mid\text{-}span) = SMF\ M_s$$

$$-M_f\ (corner) = (1\text{-}SMF)\ M_s$$

Of equal importance, the sensitivity of the frame action can be easily determined by varying frame parameters.

DISCUSSION

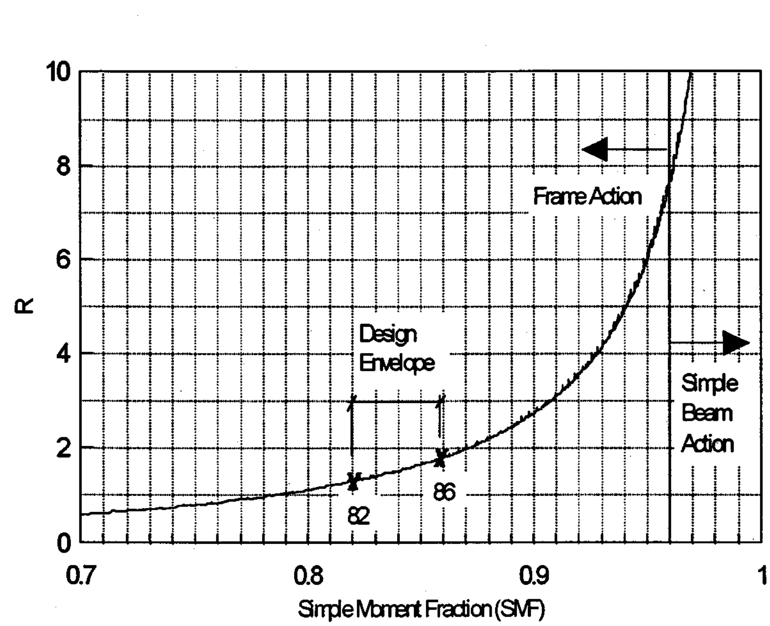
An integral abutment bridge is a frame and as in any frame the distribution of forces and moments is dependent on the relative stiffness of the frame members. Soil interaction also plays a roll in the distribution. Although, under relatively colder temperatures the bridge contracts and moves away from the soil, reducing soil interaction and allowing the frame to act as a frame. This situation produces the design positive moment (mid-span). Under relatively warmer conditions expansion moves the abutment walls into the soil thus, engaging soil interaction. This situation produces design negative moments (corner moments). The effect of 'wall stiffening' caused from soil interaction can be accounted for by reducing the length of pile to the point of fixity. This depends on soil parameters and the magnitude of thermal movements. Varying the pile length results in a SMF design envelope.

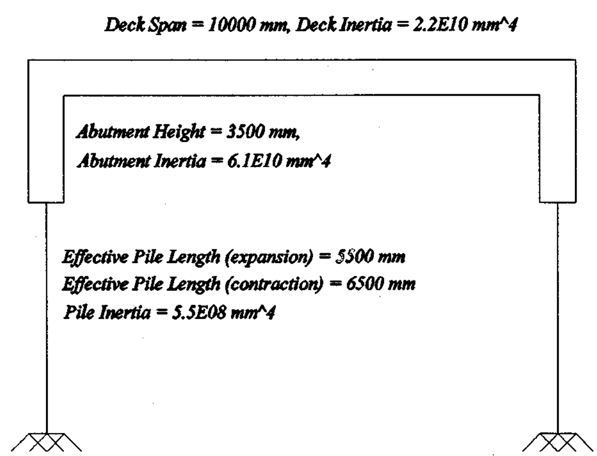
Integral abutment bridges have relatively strong abutment wall stiffness and weak pile stiffness. Due to this large difference (100x) the over all effective abutment stiffness is largely dependent on the stiffness of the weaker component, the piles. The abutment wall simply acts as a rigid link between the superstructure and the piles. The effect of varying the member stiffnesses can be seen through the ratio R. As R approaches infinity the bridge becomes a simple span, alternately as R approaches zero the bridge becomes a rigid frame. Depending on the design requirements either could be preferred. If a reduction in positive bending is of importance increasing pile stiffness maybe considered. If corner stress is to be limited pile stiffness should be reduced.

As can be seen in the Frame Moment Modifier curve the structure becomes less sensitive to varying stiffnesses as the bridge approaches a simple condition. As shown in Example 2 the SMF varies from 96 to 97% within the determined limits of effective pile length. It is recommended when the SMF is greater than 95% the bridge be designed as simply supported with nominal reinforcing in the corners.

