INTERACTIVE DESIGN

OF A

PRECAST CONCRETE SEGMENTAL BRIDGE

USING A SPREADSHEET PROGRAM

A Report

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INTERACTIVE DESIGN OF A PRECAST CONCRETE SEGMENTAL BRIDGE USING A SPREADSHEET PROGRAM

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An Engineering Report submitted to the Faculty of Graduate Studies of the University of Manitoba in partial fulfillment of the requirements of the degree of

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ABSTRACT

Spreadsheet programs are some of the most versatile and popular programs for the personal computer. The interactive features of spreadsheets make them an extremely valuable tool for engineering applications. The main purpose of this paper is to demonstrate an expedient method of designing a segmental bridge on the IBM Personal Computer using a spreadsheet program and utilizing other small computer programs. Spreadsheet models for section properties, erection of cantilevers and establishment of continuity are included for the design example presented in the paper.

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1. INTRODUCTION

Although spreadsheet programs have been available for many years on mainframe computers their use was mainly limited to financial analysis by large corporations. With the advent of the personal computer, spreadsheets have become the most popular computer program for professionals with different backgrounds including engineers. Electronic spreadsheet programs are probably becoming some of the most useful tools for engineers because of their interactive features. Another major advantage of spreadsheets is that one does not have to be a programmer to use them.

In contrast to a conventional steel girder or prestressed concrete I-girder bridge, the design of a concrete segmental bridge is a very time consuming process to be done by hand using regular calculators and design aids. A segmental bridge must be designed for the loads acting on the partially erected structure during any stage of construction as well as on the completed structure. Consequently the design is highly complex and interactive [1, 2]. It is natural to assume that one would have to resort to highly sophisticated mainframe computer programs to carry out the design. However, this paper will show that the interactive features of a spreadsheet program are extremely well suited for carrying out the complex calculations required for segmental bridge design. Only the verification analysis would have to be done on the mainframe computer using a special purpose segmental bridge program.

To show the complete design of a segmental bridge would be quite extensive so this paper will only consider the longitudinal design. The paper will present an alternate design in segmental concrete for the main spans of an actual bridge under construction with conventional steel superstructure.

The report is presented in this manner. First a description of the spreadsheet program and other programs utilized in the design and analysis is presented. The preliminary design involves discussion relative to selecting type, method of construction, span lengths, cross-sectional dimensions and manufacture of segments. The chapter on detailed design gives the design criteria and procedure for developing the spreadsheet models. The appendices include a complete printout of the spreadsheet models prepared for the longitudinal design.

This paper is mainly addressed to the practising bridge engineer. It provides information which can be readily adapted for the design of concrete segmental bridges.

2. SPREADSHEET PROGRAM

2.1 General

The calculation of section properties and design of longitudinal prestressing for the segmental bridge presented in this report was done on the IBM Personal Computer using the spreadsheet program Lotus 1-2-3*. The computer programs TIMEDEP [3] and BEAMANL** were utilized to provide the design forces used in the spreadsheet but the reader can use any other programs for this purpose.

TIMEDEP is a plane frame program for the analysis of time-dependent behaviour of segmental bridges at each stage of construction. It was used to carry out the self weight and thermal analysis. The superimposed dead load and live load plus impact analyses was carried out using BEAMANL. It is a commercially avavilable mainframe computer program for the analysis of continuous beams. The program can analyse bridge girders directly for standard AASHTO truck and lane loadings.

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*Lotus 1-2-3 is a registered trademark of Lotus Development Corporation, Cambridge, Massachusetts.

**BEAMANL is a registered trade mark of Control Data Corporation, Minneapolis, Minnesota.

2.2 LOTUS 1-2-3

Lotus 1-2-3 is primarily an electronic spreadsheet composed of rows and columns. Each row is assigned a number and each column a letter. The intersections of the rows and columns are called "cells". Cells are identified by their row-column coordinates. For example, the cell located at the intersection of column B and row 10 is called B10. These cells can be filled with three kinds of information: numbers, mathematical formulas, including special spreadsheet functions and text (or labels). A cursor, typically one row high and one column wide, allows you to write information into the cells much as a pencil lets you write on a piece of paper.

Electronic spreadsheets allow mathematical relationships to be created between cells. For example if a cell named D5 contains the formula

D5 = B2 x C2

then D5 will display the product of the contents of cell B2 and C2. The cell references serve as variables in the equation. No matter what numbers are entered in B2 and C2 cell D5 will always return their product. For example, if cell B2 contained the number 7 and cell C2 contained the number 3, the formula in cell D5 would return the value

21. If the number in cell C2 were changed to 4, D5 would also change to 28. Of course, spreadsheet formulas can be much more complex than this simple example. A cell can be added to, subtracted from, multiplied by, or divided by any other cell. In addition, built-in spreadsheet functions such as mathematical functions, financial functions and logical functions may be applied to cells.

The act of building a model on a spreadsheet defines all of the mathematical relationships in the model. Until one decides to change relationships, every sum, product, division, and subtraction etc. will remain the same. Each time one enters data into the model, computations will be calculated at the user's command without any effort.

Even more important, spreadsheets allow one to play "what-if" with the model. After a set of mathematical relationships has been built into the worksheet, the worksheet can be recalculated with amazing speed, using different sets of assumptions. This important interactive feature of spreadsheets is particularly well suited for engineering applications.

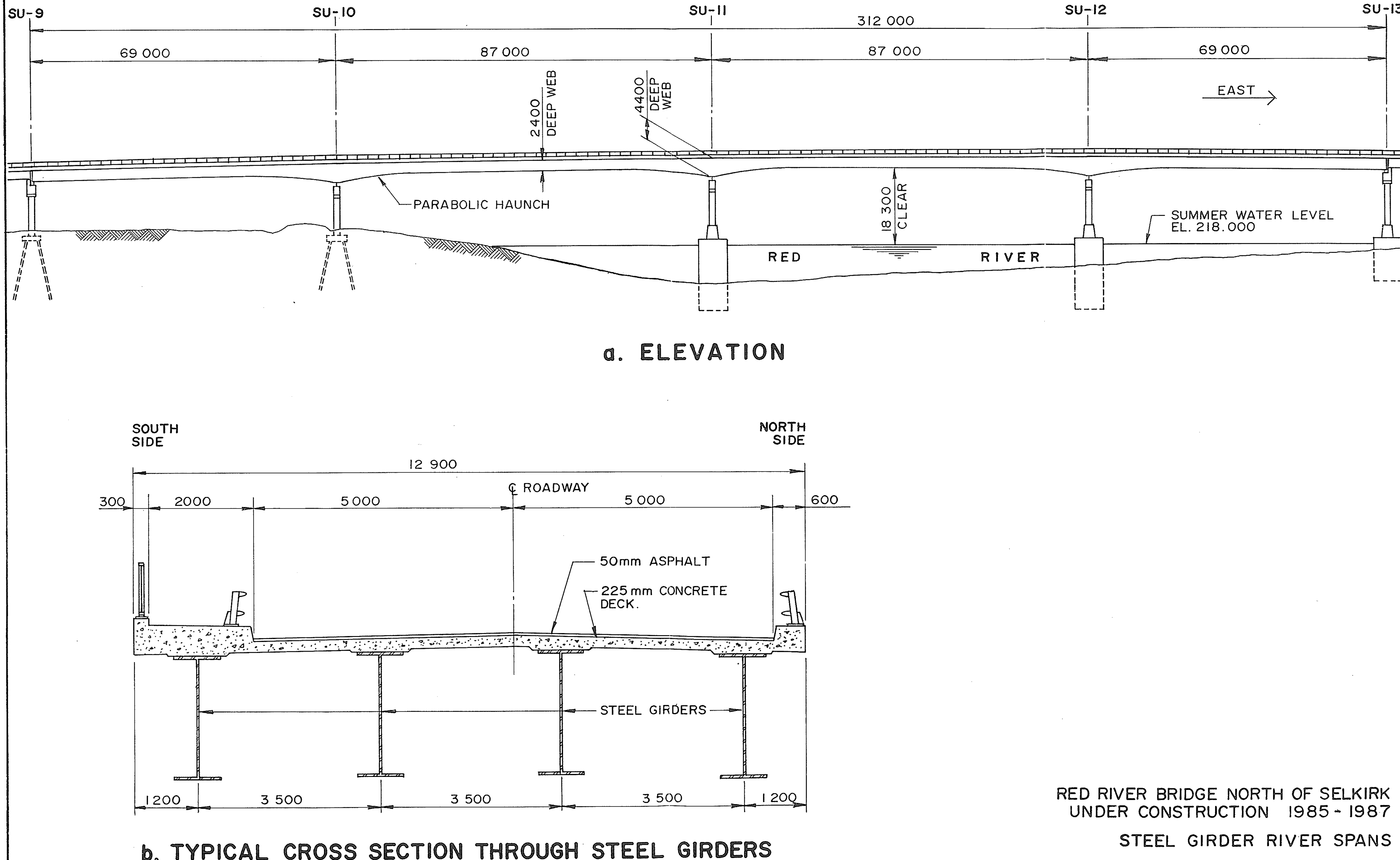
3. PRELIMINARY DESIGN

3.1 General

As a senior Structural Engineer with M. M. Dillon Limited, Consulting Engineers, the author was recently involved in the design of the Red River Bridge North of Selkirk for the Manitoba Department of Highways and Transportation. The river crossing of this new bridge consists of steel I-girders with a concrete deck [Fig.3.1].

The example problem presented in this paper involves an alternate design of the main spans for the above bridge in precast prestressed concrete segmental construction. Therefore, the design example took into consideration the actual site conditions, the clearance requirements and the length of the river crossing etc. as well as meeting the deck configuration and live load requirements of the Selkirk Bridge. The design presented here is by no means construed to represent the most economical solution for a precast segmental alternate for the above bridge.

The Selkirk Bridge (located just north of the town of Selkirk, about 50 km north of Winnipeg) is currently under construction with completion anticipated by fall 1987.



RED RIVER BRIDGE NORTH OF SELKIRK
UNDER CONSTRUCTION 1985 - 1987

STEEL GIRDER RIVER SPANS

FIG. 3.1

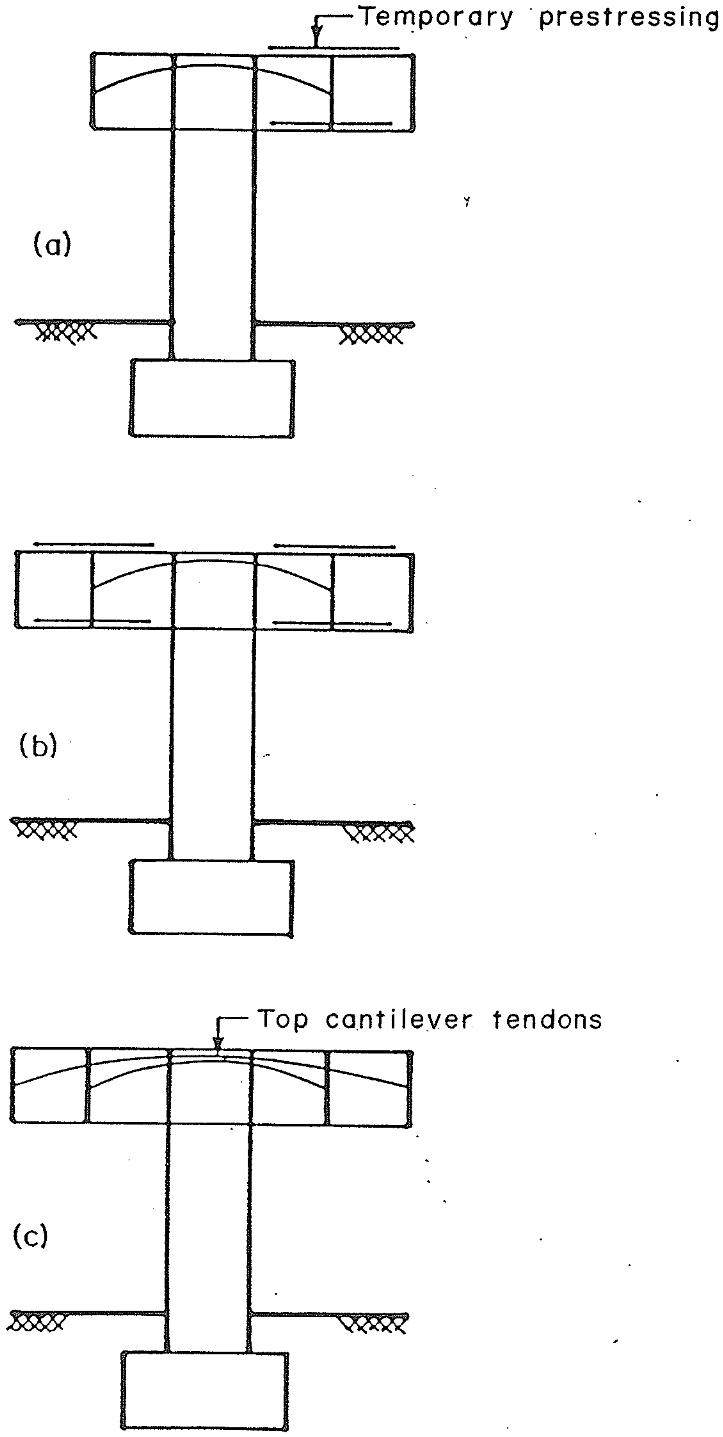
It is a two lane bridge designed in accordance with the AASHTO Code [4] for HS 30 live loading. The span arrangement for the four-span river crossing of this bridge is 69-87-87-69 m for a total length of 312 m. The superstructure consists of four haunched steel I-girders spaced at 3.50 m with a 225 mm composite concrete deck. The haunch is 18.9 m long with the depth of web varying from 2.40 m to 4.40 m. The top slab is 12.9 m wide cantileverring 1.20 m from the exterior girders. The deck is covered with a waterproofing membrane and 50 mm asphalt overlay [Fig. 3.1].

3.2 Method of Construction

The balanced cantilever method of construction was selected for constructing the proposed segmental bridge. This method has been the forerunner of segmental bridge construction technology. It was developed to eliminate falsework which is an expensive part of the overall construction cost. Most of the segmental bridges built in Canada and the U.S.A. have been constructed by this method. The other reason for selecting the balanced cantilever method was the availability of the computer program TIMEDEP which is written for this type of construction.

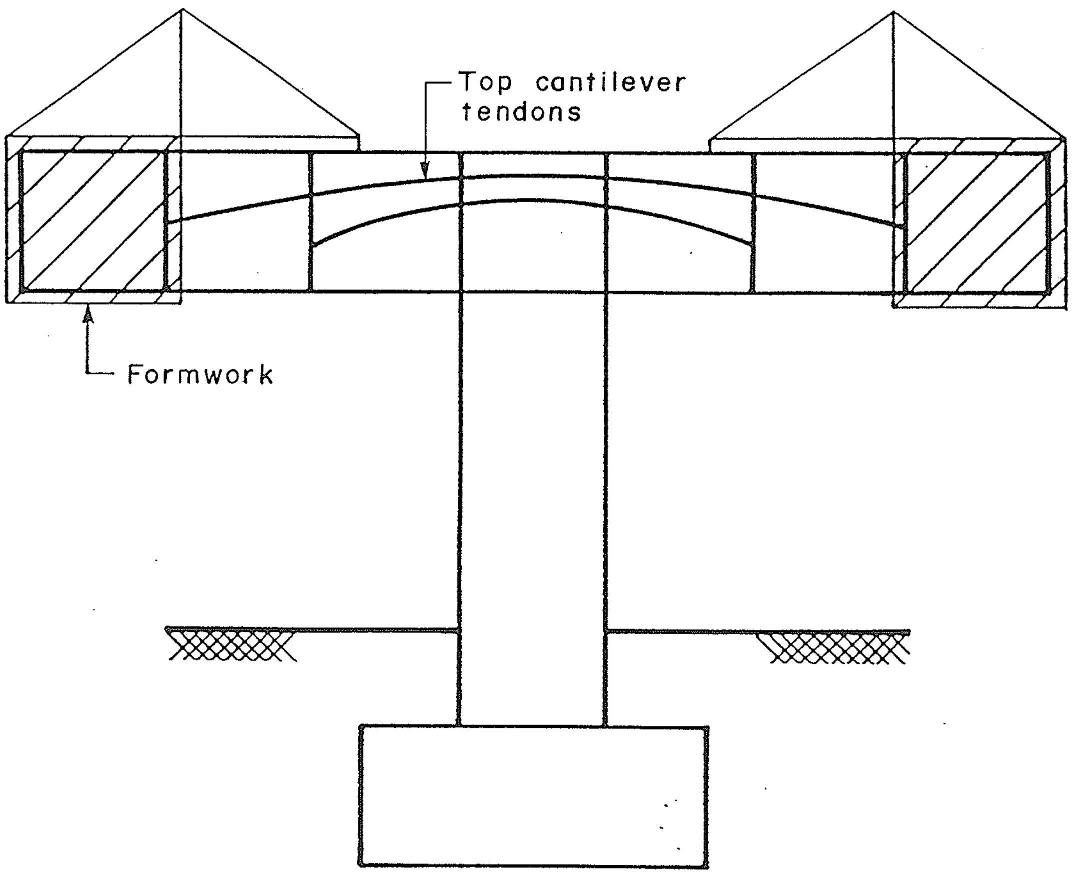
The balanced cantilever method of construction involves two separate operations: (1) erection of cantilevers and (2) establishment of continuity. The segments are simply cantilevered from each side of a pier in a balanced sequence until midspan is reached [Figs.3.2 and 3.3]. Then continuity is established with the half-span from the previous pier by pouring a cast-in-place closure segment [Fig.3.4]. This procedure is repeated until the structure is completed [1, 3].

The operations required for balanced cantilever construction for precast segments are shown in Fig. 3.2. A precast deck segment is brought in from the plant and attached to one side of the balanced cantilever employing temporary prestressing. This produces an unbalanced moment equal to the segment weight multiplied by its eccentricity from the centreline of the pier. This moment must be transmitted through the cantilever to the pier and foundations. Another segment is attached to the other side of the balanced cantilever cancelling the unbalanced moment. Cantilever tendons are stressed at the top of the segments and the temporary prestressing is removed. This procedure is repeated until midspan is reached. The procedure for cast-in-place segmental construction is shown in Fig. 3.3. It involves supporting the moveable



ERECTION OF CANTILEVERS
PRECAST CONSTRUCTION
(FROM REF. 3)

FIG. 3.2

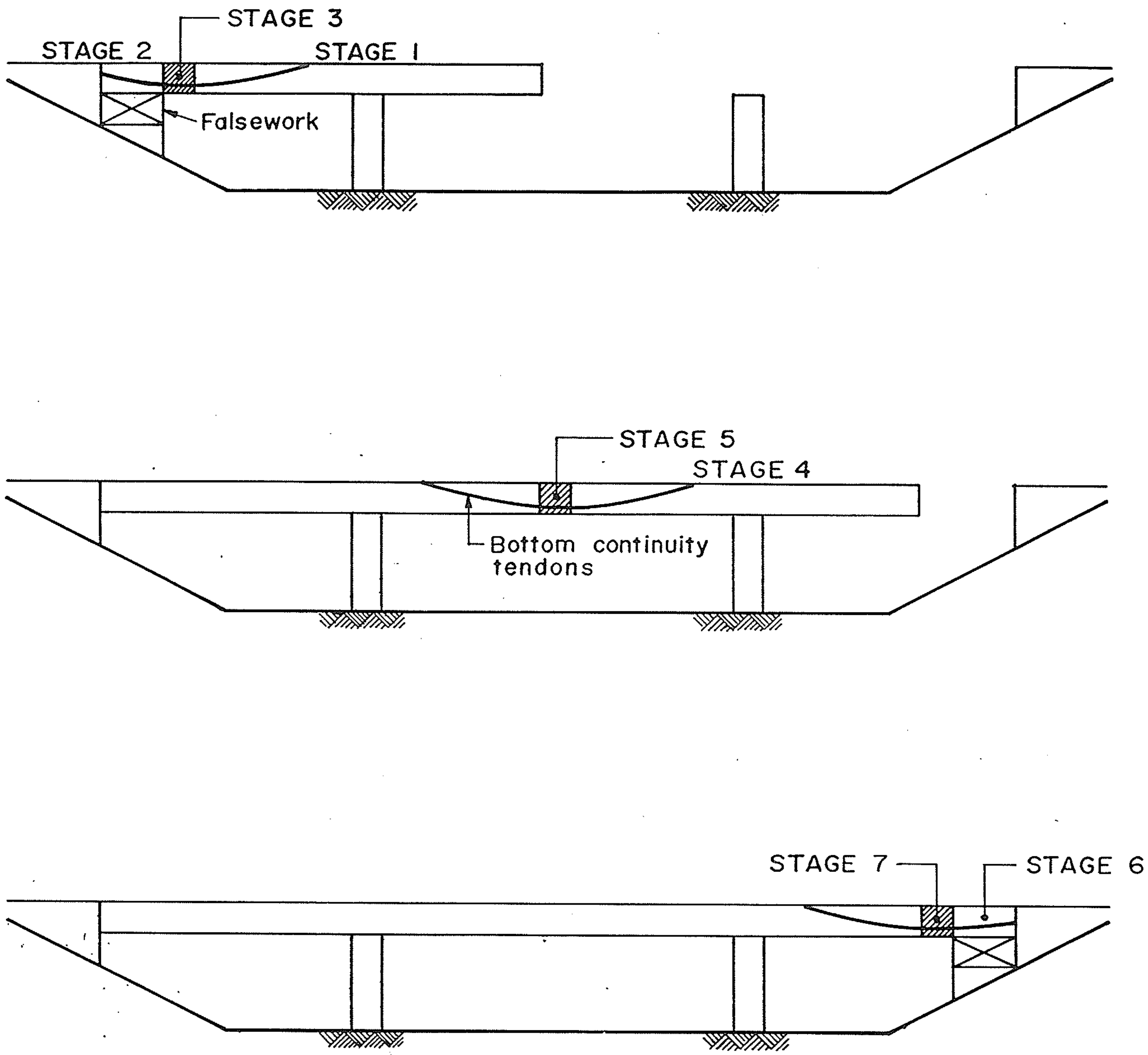


ERECTION OF CANTILEVERS
CAST-IN-PLACE CONSTRUCTION
(FROM REF. 3)

FIG. 3.3

formwork from the previously cast segment on each side of the cantilever. The unbalanced moment produced by this method is relatively small.

The operations required in respect of the establishment of continuity for the construction of a three-span bridge are shown in Fig. 3.4. Stage 1 involves erection of segments by balanced cantilever construction on the first pier and stage 2 has end span segments assembled on falsework. Placement of a cast-in-place closure segment, stressing of bottom continuity tendons and modification of support conditions takes place during stage 3. Stage 4 involves erection of segments by balanced cantilever method on the second pier while another closure segment is poured in stage 5. During stage 6 segments are assembled on false-work and the bridge is completed with the casting of the final closure segment in stage 7.



ESTABLISHMENT OF CONTINUITY
(FROM REF. 3)
FIG. 3.4

3.3 Selection of Span Arrangement

According to the Precast Segmental Box Girder Bridge Manual [5] the end span is usually selected as 65 to 70 percent of the interior span. This means that the small section of the superstructure adjacent to the abutment or exterior piers will require the use of falsework or some other erection procedure [Fig 3.4].

A literature review of some of the segmental concrete bridges designed in Canada showed that the Matapedia Bridge (Milnikek, Quebec) and Madawaska Bridge (Arnprior, Ontario - steel alternate was actually built) have main spans of 122 m. Both are three-span bridges with the end spans as 50 percent of the interior span. Matapedia was a cast-in-place concrete bridge whereas Madawaska was a precast concrete structure.

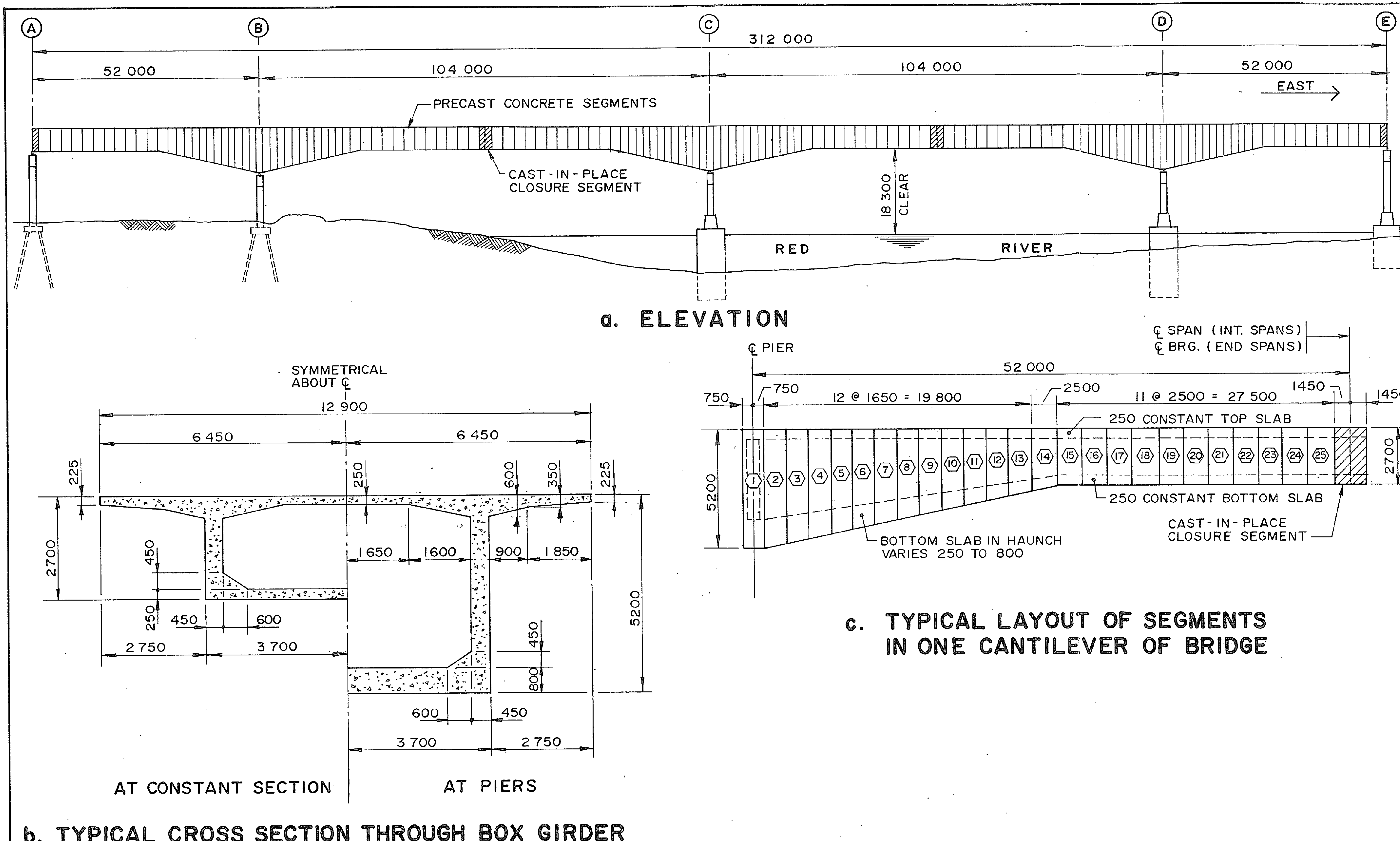
A review of the Selkirk Bridge site conditions showed that the river crossing spans at the west end are above land and over water at the east end. As the location of the exterior piers was considered to be fixed it would require construction of falsework in the water at the east end for erecting the precast segmental units. Without taking the construction costs into consideration, it was intuitively decided to construct the entire segmental structure without using any falsework.