DESIGN EXAMPLES

Examples of actual bridges built in Ontario and their SMF are given below.



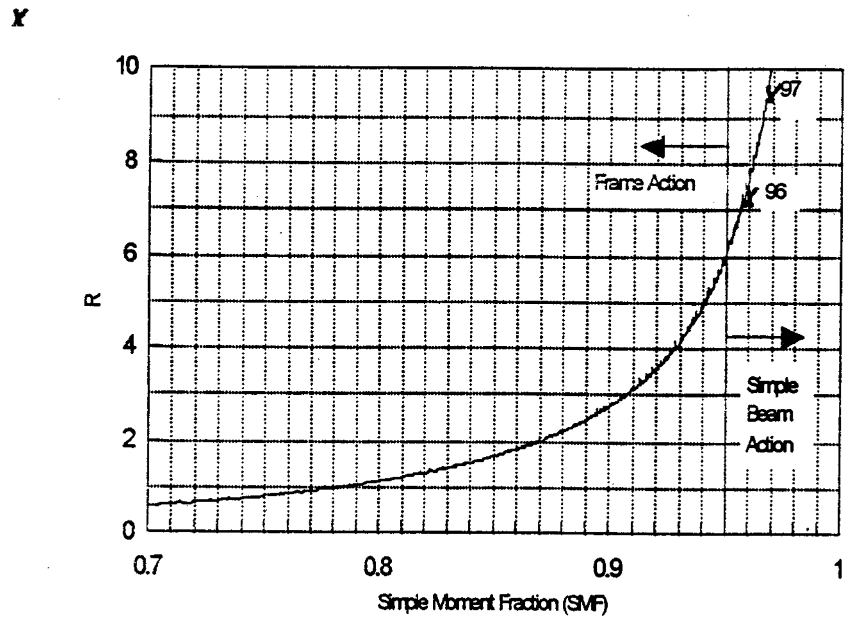


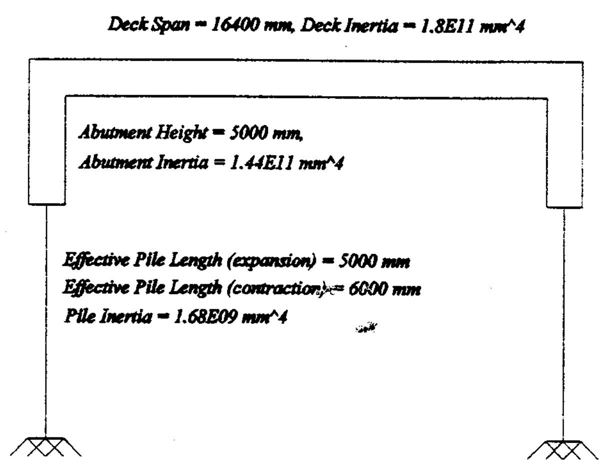
Example #1

Design Moment, Positive (mid-span) = 0.86 x simple span moment

Design Moment, Negative (corner) = (1 - 0.82) x simple span moment

Example 2.



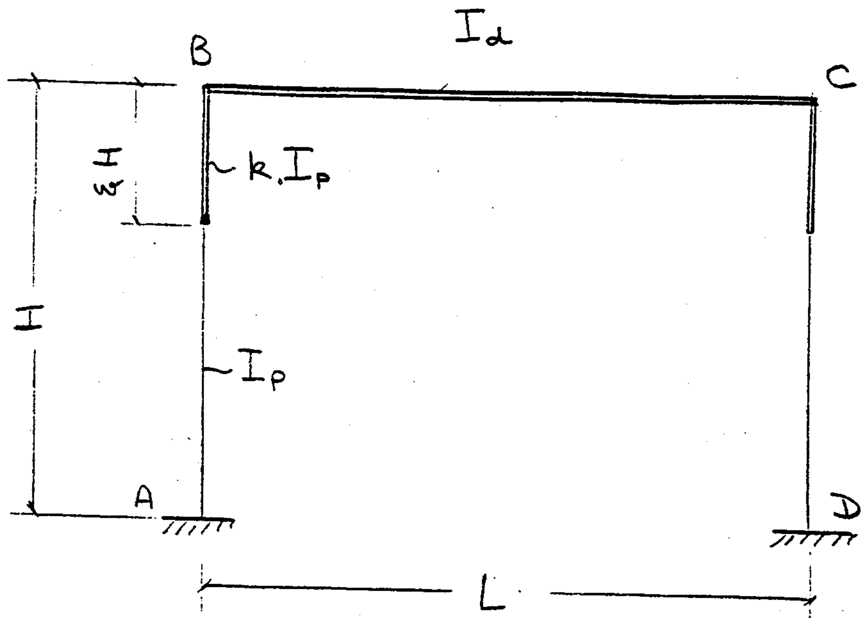


Example #2

Since SMF > 95% design as simply supported.

RIGID FRAME ANALYSIS USING FLEXIBILITY METHOD

SYMMERICAL FRAME, WITH SOLUTION FOR **GENERAL LOAD CASES**:



DEFINE THE FOLLOWING:

$$k_1 = \left[(1-\varepsilon)^3 + \frac{\varepsilon}{k}(3 - 3\varepsilon + \varepsilon^2)\right]$$

$$k_2 = \left[(1-\varepsilon) + \frac{\varepsilon}{k}\right]$$

$$k_3 = \left[(1-\varepsilon)^2 + \frac{\varepsilon}{k}(2-\varepsilon)\right]$$

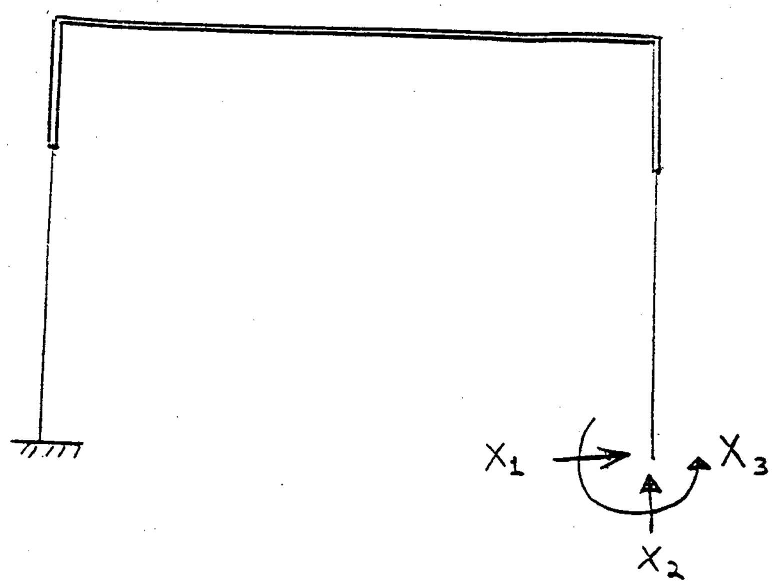
$$k_4 = \left[(1-\varepsilon^3) + \frac{\varepsilon^3}{k}\right]$$

$P = \frac{H}{L} \cdot \frac{I_d}{I_p}$, $P_1 = k_1 P$, $P_2 = k_2 P$, $P_3 = k_3 P$

THEN:

STIFFNESS $K_{BA} = \frac{EI_p}{H} \cdot \frac{4 k_4}{\left[4k_1k_2 - 3k_3^2\right]}$

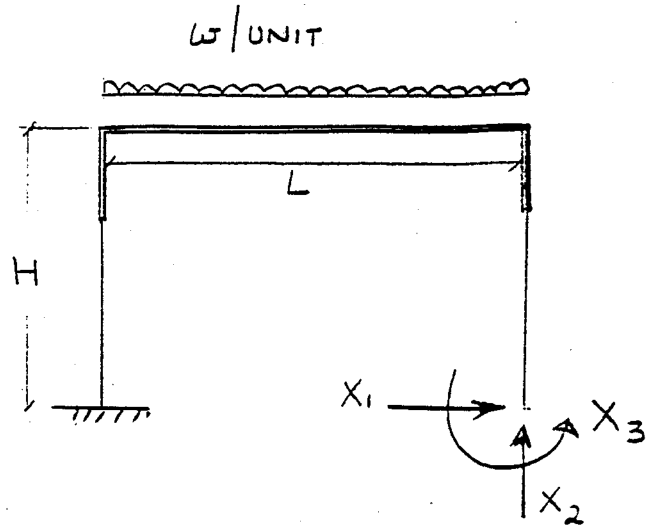
CHOOSE A RELEASE SYSTEM WHICH DOES NOT RESTRICT SOLUTIONS TO SYMMETRICAL LOAD CASES ONLY, AS SHOWN BELOW:



DERIVE FLEXIBILITY MATRIX AND FIND ITS INVERSE, APPLY DIFFERENT LOADING CONDITIONS TO FIND THE INDETERMINATE FORCES X_1, X_2, X_3

LOAD CASE 1

UNIFORMLY DISTRIBUTED LOAD ON GIRDER, w/UNIT LENGTH



$$X_1 = \frac{wL}{4} \cdot \frac{1}{R} \cdot \frac{(P_3 - 2P_2)}{\left[(3+2P_1)(1+2P_2) - 3(1+P_3)^2\right]}$$

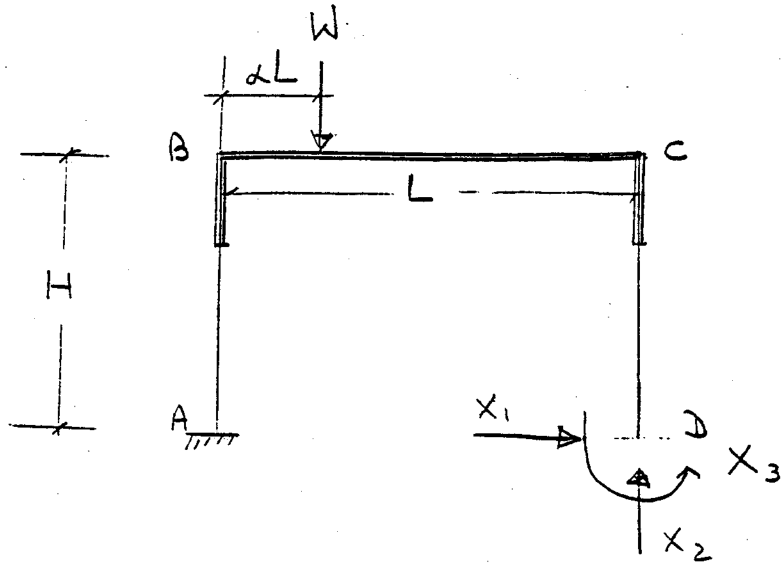
$$X_2 = \frac{wL}{2}$$

$$X_3 = \frac{wL^2}{12} \cdot \frac{(3P_3 - 2P_1)}{\left[(3+2P_1)(1+2P_2) - 3(1+P_3)^2\right]}$$

$$\left(R = \frac{H}{L} \right)$$

LOAD CASE 2.

POINT LOAD ANYWHERE ON THE SPAN



$$X_1 = \frac{3W}{2} \cdot \frac{1}{R} \cdot \alpha(1-\alpha) \cdot \frac{(P_3 - 2P_2)}{\left[(3+2P_1)(1+2P_2) - 3(1+P_3)^2\right]}$$

$$X_2 = W \cdot \alpha \cdot \left[1 - \frac{(1-\alpha)(1-2\alpha)}{(1+6P_2)}\right]$$

$$X_3 = \frac{WL}{2} \cdot \alpha(1-\alpha) \cdot \left[\frac{(3P_3 - 2P_1)}{\left[(3+2P_1)(1+2P_2) - 3(1+P_3)^2\right]} + \frac{(1-2\alpha)}{(1+6P_2)}\right]$$

WHERE αL IS THE DISTANCE OF THE LOAD FROM JOINT B, P_1, P_2, P_3 ARE DEFINED AS BEFORE,

$R = \frac{H}{L}$

GENERAL LOAD CASE :

FOR ANY GENERAL LOAD CASE, THE FOLLOWING INVERSE OF THE FLEXIBILITY MATRIX CAN BE USED, IN THE PARAMETRIC FORM :

$$
f]^{-1} = \frac{1}{(1+6P_2)\left[(3+2P_1)(1+2P_2)-3(1+P_3)^2\right]} \times
\begin{bmatrix}
\frac{3}{R^2}(1+2P_2)(1+6P_2), & 0, & -\frac{3L}{R}(1+6P_2)(1+P_3) \\
0, & 12\left[(3+2P_1)(1+2P_3)-3(1+P_3)^2\right], & -6L\left[(3+2P_1)(1+2P_2)-3(1+P_3)^2\right] \\
-\frac{3L}{R}(1+6P_2)(1+P_3), & -6L\left[(3+2P_1)(1+2P_2)-3(1+P_3)^2\right], & L^2\left[4(3+2P_1)(1+3P_2)-9(1+P_3)^2\right]
\end{bmatrix}
$$

WHERE $R = \frac{H}{L}$.