Based on these considerations the span arrangement selected for the proposed segmental bridge was 52-104-104-52 m for a total length of 312 m as shown in Fig. 3.5(a). The end span to interior span ratio of 0.5 would enable the entire structure to be constructed without any falsework but would result in tension or uplift at the exterior piers. This uplift could be prevented by post-tensioning the exterior piers with rock anchors into bedrock. Another method of preventing uplift could be to fill some of the box girders in end spans with ballast. Detailed design of countering this uplift at the exterior piers is not included in this report.

3.4 Dimensions of Segments

According to the Segmental Box Girder Bridge Manual a single cell box section can be used for segment widths up to about 12 m. The recommended span/depth ratios for variable depth structures are 18 to 20 at the support and 40 to 50 at midspan.

For the proposed segmental bridge it was established that



PROPOSED SEGMENTAL BRIDGE

FIG. 3.5

the segment section would be a single cell box section with a depth of 2.70 m at midspan and 5.20 m at the piers. The transition from one depth to the other was achieved by means of a straight haunch section. From preliminary design considerations the haunch length was established as about 23 m with the haunch point located at a joint between segments [see Fig.3.5(c)].

The other detail dimensions of the segments - such as thickness of top slab, bottom slab, webs and fillets - are generally determined by structural considerations and numerous practical factors related to production of the segments as well as by past experience. For the proposed segmental bridge the chief point taken into consideration was that all dimensions must be able to accomodate the post-tensioning ducts, anchorages and mild steel reinforcement as well as placement of concrete to extremely close tolerances. After reviewing several cross sections of existing segmental bridges, the remaining concrete dimensions established are shown in Fig. 3.5(b). The thickness of the bottom slab varies in the haunch section - increasing linearly from 250 mm at the constant depth section to 800 mm at the interior piers.

3.5 Manufacture of Segments

The precast units for segmental bridges are always match cast. Each segment is cast against the segment which will be adjacent to it in the completed structure. The method of match casting is critical for balanced cantilever construction since small discrepancies in the geometry of a joint near the pier are magnified by the lever arm of the cantilever to produce large variations at midspan. There are essentially two methods of match casting the segments - the "long-line" or the "short-line" method [1]. The decision of choosing the method of casting the segmental units normally lies with the contractor.

The long-line method utilizes a fixed soffit form having the same profile as the underside of the bridge. There are movable side forms that travel along it. Each segment is cast against a steel bulkhead on one end and the previously cast segment on the other. This casting scheme requires minimum of geometric control but needs substantial amount of space and is therefore usually set up near the site. The minimum length is normally slightly more than half the length of the longest span of the structure. It must be constructed on a firm foundation which will not settle or deflect under the weight of the segments.

The short-line method uses a single stationary form in which each segment is cast individually against the previously cast segment. This casting system is set up in a precast concrete plant but unfortunately geometric control becomes quite complicated.

The criteria normally used for establishing the length to which the segments are manufactured is "constant length" and "constant weight".

A constant length unit is most suitable for casting by the short-line method as it has formwork advantages. However, constant length units of varying depth would obviously vary considerably in weight. A constant weight segmental unit becomes more suitable when hoisting equipment is taken into consideration. A precast segmental bridge built by the balanced cantilever method generally uses some kind of a launching truss or a crane. Consequently, it would be more economical to lift many loads of approximately equal magnitude instead of sizing the equipment to lift a few heavy loads and having it under-utilized for most of the time. On the other hand constant weight units of varying depth would vary in length and increase forming costs.

After a literature review of the design of precast segmental bridges built in North America and in particular the design-construction features of the Islington Avenue Bridge (Toronto) [6] the segment units were designed for constant length for this segmental bridge. To avoid problems with transportation restrictions it was decided that the segment weight would be limited to about 55 tonnes.

4. DETAILED DESIGN

4.1 General

The detailed design of a segmental bridge involves the following steps:

1. Determine section properties.
2. Design for longitudinal flexure during cantilever construction (determine configuration and number of cantilever tendons for each stage).
3. Design for longitudinal flexure during the establishment of continuity (determine configuration and number of continuity tendons for each stage).
4. Design for longitudinal flexure after completion of structure with application of superimposed dead loads and live loads (determine configuration and number of any additional tendons).
5. Design for transverse flexure (proportion transverse reinforcing and prestressing).
6. Design for shear and torsion (proportion longitudinal stirrups).
7. Check service stresses.
8. Check ultimate strength.

9. Design piers (for maximum unbalanced moment as well as vertical and lateral loads).
10. Design abutments.
11. Design foundations.
12. Design bearings (for movements due to creep and shrinkage as well as temperature).
13. Design expansion joints (for movements due to creep and shrinkage as well as temperature).
14. Design railings and barrier curbs.
15. Determine casting and erection schedule.
16. Compute quantities.
17. Estimate construction costs.

To show all aspects of the detailed design is beyond the scope of this study. This paper will only cover the longitudinal design in detail as it is the most difficult and special problem in segmental bridges.

4.2 Design Data

Design Code		- AASHTO-1983 [4]
Design References		- PCI/PTI Precast Segmental Box Girder Bridge Manual [5]
		- Design of Modern Concrete Highway Bridges [7]
Design Live Loading		- HS 30

Materials:

Concrete	f'c	= 41.4 MPa (6000 psi)
Tendons	12/16 (12/0.6") Strands (low relaxation)	
	f_{pu}	= 1862 MPa (270 ksi)
	UTS	= 3128.0 kN/tendon (703.2 k/tendon)
	0.6 UTS	= 1878.6 kN/tendon (final force used)

The following loading cases were considered in the design:

(a) Self weight.

(b) Time-dependent effects (creep and shrinkage).

(c) Prestressing (primary effects).

(d) Prestressing (secondary effects).

(e) Temperature.

(e) Superimposed dead loads.

(f) Live load plus impact.

The design was carried out by elastic methods to meet the following criteria:

(a) Concrete bending stresses with allowable limits specified in AASHTO for concrete strength of 41.4 MPa. That is, 0.55 f'c at transfer and 0.4 f'c under full service load.

(b) No tension allowed for all combinations of loadings.

(c) Cracking safety under 110 percent of dead load and 125 percent of live load.

(d) Ultimate load capacity of 175 percent of dead load and 225 percent of live load.
(Note: assumptions (b), (c) and (d) above are generally somewhat more conservative than required by AASHTO and PCI recommendations).

(e) Initial tendon forces are 70 percent of ultimate.

(f) Final tendon forces are 60 percent of ultimate.
(Note: A final force of 0.6 UTS was assumed for all prestressing calculations. The exact analysis for prestressing losses would be normally taken into account in the verification analysis).

4.3 Design Procedure

The longitudinal design was carried out in accordance with the following steps [Fig. 4.3 and 4.6].

Step 1: Erection of cantilevers plus cantilever Group 1 tendons. Stress check at all stages of cantilever erection.

Step 2: Establishment of span 1 continuity plus Group 2 tendons. Stress check.

Step 3: Establishment of span 2 continuity plus Group 3 tendons. Stress check.

Step 4: Establishment of span 3 continuity plus Group 4 tendons. Stress check.

Step 5: Establishment of span 4 continuity plus Group 5 tendons. Stress check.

Step 6: Application of thermal loading. Stress check.

Step 7: Addition of superimposed dead loads. Stress check.

Step 8: Application of live loads. Stress check.

Step 9: Influence of time at 360 days. Dead load moment redistribution due to creep and shrinkage. Stress check.

Step 10: Final Stress check at 3600 days (10 years).

4.4 Section Properties

The section properties for the segments were entirely calculated using Lotus 1-2-3. The section properties of any general cross section are given by:

$$A = \int_0^d b_y \, dy \tag{4.1}$$

$$\bar{y} = \int_0^d b_y \, y \, dy / A \tag{4.2}$$

$$I_z = \int_0^d b_y \, y^2 \, dy \tag{4.3}$$

$$I = I_z - A \, \bar{y}^2 \tag{4.4}$$

where y = depth of section at any point from origin

b_y = width of section at depth y

d = total depth of section

A = area of section

$\bar{y}$ = depth of neutral axis

I_z = moment of inertia of section about origin

I = moment of inertia about neutral axis

A numerical method has been developed from the above integrals to calculate the section properties of a general section [8]. It uses a system of numbering nodes in which clockwise is considered a positive area and the counter-clockwise direction is a negative area. The node numbering system used in the numerical analysis for a general bridge section is shown in Fig. 4.1. The method then utilizes the coordinates of the nodes in the following relationships to determine the section properties:

$$A = 1/2 \sum_{k=1}^{n} (x_k \, y_{k+1} - x_{k+1} \, y_k) \tag{4.5}$$

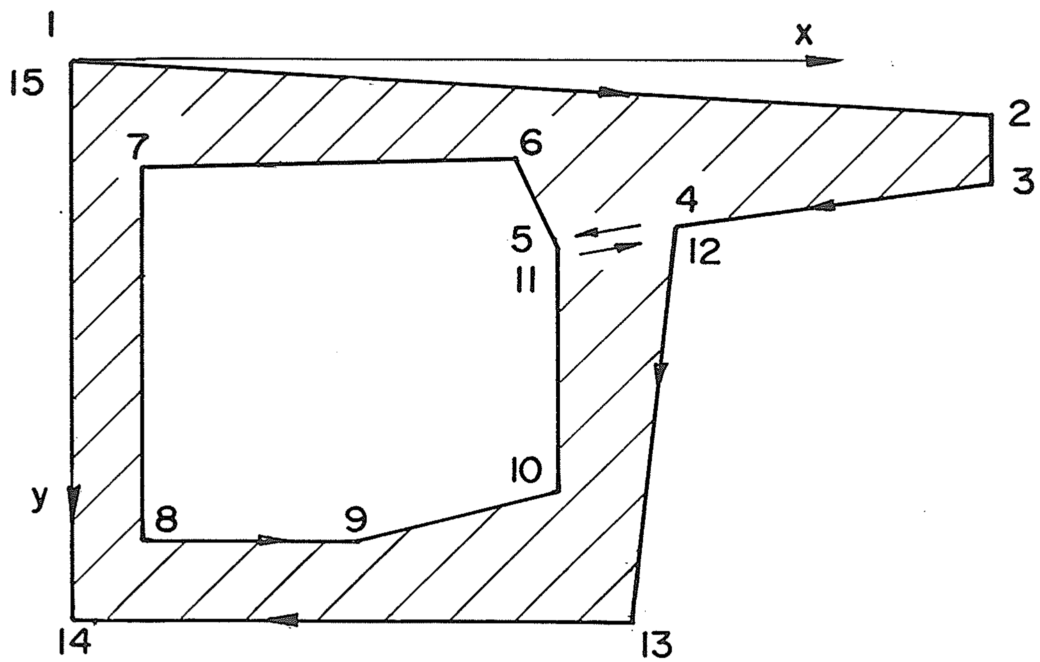
$$\bar{y} = 1/6 \sum_{k=1}^{n} [(x_k \, y_{k+1} - x_{k+1} \, y_k) (y_k + y_{k+1})]/A \tag{4.6}$$

$$I_z = 1/12 \sum_{k=1}^{n} [(x_k \, y_{k+1} - x_{k+1} \, y_k) (\{y_k + y_{k+1}\}^2 - y_k \, y_{k+1})] \tag{4.7}$$

$$I = I_z - A \, \bar{y}^2 \tag{4.8}$$

where k = node number

n = number of nodes (15 in Fig. 4.1)

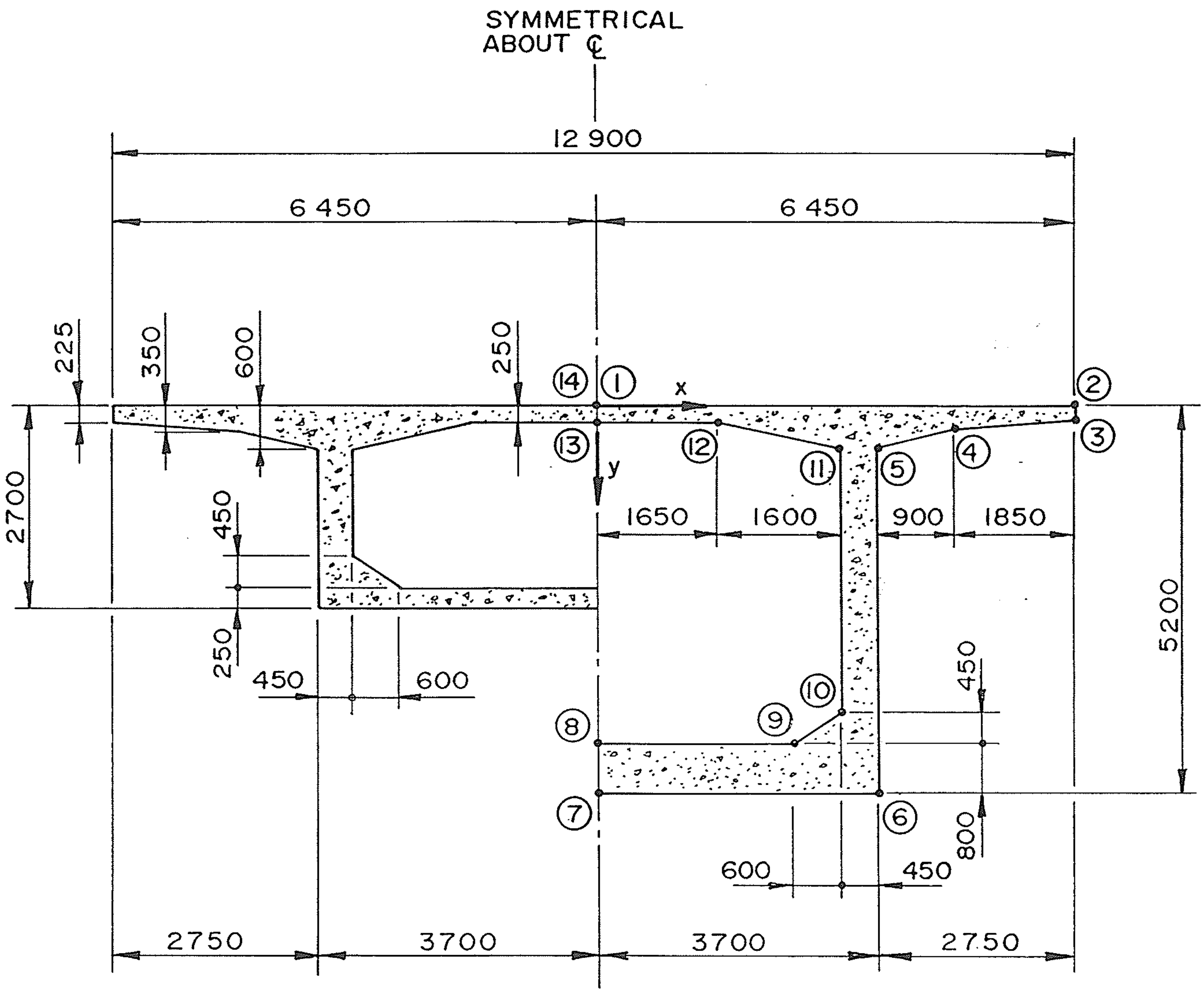


SECTION PROPERTIES
GENERAL CASE
(FROM REF. 8)

FIG. 4.1

Equations (4.5), (4.6), (4.7) and (4.8) were incorporated into a Lotus 1-2-3 spreadsheet model [see Appendix A] described below for the calculation of section properties. The node numbers for the box section of the proposed segmental bridge are given in Fig. 4.2. Due to symmetry only one-half of the section had to be numbered.

Initially the spreadsheet model was established with the coordinates of the nodes relative to the maximum section in the haunch. The coordinates of all nodes remained constant throughout the haunch except the y-coordinates of nodes 6, 7, 8, 9 and 10. For these five nodes relationships were developed so that only the ordinates of nodes 7 and 8 were unknown. The coordinates of nodes 7 and 8 are based on the depth of section and the thickness of the bottom slab at a particular joint. In addition to the equations for area, location of neutral axis and moment of inertia of the section, formulas were entered to find the segment volume (based on the average end area method) and the segment weights. Once the basic spreadsheet model had been developed it was simply a matter of changing the ordinates of nodes 7 and 8 to determine the section properties at any point in the haunch. The strength of 1-2-3 as an interactive tool was clearly evident during the establishment of the segment lengths and weights in a simple and



SECTION PROPERTIES
PROPOSED SEGMENTAL BRIDGE

FIG. 4.2

efficient manner using this basic spreadsheet model. The efficiency of calculating the section properties was further enhanced by utilizing the "macro" and "windows" capabilities of 1-2-3.

The macro facility allows one to store sequences of keystrokes for future use. It is in fact possible to develop the keystrokes into a program in the 1-2-3 macro command language. A looping macro was created to expedite the final calculation of the segment section properties. The windows feature in 1-2-3 allows one to split the screen into two parts - either horizontally or vertically. This feature facilitates in keeping track of the effect of changes in different areas of large worksheets.

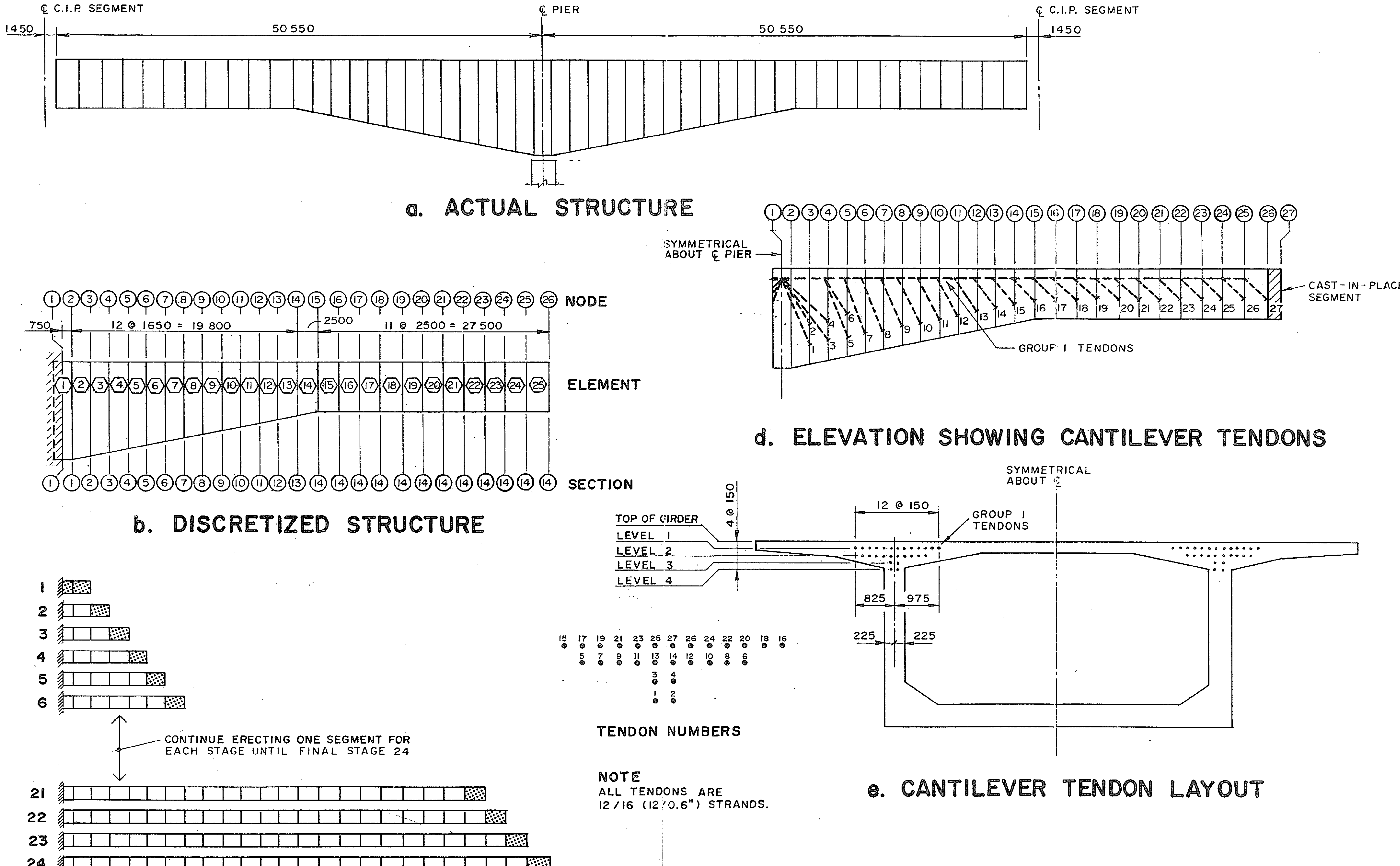
The final segment length established for the haunch was 1.650 m with the weight of the units varying from 37 to 56 tonnes (based on concrete unit weight of 2400 kg/m^3). In the constant depth section the segments were 2.500 m long and weighed about 51 tonnes. The pier segment was 1.500 m long with a weight of about 52 tonnes. There were 25 elements in one cantilever of the bridge plus a cast-in-place closure segment of 2.900 m [Fig. 3.5(b)].

4.5 Erection of Cantilevers

The analysis of the proposed segmental bridge for construction by the balanced cantilever method was carried out using the computer program TIMEDEP.

The discretized structure for preparing the input for this program is shown in Fig.4.3(b). Only one-half of the structure was modelled, as it was symmetrical, and it was assumed to be fixed at the centreline of the pier. The model comprised 26 nodes, 25 elements, 14 sections and 24 construction stages. Each element was equivalent to an actual physical segment and the 14 sets of section properties represented the variation in the height in the haunch. Each construction stage indicated the erection of an additional segment. It was only necessary to carry out an elastic analysis for this phase of the design as there is no time-dependent redistribution of forces for statically determinate structures.

TIMEDEP gave the bending moment at each node for each stage. These bending moment values were incorporated into the Lotus 1-2-3 spreadsheet model to proportion the cantilever prestressing [Fig.4.3(d)] at each stage and check stresses. The 1-2-3 model for design of cantilever



ERECTION OF CANTILEVERS
FIG. 4.3

tendons is given in Appendix B. The main points in the development of this spreadsheet model are described below.

First these section properties were entered at each joint: height (h), thickness of bottom slab (t) - entered for information only, area (A), distance to neutral axis from top (YT), distance to neutral axis from bottom (YB), moment of inertia about the neutral axis (I), section modulus at top (ST), and section modulus at bottom (SB). The values were obtained from the previous spreadsheet model for calculation of section properties [Appendix A]. It should be noted that it is not necessary to individually enter the complete set of section properties at each joint as some values can be calculated within the worksheet. Therefore only h, A, YT and I were initially entered and YB, ST and SB subsequently calculated.

At this point it is worth mentioning about the copy command of 1-2-3. The copy command is used to make replicas of values, labels or formulas in other cells. This replication allows the user to develop quickly a model by building a few quick relationships, then replicating them over the entire workspace. This feature of spreadsheets can save one a great deal in time and keystrokes. But more important this is the key to one of 1-2-3's greatest strengths: the ability to project and extrapolate. The copy command can handle "absolute" and "relative" cell addresses. An absolute cell address is exactly the same in the copied formula as in the original formula. A relative cell address is different in the copied formula from the original formula. The copy command features of 1-2-3 were used extensively for all the spreadsheet models presented in this report. In fact the availability of this feature was instrumental in the author's decision of designing the segmental bridge using a spreadsheet program.

The design of cantilever tendons in the spreadsheet model was handled by establishing four levels for locating the tendons in each web, with each level at 150 mm interval starting from the top of the box section [Fig. 4.3(e)]. With the tendon location fixed it was then simply a matter of calculating the centre of gravity of steel (cgs) at each joint for the required number of tendons. Formulas were incorporated for the calculation of the eccentricity (e), effective force in the tendons (P) based on 0.6 UTS, and moment due to prestressing (Mp = P x e).

The prestress stresses were converted to equivalent moments for purposes of analysis by establishing the following relationship:

$$P/A + Mp/S = \text{prestress stress} \quad (4.9)$$

$$(P/A \times S) + Mp = \text{prestress stress} \times (S) \quad (4.10)$$

where (P/A x S) = moment of resistance. The moment of resistance was computed for the compressive stress on the top and bottom fibers:

$$Mt = P/A \times ST \quad \text{(moment of resistance at top)} \quad (4.11)$$

$$Mb = P/A \times SB \quad \text{(moment of resistance at bottom)} \quad (4.12)$$

The top and bottom fiber moments were combined for prestress, that is, the Mp values were combined with P/A x S to give the total prestress effect. This was done for the top fiber (Mp+Mt) and the bottom fiber (Mp+Mb).

Next the dead load moments, Md, (from TIMEDEP) were added to the total prestress moments for the top and bottom fibers - columns Mp+Mt+Md and Mp+Mb+Md in the worksheet.

Finally the stresses were computed:

$$\text{stress at top} = (Mp+Mt+Md)/ST \quad (4.13)$$

$$\text{stress at bottom} = (Mp+Mb+Md)/SB \quad (4.14)$$

SI units were used throughout the design except that all stresses were calculated in imperial units of "psi" in the spreadsheet models. This was purely a personal choice.

All the above items were progressively built into the worksheet by using the copy command of the spreadsheet. Once all the formulas for each joint had been entered the only variable was the number of tendons at each level.

The cantilever tendons were designed for all 24 stages using the above spreadsheet model. Only the worksheet for the final stage is included in Appendix B of this report.

The design was very simple with the spreadsheet model. It involved changing the value of the number of tendons and checking that the allowable stresses were not exceeded. All calculations were done instantaneously by 1-2-3 for a new trial for the number of tendons. The design was truly interactive since splitting the screen vertically allowed stresses to be checked immediately for each trial. Design by a conventional computer program would involve preparing the input (conforming to some format), executing the program and then reviewing the output for each trial.

The final cantilever post-tensioning consisted of 27 tendons in each web (named Group 1) [Fig. 4.3(d), (e)].

4.6 Establishment of Continuity

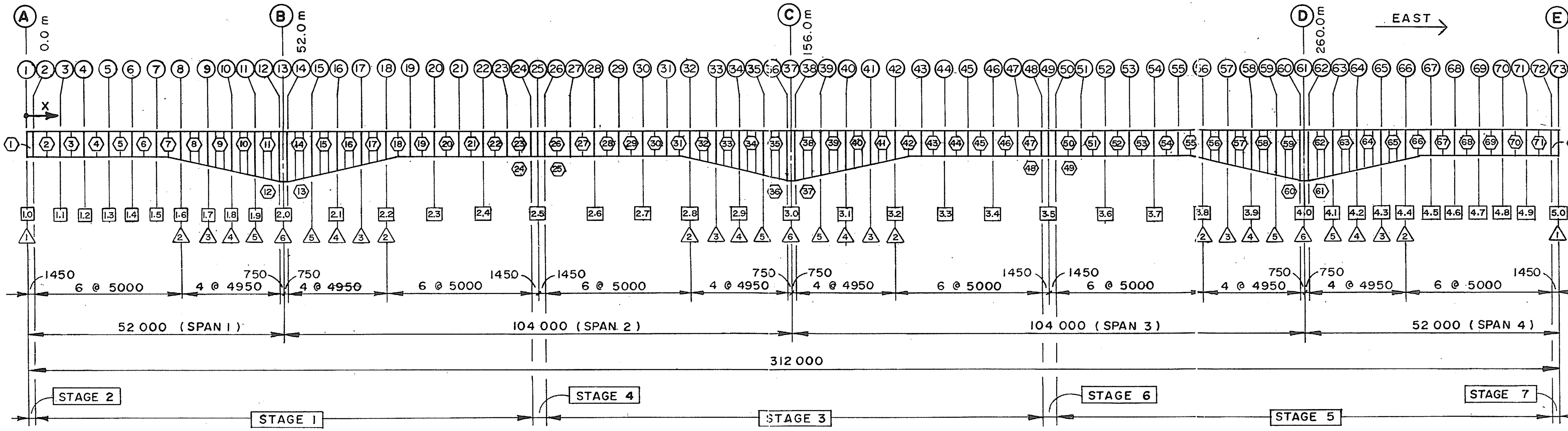
The time-dependent analysis for the establishment of continuity was carried out using the computer program TIMEDEP.