Appendix - 4

Integral Abutment Bridges

In

Ontario

INTEGRAL ABUTMENT BRIDGES IN ONTARIO

SITE NO.	REGION	DATE	NAME	NO./SPAN	SPAN ARR.	ALIGN.	SKEW	WIDTH	TYPE	PIER	FOUND.
164-151-1A	C	59	WATERLOO TOWNSHIP BRIDGE No. 2	X	XX	XX	XX	XXXX	XXX	X/X	XX
164-150-1A	C	59	WATERLOO TOWNSHIP BRIDGE No. 3	X	XX	XX	XX	XXXX	XXX	X/X	XX
46-141	NW	86	MOXAM'S CREEK BRIDGE, REG. RD. 55	7	6.1-6.1-6.1-6.1-6.1-6.1-6.1	ST	0	14.33	SI	TP	TP
33-151	SW	90	REGIONAL ROAD # 36	4	12-19-19-12	ST	10	7.2	PBG	COL.	CO
42-85S	SW	90	SEVERN RIVER OVERFLOW CHAN-SB	1	26	ST	10	16.0	PCI	N/A	PI
42-85N	SW	90	SEVERN RIVER OVERFLOW CHAN-NB	1	26	ST	10	18.3	PCI	N/A	PI
42-87S	SW	90	SEVERN RIVER OVERFLOW BOAT CHANNEL	3	31.5-55-31.5	ST	0	12.0	SI	COL.	PI
33-339	SW	85	FISHER MILLS CREEK	1	30	ST	5	29.0	PCI	N/A	PI
23-442	SW	91	CEDAR CREEK BRD. N/S-W RAMP HWY 401	1	26.6	CC/SC	10	9.21	PCI	N/A	PI
23-443	SW	91	CEDAR CREEK BRD W/N-S RAMP HWY 401	1	26.6	CC/SC	10	9.21	PCI	N/A	PI
30-203	SW	91	PINE RIVER BRIDGE HWY 90	3	11-16.5-11	ST	0	13.21	SI	PI	PI
16-309	E	92	GLEL SMAIL RD. U/PASS NBL HWY 416	1	37	ST	0	9.46	SB	N/A	PI
16-309	E	92	GLEN SMAIL RD. U/PASS SBL HWY 416	1	37	ST	0	9.46	SB	N/A	PI
48W-70	NW	92	SLATER RIVER HWY 61	1	35	ST	15	13.41	SI	N/A	PI
48W-86	NW	93	SLATER RIVER	1	27	ST	0	12.41	SI	N/A	PI
45-28	NW	93	PINE RIVER BRIDGE HWY 619	2	27.6-27.6	ST	0	9.6	PCI	PI	PI
38S-211	NW	92	TWO TREE RIVER BRIDGE HWY 548	1	25	ST	30	9.6	SI	N/A	PI
19-47	SW	93	AUSABLE RIVER BRIDGE HWY 7	3	16-26-16	ST	15	11.96	PCI	SH	PI
48W-33	NW	93	CN O'HEAD AT SISTONENS COR. HWY 11/17	3	12-15-12	ST	3	11.95	SI	SH	PI
18-20	C	93	EIGHTEEN MILE CREEK ON QEW WBL	3	19-22-19	ST	9	21.2	PCI	3CC	CO
18-20	C	93	EIGHTEEN MILE CREEK ON QEW EBL	3	19-22-19	ST	9	21.2	PCI	3CC	CO
18-374	C	93	EIGHTEEN MILE CREEK ON QEW N. S. RD.	3	19-22-19	ST	9	12.91	PCI	2CC	PI
18-375	C	93	EIGHTEEN MILE CREEK ON QEW S. S. RD.	3	19-22-19	ST	9	12.91	PCI	2CC	PI
44-365	N	94	McGILLVARY CREEK HWY 11	1	34	ST	0	20.46	PCI	N/A	PI
XX-XXX	E	94	PALLADUM DRIVE INTERCHANGE	2	36.5-36.5	ST	0	20.41	PIC	PI	PI
18-19	C	94	JORDAN HARBOUR QEW EBL	3	27.5-28.5-27.5	ST	0	21.21	PCI	3CC	CO
18-19	C	94	JORDAN HARBOUR QEW WBL	3	27.5-28.5-27.5	ST	0	21.21	PCI	3CC	CO