It is customory in bridge design to check stresses at every tenth-point in each span. In modelling the structure for TIMEDEP the aim therefore was to have the nodes at the tenth-points. Fortunately it was more by accident than design that the tenth-points occured approximately at the segment joints and it was possible merely to lump together two or three segments to form the elements for input into TIMEDEP. It should be noted that a separate element is required for the cast-in-place closure segment to analyse the effect of continuity.

The discretized structure for the establishment of continuity for the proposed segmental bridge is shown in Fig. 4.4 while Fig. 4.5 shows the construction stages. The model comprised 73 nodes, 72 elements, 6 sections and 9 construction stages for the time-dependent analysis. It was assumed that the cast-in-place closure segments are cast 3 days before they are erected while the precast segments are match cast at the rate of one segment per day. The erection dates were based on the assumption that it takes 3 days to assemble the pier segment followed by the erection of 4 segments per day to reach midspan (or exterior pier for end spans). Load transfer (erection) of the cast-in-place segment would be 3 days after casting. Lastly, it was assumed that service loads are applied at 360 days (stage 9) and that all time-dependent redistribution is complete by 3600 days (stage 10).

The program TIMEDEP uses the ACI 209 model for creep and shrinkage and assumes that the segments are moist cured. Therefore, the creep and shrinkage coefficients used in the input were 2.35 and -0.00080 respectively, while the curing period used was 7 days. The concrete has a compressive strength (at 28 days) of 41 400 kPa, a modulus of elasticity (at 28 days) of 32 378 800 kPa and a unit weight of 23.6 kN/m^3. Note that consistent units, m and kN (or ft. and kips), must be used in the program.

TIMEDEP gave the bending moments at each node for each stage of construction. These moments were again incorporated into another Lotus 1-2-3 spreadsheet model to proportion the prestressing for each stage of developing continuity in the structure. The continuity tendons are named Group 2, Group 3, Group 4 and Group 5 for



a. DISCRETIZED STRUCTURE

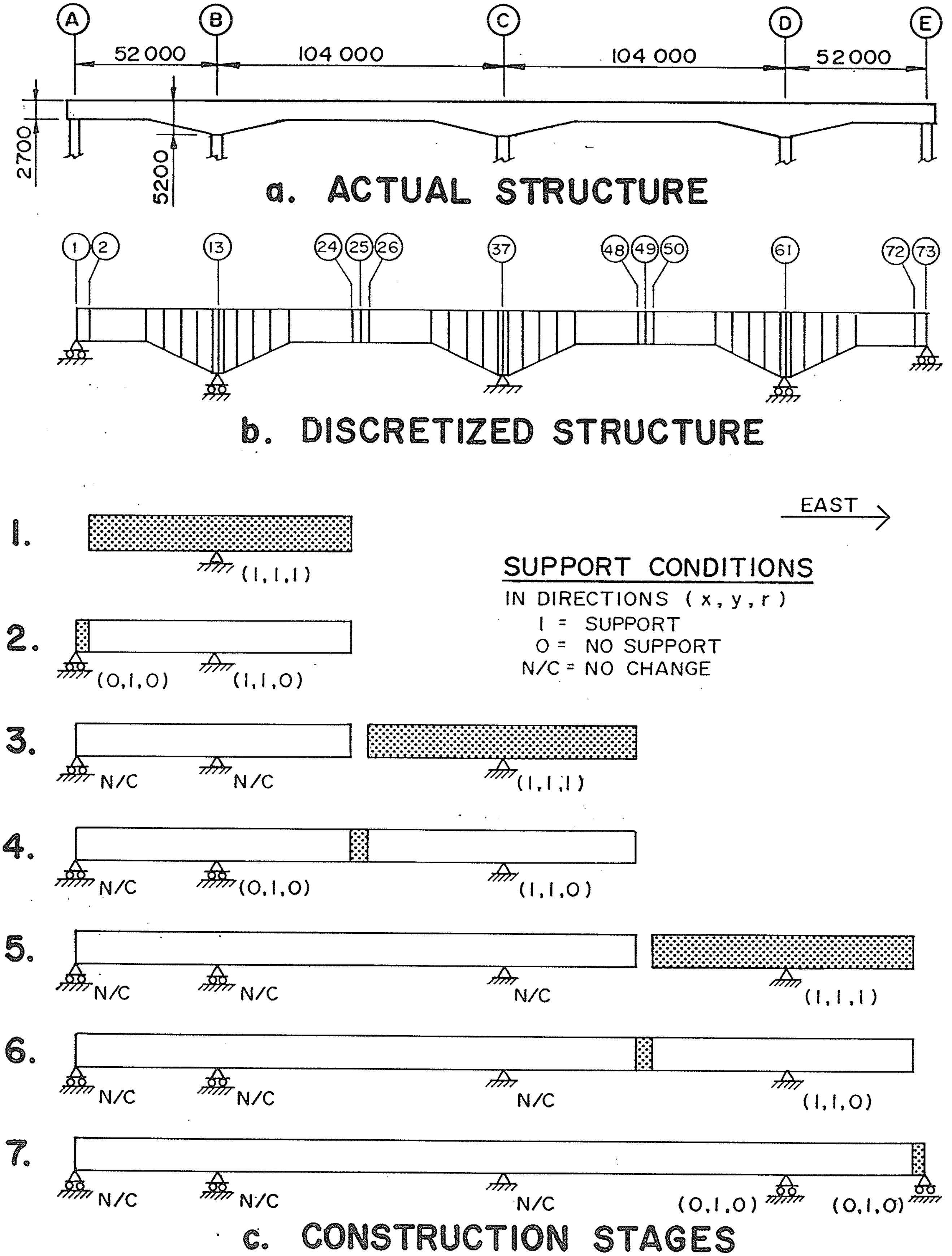
LEGEND

- (15) CONTINUITY JOINT NO.
- ⟨18⟩ ELEMENT NO.
- [1.2] APPROX. POINT ON SPAN.
- △5 SECTION NO.

DESIGN DATA & ASSUMPTIONS FOR TIME-DEPENDENT ANALYSIS

1. MATCH CASTING OF PRECAST UNITS AT THE RATE OF ONE SEGMENT PER DAY STARTING AT PIER B GOING WEST.
2. CASTING OF CAST-IN-PLACE SEGMENT TAKES 3 DAYS.
3. ERECTION STARTS ON DAY 100 AT PIER B GOING WEST.
4. ERECTION OF PIER SEGMENT TAKES 3 DAYS.
5. ERECTION OF CAST-IN-PLACE SEGMENT TAKES 3 DAYS (LOAD TRANSFER IS 3 DAYS AFTER CASTING).
6. ERECTION OF PRECAST UNITS AT THE RATE OF FOUR SEGMENTS PER DAY.
7. ALL SERVICE LOADS APPLIED AT 360 DAYS.
8. ALL TIME-DEPENDENT REDISTRIBUTION IS COMPLETE BY 3600 DAYS (10 YEARS).
9. CREEP COEFFICIENT $C_u = 2.35$
10. SHRINKAGE COEFFICIENT $\epsilon_{SHu} = -0.00080$
11. CONCRETE STRENGTH AT 28 DAYS $f'c = 41\ 400$ kPa
12. MODULUS OF ELASTICITY $E = 32\ 378\ 000$ kPa
13. UNIT WEIGHT OF CONCRETE 23.6 kN/m^3
14. SEGMENTS MOIST CURED FOR 7 DAYS

ESTABLISHMENT OF CONTINUITY
DISCRETIZED STRUCTURE
FIG. 4.4



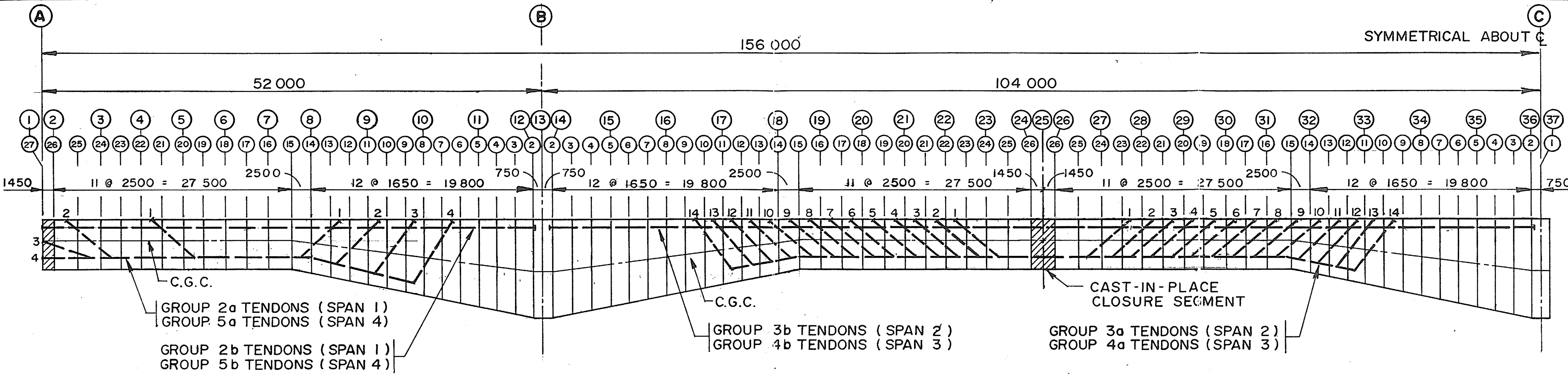
STAGE 8 – STRUCTURE AT 360 DAYS.
STAGE 9 – STRUCTURE AT 3600 DAYS.

ESTABLISHMENT OF CONTINUITY
CONSTRUCTION STAGES

FIG. 4.5

establishing continuity in Span 1, Span 2, Span 3 and Span 4 respectively as illustrated in Fig.4.6.

The 1-2-3 model for design of continuity tendons [see Appendix C] was developed along the same lines as the spreadsheet model for designing cantilever tendons. The first column contains the continuity joint numbers at the tenth-points as well as the coinciding cantilever joint numbers for reference purposes. This was followed by the data for section properties. Next the data for cantilever (Group 1) tendons was entered for the final stage (24) of the balanced cantilever erection. This was taken from the spreadsheet in Appendix B. Next four levels in the bottom slab were established to locate Group 2, Group 3, Group 4 and Group 5 tendons as shown in Fig. 4.6(b). As before formulas were then incorporated for the calculation of the centre of gravity of steel (cgs), eccentricity (e), effective force in the tendons (P) based on 0.6 UTS, moment due to prestressing force (Mp = P x e) and the total equivalent moments for the prestressing effect (Mp + Mt and Mp + Mb). After this additional information was entered into the 1-2-3 model, as explained in subsequent sections, to check stresses as continuity was established in each span of the structure.

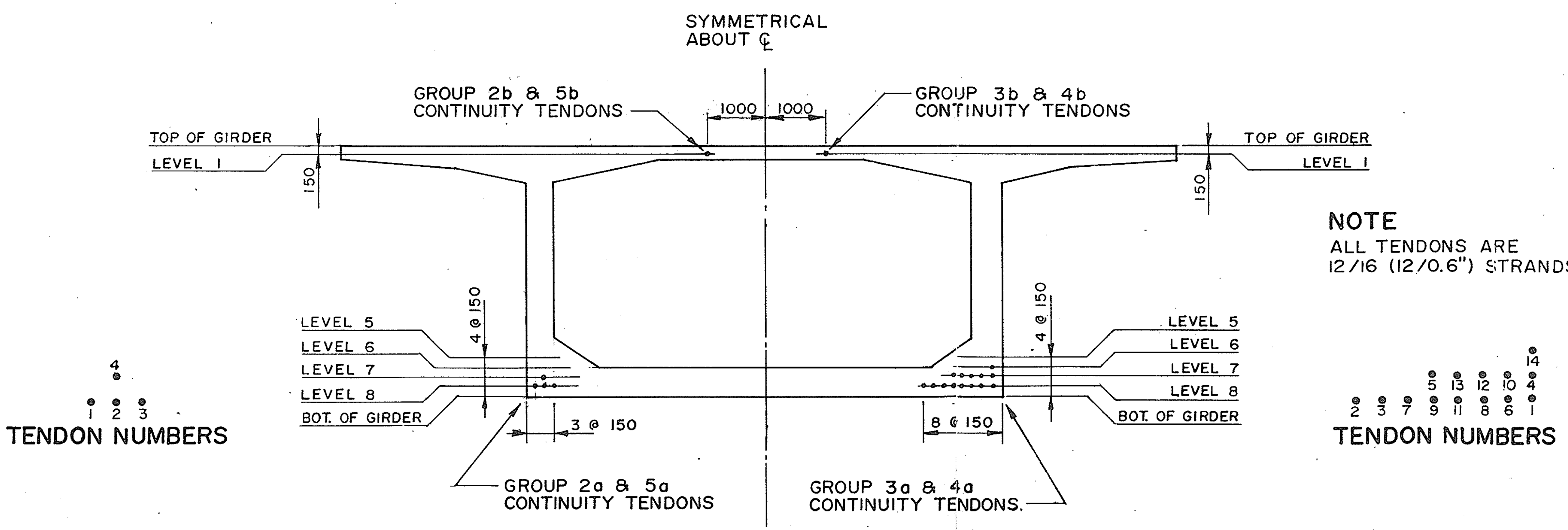


a. ELEVATION SHOWING CONTINUITY TENDONS

LEGEND

(21) CONTINUITY JOINT NO.

(21) CANTILEVER JOINT NO.



NOTE

ALL TENDONS ARE
12/16 (12/0.6") STRANDS.

b. CONTINUITY TENDON LAYOUT

ESTABLISHMENT OF CONTINUITY
CONTINUITY TENDONS

FIG. 4.6

4.7 Secondary Moments

The design and details of continuous prestressed concrete structures differ from simple beam design in that secondary moments are introduced by the primary moments (due to post-tensioning) and slope discontinuity over the interior supports. AASHTO requires the calculation of the secondary moment to equalize the slope of adjacent spans across interior supports.

Calculation of secondary moments was handled in the spreadsheet model using the classical area-moment method of determining slopes and deflections in beams.

The following procedure for application of area-moment method to calculate secondary moments, outlined in the CPCI Handbook [9], was adapted for the spreadsheet model.

Consider the three-span post-tensioned beam shown in Fig. 4.7(a). For analysis the beam is cut at interior supports and each span is considered as a simple beam with primary moments, Mp, (Mp = P x e). From Fig. 4.7(b) the slope of the end span at the first interior support B due to Mp is given by:

$$\Theta_B \quad = \quad \Sigma \ (Mp \ \Delta L/EI) \ (X/L_1) \qquad (4.15)$$

Next apply a secondary fixed end moment (M'_{BA}) on the end span at B to rotate the beam back to zero slope. For a two span symmetrical structure, this fixed end moment (FEM) would be the secondary moment due to the primary moment and no further calculations are required. For structures with three or more spans as well as unsymmetrical structures, the fixed end moment for each span has to be distributed to obtain the final secondary moments. Application of M'_{BA} at B produces a triangular moment diagram over the end span as shown in Fig. 4.7(c). Rotation at support B due this moment diagram is:

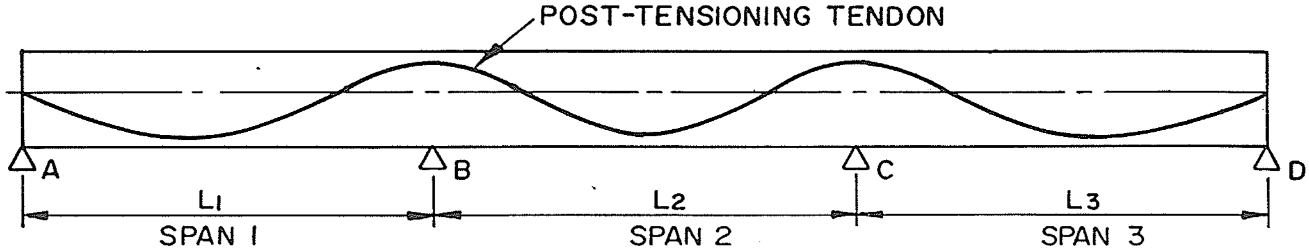
$$\Theta'_B \quad = \quad (M'_{BA} \ L_1)/3EI \qquad (4.16)$$

Equating Eq. (4.15) and Eq. (4.16) we get,

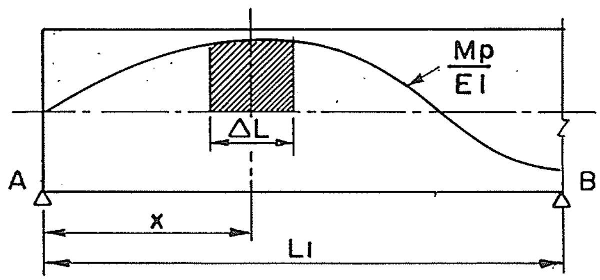
$$(M'_{BA} \ L_1)/3EI \quad = \quad \Sigma(Mp \ \Delta L/EI) \ (X/L_1) \qquad (4.17)$$

Simplifying Eq. (4.17) we get,

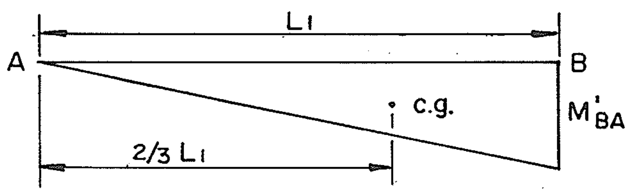
$$M'_{BA} \quad = \quad 3/(L_1)^2 \ \Sigma(Mp \ \Delta L \ X) \qquad (4.18)$$



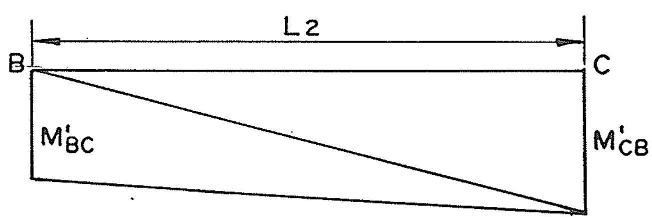
a. POST-TENSIONED BEAM



b. SPAN 1 PRIMARY MOMENT



c. SPAN 1 SECONDARY F E M



d. SPAN 2 SECONDARY F E M

F E M = FIXED END MOMENT

AREA-MOMENT METHOD
GENERAL CASE
(FROM REF. 9)

FIG. 4.7

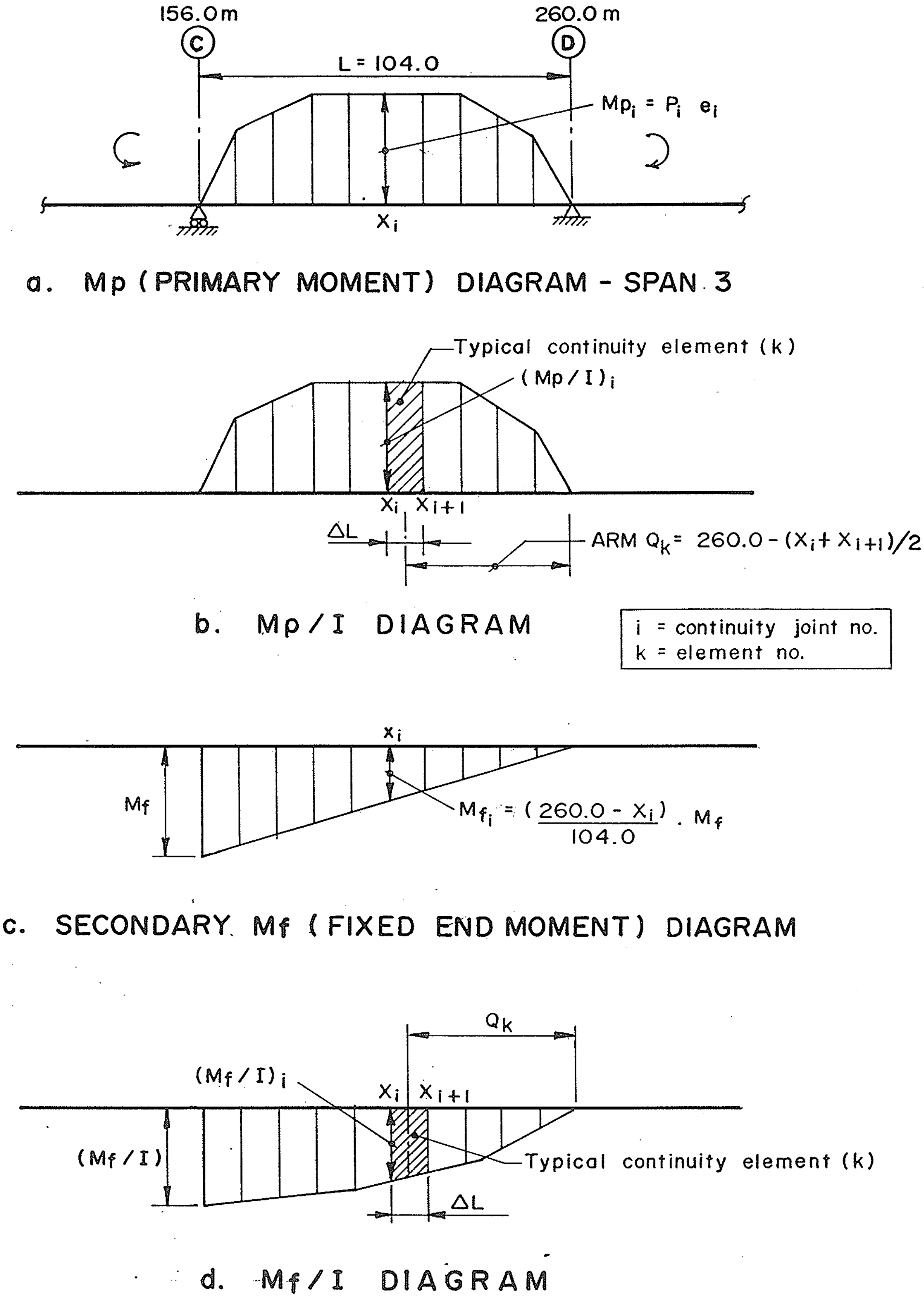
Eq. (4.18) gives secondary fixed end moment in terms of the primary post-tensioning moment, Mp. Similary, the secondary fixed end moments, M'_{BC} and M'_{CB}, for the interior span can also be calculated. The final secondary moments at the supports can be obtained by the moment distribution technique.

Using linear interpolation between the secondary moments at the supports, secondary moments at other points on the span can be readily calculated. The final moments due to post-tensioning are calculated as the algebraic sum of the primary and secondary moments.

The above procedure was utilized to find secondary fixed end moments using the spreadsheet program. The method involves M/EI diagrams but since E was assumed to be constant, only values of M/I were required.

No secondary moments were introduced during the establishment of continuity in span 1 as the structure was still statically determinate.

The model for the typical calculation of secondary moments by the area-moment method is described below for the establishment of continuity in span 3 [see Fig. 4.8].



AREA - MOMENT METHOD
PROPOSED SEGMENTAL BRIDGE
FIG. 4.8

First values of the primary moment ($Mp = P \times e$) and Mp/I were calculated at each element joint [Fig. 4.7(a)]. Note that "I" was already available at each joint since it was entered in the section property portion of the worksheet.

Then by using straight lines between each value of Mp/I, areas and moments of areas (about support D) were calculated by using semigraphical integration. This calculation was simplified to some extent since the structure was already subdivided into elements for the establishment of continuity. The calculation for a typical element using an average value of Mp/I was:

$$\text{Area, } A_k = \Delta L \, [(Mp/I)_i + (Mp/I)_{i+1}]/2 \quad (4.19)$$

$$\text{Moment of area, } M_k = A_k \, Q_k \quad (4.20)$$

where ΔL = length of element (already calculated under section properties in spreadsheet model)

Q_k = moment arm about support D from c.g. of element

$= 260.0 - (X_{i+1} + X_i)/2$

i = continuity joint number

k = element number

From the area-moment theorem the slope at support C due to the primary moment was given by:

$$\Theta_C = \Sigma\ (Mp/I)\ \Delta L\ Q\ /\ L \quad (4.21)$$

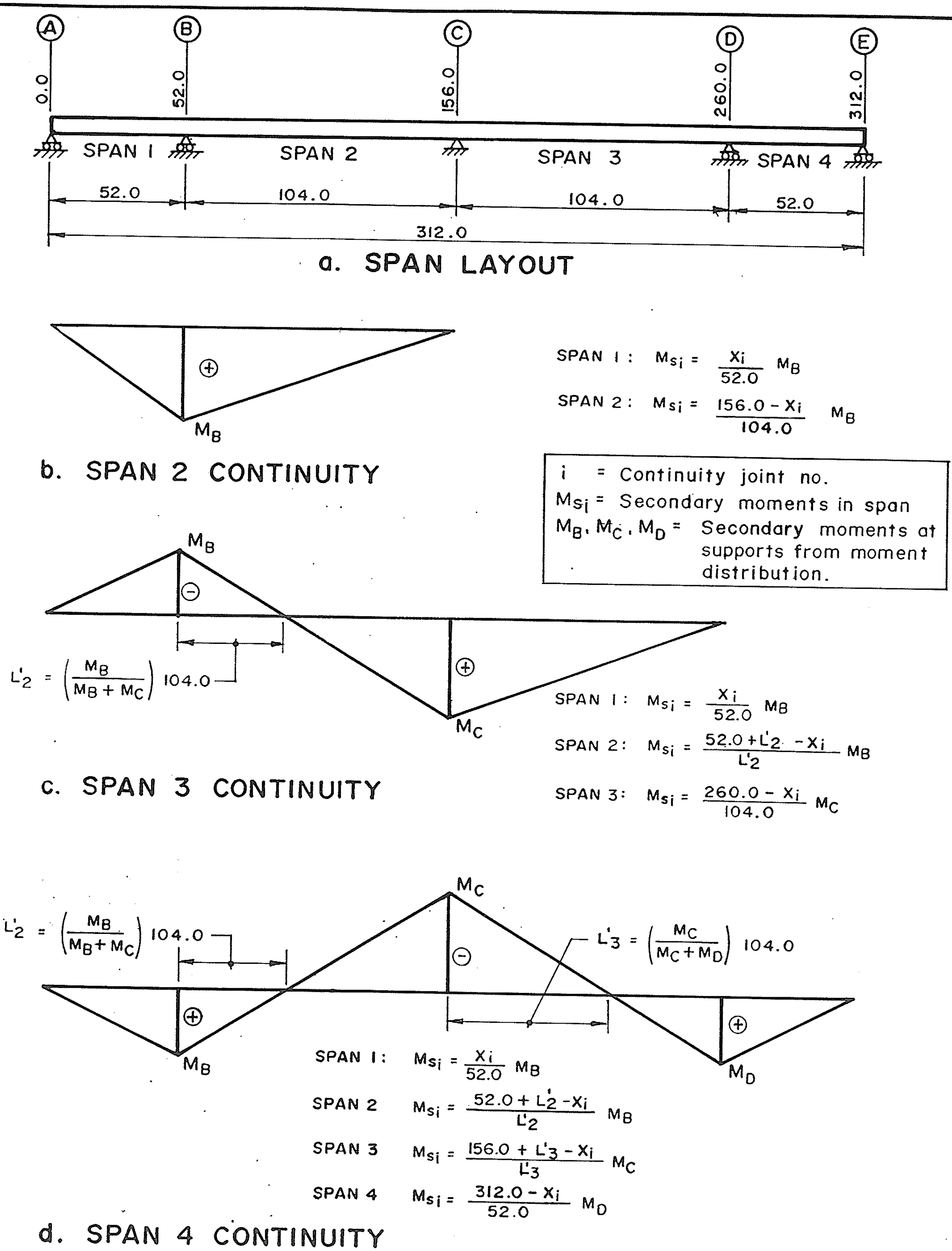
Next a secondary fixed end moment (Mf) was applied at the same support (C) to rotate the beam back to zero slope. Again Mf/I was calculated at each joint followed by the moments of areas. The rotation at C due to Mf was,

$$\Theta'_C = \Sigma\ (Mf/I)\ \Delta L\ Q\ /L \quad (4.22)$$

Equating Eq (4.21) and Eq (4.22), the value of Mf was found in terms of the primary moment (Mp).