INTEGRAL ABUTMENT BRIDGES IN ONTARIO

SITE NO.	REGION	DATE	NAME	NO./SPAN	SPAN ARR.	ALIGN.	SKEW	WIDTH	TYPE	PIER	FOUND.
25-0024	SW	94	HANNA BRIDGE	1	26.2	ST	0	9.3	PBG	N/A	PI
23-0273	SW	94	OXFORD STREET BRIDGE	1	39	ST	0	23.75	PCI	N/A	PI
23-0164	SW	94	TECUMSEH STREET BRIDGE	1	33.5	ST	0	12.0	PCI	N/A	PI
30-0064	SW	94	9TH CONCESSION BRIDGE	1	24.84	ST	0	10.5	PCI	N/A	PI
30-0274	SW	94	ADJALA BRIDGE NOTTAWASAGA ROAD	1	30	ST	0	10.41	PCI	N/A	PI
14-0186	SW	95	SLEMAN BRIDGE	3	20.7-23.8-20.7	ST	0	9.91	PCI	PI	PI
11-0050	E	95	ROBINSON'S BRIDGE	1	19.0	ST	0	9.41	PCI	N/A	SH
13-0053	SW	95	LITTLE BEAR CREEK BRIDGE	1	23.3	ST	0	9.79	PBG	N/A	PI
37-1476	C	95	STEELS AVE. CNR O/PASS	1	21.7	ST	1	31.2	PBG	N/A	PI
36-0116	C	95	FAIRCHILD CREEK BRIDGE CON. 2	1	11.6	C & ST	10	10.4	PHS	N/A	PI
13-0086	SW	95	WINTERLINE ROAD BRIDGE	1	9.14	ST	0	12.195	PHS	N/A	PI

LEGEND

C – CIRCULAR CURVE
CC – CIRCULAR CAISSON
CO – COMMON FOOTING
COL – COLUMN
N/A – NOT APPLICABLE
PBG – PRESTRESSED BOX GIRDER
PCI – PRESTRESSED CONCRETE GIRDER
PHS – PRESTRESSED HOLLOW SLAB
PI – STEEL PILE
SB – STEEL BOX GIRDER
SC – SPIRAL
SH – SHALLOW FOUNDATION
SI – STEEL PLATE GIRDER
ST – TANGENT
TP – TIMBER PILE
X – NOT AVAILABLE

INTEGRAL ABUTMENT BRIDGES IN ONTARIO

STRUCTURE NO.	REGION	DATE	NAME	NO./SPAN	SPAN ARR.	ALIGN.	SKEW	WIDTH	TYPE	PIER	FOUND.
D4A	C	95	HWY. 407 WBL/MIMICO CREEK	3	12.4-16-12.4	ST	9	19.91	PCI	X/X	XX
D4B	C	95	HWY. 407 EBL/MIMICO CREEK	3	12.4-16-12.4	ST	9	16.61	PCI	X/X	XX
E24	C	95	HWY. 407 EBL/CN BALA	3	26.4-31.2-18.8	ST	6°6'44'	20.41	PCI	XX	XX
E25	C	95	HWY. 407 WBL/CN BALA	3	26.4-31.2-18.8	ST	6°6'44'	24.88	PCI	XX	XX
E90	C	95	RAMP 404N-407E/RAMP407W 4-04N	1	33.1	ST	11°25'11"	14.7	PCI	N/A	XX
D63A	C	95	HWY. 407 EBL/RAINBOW CREEK	1	38.7	ST	16	21.28	PCI	N/A	XX
D63B	C	95	HWY. 407 WBL/RAINBOW CREEK	1	38.7	ST	16	17.5	PCI	N/A	XX
D30	C	95	MARTINGROVE RD./HWY. 407	2	41.5-41.5	ST	6°38'33"	20.83	PCI	XX	XX
E06	C	95	HWY. 407 EBL/WEST DON RIVER	1	38.0	ST	14°59'03"	17.73	PCI	N/A	XX
E07	C	95	HWY. 407 WBL/WEST DON RIVER	1	38.0	ST	14°59'03"	17.73	PCI	N/A	XX
E09	C	95	HWY. 407 EBL/CENTER ST.	2	17.02-20.31	ST	7°7'15"	17.46	PCI	XX	XX
E10	C	95	HWY. 407 WBL/CENTER ST.	2	17.02-20.31	ST	7°7'15"	17.46	PCI	XX	XX