This value of Mf was distributed across the spans under consideration, using moment distribution method, to find the secondary moments (M_B, M_C and M_D) at the supports. A separate model for moment distribution was created for establishment of continuity in spans 2, 3 and 4.

Once the support moments were known the actual secondary moments (Ms) at each joint were calculated using straight line interpolation. This involved entering formulas in the spreadsheet model for locating the inflection points and calculating the secondary moments at each joint [see Fig. 4.9].



SECONDARY MOMENTS
LINEAR INTERPOLATION

FIG. 4.9

The spreadsheet model for moment distribution is given in Appendix C. It is based on the standard Hardy Cross method of moment distribution known to all engineers. For this model the section was assumed to have variable moment of inertia. The stiffness and carry-over factors were obtained from the PCA Handbook [10].

The above appears to be a rather tedious task. However, it was easily reduced to manageable proportions by the use of Lotus 1-2-3. It should be noted that the spreadsheet model for secondary moments and moment distribution had to be created only once. The variable quantities in both models are related to the number of tendons. Once the model was created everything was instantaneously recalculated as the quantity and location of tendons was varied to keep within allowable stresses at each joint.

The rest of the spreadsheet model involved calculation of the combined equivalent moment at the top and bottom fiber due to both cantilever and continuity post-tensioning tendons. This was done similar to erection of cantilevers.

A complete printout of the spreadsheet model for establishment of continuity as well as secondary moments and moment distribution is given in Appendix C.

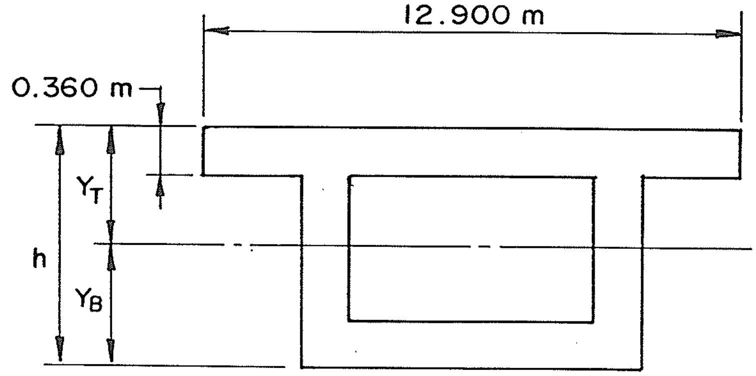
4.8 Thermal Analysis

Temperature is an important loading for segmental bridges. The spreadsheet model for thermal analysis is given in Appendix C. The primary moments were calculated by the spreadsheet at each joint and combined with the secondary moments (obtained from TIMEDEP) to get the total stresses for thermal loading.

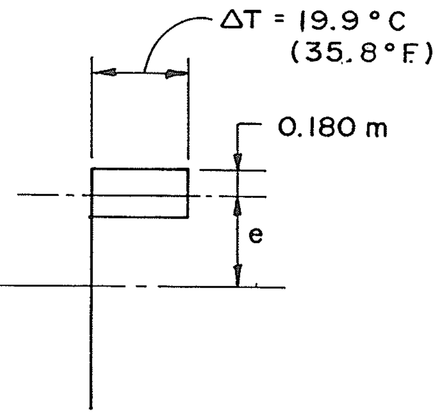
The thermal analysis is governed by two parameters - the temperature differential and the thermal distribution. This information is obtained from the code requirements or experimental results.

For this study the modified PCI-PTI temperature distribution was used. This is a uniform temperature gradient in the top slab of 19.9°C (35.8°F) as shown in Fig. 4.10(b). This value is approximately twice the PCI-PTI [5] recommended value of 10°C (18°F) but it is more consistent with experimental results [11]. The coefficient of thermal expansion used was 0.000010 /°C and the modulus of elasticity was 32 378 800 kPa.

Stresses are produced by restraint to expansion and rotation during temperature changes. The restraint is



a. CROSS SECTION MODEL FOR THERMAL ANALYSIS



b. MODIFIED P.C.1 - P.T.1 TEMPERATURE DISTRIBUTION
(FROM REF. 11)

THERMAL ANALYSIS

FIG. 4.10

provided by the cross section and the support conditions in statically indeterminate structures such as a segmental bridge.

Priestley [12] derived the following relationships for the average strain and curvature in the unrestrained section, using the equations of equilibrium, assuming that plane sections remain plane:

$$\epsilon = \alpha/A \; \Delta T \int_0^d t(y)\, b(y)\, dy \qquad (4.23)$$

$$\varnothing = \alpha/I \; \Delta T \int_0^d t(y)\, b(y)(y - y_b)\, dy \qquad (4.24)$$

and an expression for the stress

$$f(y) = E[\epsilon + \varnothing y - \alpha t(y)] \qquad (4.25)$$

where $t(y)$ = temperature distribution

$b(y)$ = width of section

y = distance from bottom of section to point under consideration

y_b = distance to neutral axis from bottom

d = depth of section

The axial force and bending moment are found for the restrained section, knowing that ϵ = N/EA and Ø = M/EI, as follows:

$$N = E\alpha \, \Delta T \int_0^d t(y)\, b(y)\, dy \tag{4.26}$$

$$M = E\alpha \, \Delta T \int_0^d t(y)\, b(y)(y - y_b)\, dy \tag{4.27}$$

Shushkewich [3] has adapted the above expressions into the following form for use in TIMEDEP:

$$N = E\alpha \, \Delta T \, S_1 \tag{4.28}$$

$$M = E\alpha \, \Delta T \, S_2 \tag{4.29}$$

where

$$S_1 = \int_0^d t(y)\, b(y)\, dy \tag{4.30}$$

$$S_2 = \int_0^d t(y)\, b(y)\, (y-y_b)\, dy \tag{4.31}$$

S_1 and S_2 are considered as section properties for a particular temperature distribution by the program. Since the PCI-PTI temperature distribution [5] is confined to the depth of the top slab, S_1 is simply the cross sectional area of the top slab and S_2 becomes the first moment of the area about the centroid of the section.

The total stresses produced by the thermal loading are:

At top $f_{top} = f_t - Np/A - Mp/ST + Ms/ST$ (4.32)

At bottom $f_{bot} = Np/A - Mp/SB + Ms/SB$ (4.33)

where f_t = stress due to temperature differential

= $E \alpha \Delta T$

Np = axial tensile load due to primary effects

= $(E \alpha \Delta T) S_1$

Mp = moment due to primary effects

= $(E \alpha \Delta T) S_2$

Ms = moment due to secondary effects, given by TIMEDEP.

The sign convention used in Eq. (4.32) and (4.33) was:

+M produces compression at top, tension at bottom.

-M produces tension at top, compression at bottom.

Hence, the equivalent moments were:

$$M_{top} = f_t \times ST - Np/A \times ST - Mp + Ms \qquad (4.34)$$

$$M_{bot} = Np/A \times SB - Mp + Ms \qquad (4.35)$$

For the box section of this paper an equivalent constant thickness of 360 mm was calculated first for the top slab [see Fig.4.9]. Then S_1 and S_2 were calculated as follows:

$$S_1 = 12.9 \times 0.360 \text{ ... constant for all sections}$$
$$= 4.644 \text{ m}^2 \qquad (4.36)$$

$$S_2 = S_1 \times e \text{ ... calculated for 6 sections}$$
$$= S_1 \, (YT - 0.360/2)$$
$$= S_1 \, (YT - 0.180) \text{ m}^3 \qquad (4.37)$$

S_1, S_2 and $E \alpha \Delta T$ was the only additional data required in the spreadsheet model to carry out the thermal analysis. All other section properties were already available from previous columns.

The equivalent moments for thermal loading were added to the other loadings to obtain the final stresses for the structure.

4.9 Superimposed Dead Load and Live Load Analysis

The superimposed dead load (SDL) and live load plus impact (LL+I) analysis was carried out by using BEAMANL. This program uses imperial units. Since the self weight analysis had already been carried out using TIMEDEP, the unit weight of concrete was omitted from the input so that the effect of SDL could be obtained directly. The discretized model for the establishment of continuity [Fig. 4.4] was used to prepare the input for BEAMANL.

The output moments for SDL and LL+I were incorporated into the spreadsheet model given in Appendix C. The imperial values were simply entered in one column and converted to SI by using the appropriate conversion factor. This was accomplished by a few keystrokes using the copy command.

After preparing the above spreadsheet model, the final design of continuity tendons was again an interactive procedure relative to the allowable stresses. Stresses were checked at each continuity joint for all ten steps of the longitudinal design. Although the spreadsheet model for the establishment of continuity was 16 pages wide, the interactive process was carried out very effectively by utilizing the "windows" feature of 1-2-3.

5. CONCLUSIONS

The interactive design of a precast prestressed concrete segmental bridge using a spreadsheet program has been presented. The design example in the paper considered a precast segmental alternate for the main spans of an actual bridge under construction with conventional steel superstructure. It highlighted some of the background information that is unique to segmental bridge construct-ion and showed how a numerical method for calculating section properties was adapted for the spreadsheet. The spreadsheet models for the establishment of continuity made use of the area-moment method and moment distribution techniques to handle secondary moments.

Most engineering organizations with personal computers generally have some form of spreadsheet program. The use of these programs should not be limited to accounting, cost estimates and progress payments. The potential of an intergrated software like Lotus 1-2-3 is phenomenal and only limited by the imagination and innovation of the user. This study has provided a starting point to explore the full potential of spreadsheet programs for engineering applications.

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appendices

APPENDIX A

SPREADSHEET MODEL FOR SECTION PROPERTIES

T A B L E A - NUMERICAL METHOD OF FINDING SECTION PROPERTIES

NODE	X (m)	Y (m)	COL D	COL E	COL F
1	0.000	0.000	0.000	0.000	0.000
2	6.450	0.000	1.451	0.327	0.073
3	6.450	0.225	1.222	0.703	0.308
4	4.600	0.350	1.465	1.392	1.015
5	3.700	0.600	17.020	98.716	519.450
6	3.700	5.200	19.240	200.096	1560.749
*7	0.000	5.200	0.000	0.000	0.000
*8	0.000	4.400	-11.660	-102.608	-677.213
9	2.650	4.400	-3.833	-32.001	-200.603
10	3.250	3.950	-10.888	-49.538	-199.595
11	3.250	0.600	-0.178	-0.151	-0.102
12	1.650	0.250	0.413	0.206	0.077
13	0.000	0.250	0.000	0.000	0.000
14	0.000	0.000	0.000	0.000	0.000
SUM HALF SECTION			14.254	117.141	1004.160

h (m)	t (m)	A (m^2)	YT (m)	YB (m)	I (m^4)
5.200	0.800	14.254	2.739	2.461	60.394

NOTES:

1. HALF SECTION USED FOR NUMBERING NODES (SEE FIG. A.1)

2. COL D = SUM(Xi Yi+1 - Xi+1 Yi)
3. COL E = SUM(Xi Yi+1 - Xi+1 Yi)(Yi + Yi+1)
4. COL F = SUM[(Xi Yi+1 - Xi+1 Yi)({Yi + Yi+1}^2 - Yi Yi+1)]

5. A = 1/2 (COL D) x 2
6. YT = 1/6 (COL E)/A x 2
7. I = 1/12(COL F)x2 - A x YT^2
8. YB = h - YT

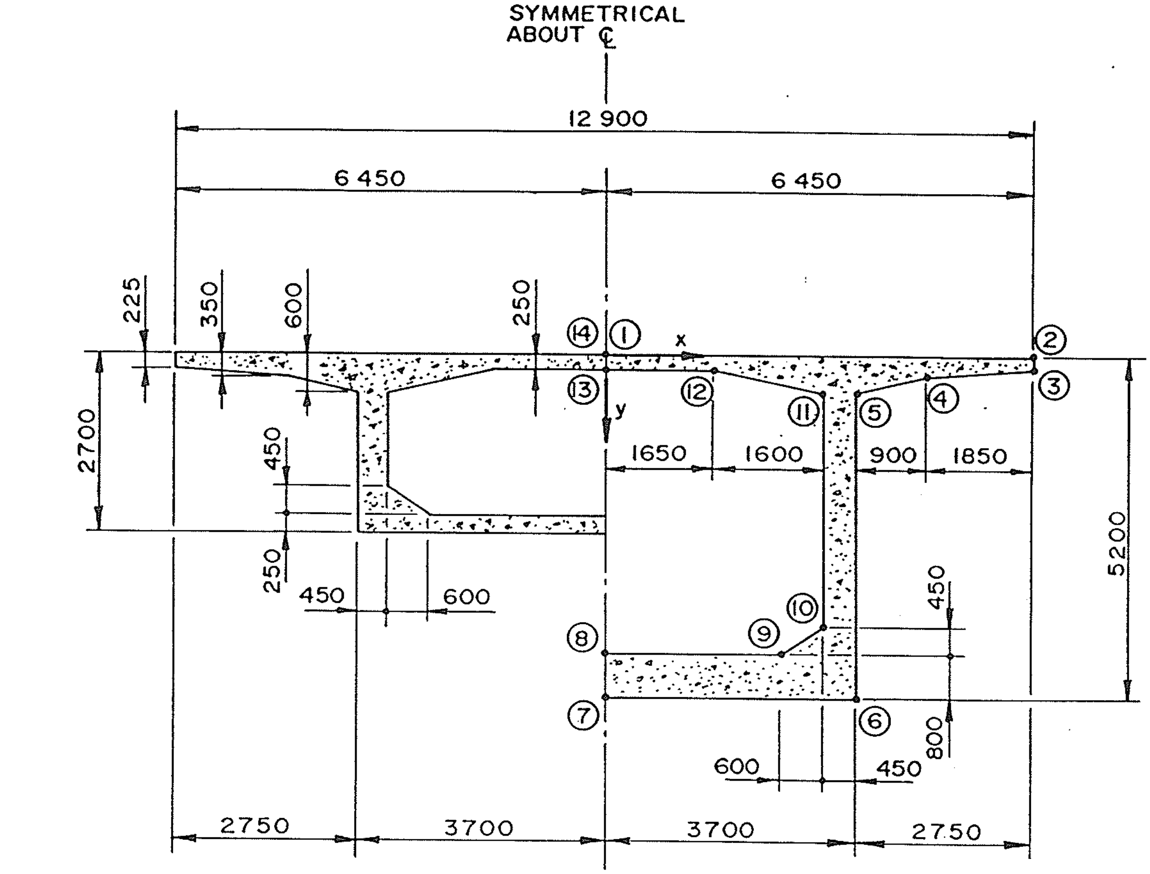
9. h = DEPTH OF SECTION
10. t = THICKNESS OF BOTTOM SLAB
11. A = AREA OF SECTION
12. YT & YB = DIST. TO N.A. FROM TOP & BOTTOM
13. I = MOMENT OF INERTIA ABOUT N.A.
14. *Y-COORDINATE OF NODES 7 AND 8 (Y7 AND Y8) VARIES W.R.T. THICKNESS OF BOTTOM SLAB.
15. CALCULATE Y7 AND Y8 IN TABLE B AND ENTER IN TABLE A TO FIND A, YT, I AND YB.
16. USE TABLE B TO FIND WEIGHT OF SEGMENTS.

T A B L E B - SECTION PROPERTIES IN HAUNCH

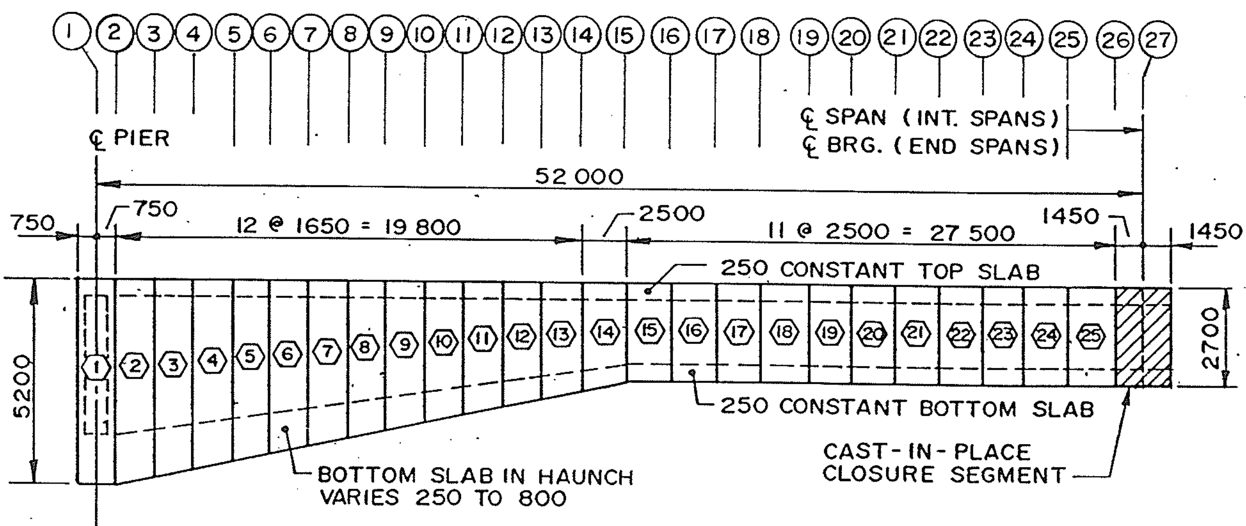
JOINT NO.	SEG LGTH DL(m)	DIST(m)	h OR Y7 (m)	Y8 (m)	t (m)	A (m^2)	MASS(t)	YT (m)	YB (m)	I (m^4)	WT (kN)	ST (m^3)	SB (m^3)
1	0.750	0.000	5.200	4.400	0.800	14.254	25.657	2.739	2.461	60.394	252.291	22.046	24.545
2	1.650	0.750	5.200	4.400	0.800	14.254	55.591	2.739	2.461	60.394	546.649	22.046	24.545
3	1.650	2.400	5.015	4.256	0.759	13.823	53.885	2.610	2.405	54.737	529.866	20.973	22.758
4	1.650	4.050	4.830	4.111	0.719	13.392	52.178	2.481	2.349	49.403	513.088	19.914	21.029
5	1.650	5.700	4.645	3.967	0.678	12.961	50.472	2.352	2.293	44.383	496.310	18.869	19.357
6	1.650	7.350	4.460	3.823	0.637	12.530	48.765	2.224	2.236	39.672	479.527	17.836	17.743
7	1.650	9.000	4.275	3.679	0.597	12.099	47.059	2.097	2.178	35.262	462.743	16.817	16.188
8	1.650	10.650	4.090	3.534	0.556	11.668	45.351	1.970	2.120	31.149	445.956	15.811	14.693
9	1.650	12.300	3.905	3.390	0.515	11.237	43.644	1.844	2.061	27.324	429.168	14.817	13.258
10	1.650	13.950	3.720	3.246	0.474	10.806	41.937	1.719	2.001	23.783	412.385	13.834	11.885
11	1.650	15.600	3.535	3.101	0.434	10.375	40.231	1.595	1.940	20.517	395.602	12.863	10.575
12	1.650	17.250	3.350	2.957	0.393	9.944	38.524	1.472	1.878	17.520	378.819	11.902	9.328
13	1.650	18.900	3.165	2.813	0.352	9.513	36.817	1.350	1.815	14.786	362.036	10.950	8.147
14	2.500	20.550	2.980	2.669	0.312	9.082	52.532	1.230	1.750	12.308	516.561	10.007	7.032
15	2.500	23.050	2.700	2.450	0.250	8.429	50.573	1.051	1.649	9.024	497.296	8.587	5.472
16	---	25.550	2.700	2.450	0.250	8.429	---	1.051	1.649	9.024	---	8.587	5.472

NOTES:

1. ELEMENT NO. 1 IS ONE-HALF PIER SEGMENT.
2. ELEMENT NOS. 2 TO 14 ARE VARIABLE DEPTH SEGMENTS IN THE IN THE HAUNCH.
3. ELEMENT NO. 15 IS THE TYPICAL CONSTANT DEPTH SEGMENT.
4. MASS = (Ai + Ai+1)/2 x DL x 2.400 tonne (t)
5. WT = MASS (t) x 9.81 kN.



a. NODE NUMBERS FOR SECTION PROPERTIES



b. TYPICAL LAYOUT OF SEGMENTS IN ONE CANTILEVER OF BRIDGE

SECTION PROPERTIES

FIG. A-1

APPENDIX B

SPREADSHEET MODEL FOR ERECTION OF CANTILEVERS

Page

CANT JOINT NO.	DIST X(m)	ELEMENT LENGTH DL(m)	SECTION PROPERTIES h (m)	t (m)	A (m^2)	YT (m)	YB (m)	I (m^4)	ST(m^3)	SB(m^3)
1	0.000	0.750	5.200	0.800	14.254	2.739	2.461	60.394	22.046	24.545
2	0.750	1.650	5.200	0.800	14.254	2.739	2.461	60.394	22.046	24.545
3	2.400	1.650	5.015	0.759	13.823	2.610	2.405	54.737	20.973	22.758
4	4.050	1.650	4.830	0.719	13.392	2.481	2.349	49.403	19.914	21.029
5	5.700	1.650	4.645	0.678	12.961	2.352	2.293	44.383	18.869	19.357
6	7.350	1.650	4.460	0.637	12.530	2.224	2.236	39.672	17.836	17.743
7	9.000	1.650	4.275	0.597	12.099	2.097	2.178	35.262	16.817	16.188
8	10.650	1.650	4.090	0.556	11.668	1.970	2.120	31.149	15.811	14.693
9	12.300	1.650	3.905	0.515	11.237	1.844	2.061	27.324	14.817	13.258
10	13.950	1.650	3.720	0.474	10.806	1.719	2.001	23.783	13.834	11.885
11	15.600	1.650	3.535	0.434	10.375	1.595	1.940	20.517	12.863	10.575
12	17.250	1.650	3.350	0.393	9.944	1.472	1.878	17.520	11.902	9.328
13	18.900	1.650	3.165	0.352	9.513	1.350	1.815	14.786	10.950	8.147
14	20.550	2.500	2.980	0.312	9.082	1.230	1.750	12.308	10.007	7.032
15	23.050	2.500	2.700	0.250	8.429	1.051	1.649	9.024	8.587	5.472
16	25.550	2.500	2.700	0.250	8.429	1.051	1.649	9.024	8.587	5.472
17	28.050	2.500	2.700	0.250	8.429	1.051	1.649	9.024	8.587	5.472
18	30.550	2.500	2.700	0.250	8.429	1.051	1.649	9.024	8.587	5.472
19	33.050	2.500	2.700	0.250	8.429	1.051	1.649	9.024	8.587	5.472
20	35.550	2.500	2.700	0.250	8.429	1.051	1.649	9.024	8.587	5.472
21	38.050	2.500	2.700	0.250	8.429	1.051	1.649	9.024	8.587	5.472
22	40.550	2.500	2.700	0.250	8.429	1.051	1.649	9.024	8.587	5.472
23	43.050	2.500	2.700	0.250	8.429	1.051	1.649	9.024	8.587	5.472
24	45.550	2.500	2.700	0.250	8.429	1.051	1.649	9.024	8.587	5.472
25	48.050	2.500	2.700	0.250	8.429	1.051	1.649	9.024	8.587	5.472
26	50.550	---	2.700	0.250	8.429	1.051	1.649	9.024	8.587	5.472

NOTES:

1. CANT JOINT NO. = CANTILEVER JOINT NO.
2. X = DIST. FROM ORIGIN (AT JOINT 1)
3. DL = LENGTH OF ELEMENT
4. h = DEPTH OF ELEMENT
5. t = THICKNESS OF BOTTOM SLAB
6. ONE CANTILEVER OF BRIDGE CONTAINS 26 JOINTS AND 25 ELEMENTS.
7. A = AREA OF SECTION
8. YT = DIST. TO N.A. FROM TOP
9. YB = DIST. TO N.A. FROM BOTTOM
10. I = MOMENT OF INERTIA ABOUT N.A.
11. ST = SECTION MODULUS AT TOP
12. SB = SECTION MODULUS AT BOTTOM

CANTILEVER TENDONS (GROUP 1) EACH WEB - FINAL STAGE

CANT JOINT NO.	TOTAL N	TENDON LOCATION L1	L2	L3	L4	Ycgs(m)	e (m)	P (kN)	Mp(kN.m)	Mt	Mb	Mp+Mt	Mp+Mb
1	27	13	10	2	2	0.261	2.478	101347	251170	156753	-174517	407923	76653
2	27	13	10	2	2	0.261	2.478	101347	251170	156753	-174517	407923	76653
3	25	13	10	2	0	0.234	2.376	93840	222951	142384	-154502	365335	68449
4	23	13	10	0	0	0.215	2.266	86333	195592	128381	-135568	323973	60025
5	21	13	8	0	0	0.207	2.145	78826	169085	114756	-117726	283842	51359
6	20	13	7	0	0	0.203	2.022	75072	151772	106867	-106307	258639	45465
7	19	13	6	0	0	0.197	1.899	71318	135464	99133	-95422	234597	40041
8	18	13	5	0	0	0.192	1.778	67565	120159	91556	-85081	211715	35078
9	17	13	4	0	0	0.185	1.659	63811	105855	84141	-75289	189996	30566
10	16	13	3	0	0	0.178	1.541	60058	92547	76890	-66055	169438	26492
11	15	13	2	0	0	0.170	1.425	56304	80234	69808	-57389	150042	22845
12	14	13	1	0	0	0.161	1.311	52550	68910	62900	-49297	131809	19613
13	13	13	0	0	0	0.150	1.200	48797	58569	56171	-41789	114741	16780
14	12	12	0	0	0	0.150	1.080	45043	48645	49630	-34875	98274	13769
15	11	11	0	0	0	0.150	0.901	41290	37196	42066	-26805	79262	10391
16	10	10	0	0	0	0.150	0.901	37536	33815	38242	-24368	72057	9446
17	9	9	0	0	0	0.150	0.901	33782	30433	34418	-21932	64851	8502
18	8	8	0	0	0	0.150	0.901	30029	27052	30594	-19495	57645	7557
19	7	7	0	0	0	0.150	0.901	26275	23670	26769	-17058	50440	6612
20	6	6	0	0	0	0.150	0.901	22522	20289	22945	-14621	43234	5668
21	5	5	0	0	0	0.150	0.901	18768	16907	19121	-12184	36028	4723
22	4	4	0	0	0	0.150	0.901	15014	13526	15297	-9747	28823	3778
23	3	3	0	0	0	0.150	0.901	11261	10144	11473	-7311	21617	2834
24	2	2	0	0	0	0.150	0.901	7507	6763	7648	-4874	14411	1889
25	1	1	0	0	0	0.150	0.901	3754	3381	3824	-2437	7206	945
26	0	0	0	0	0	0	0	0	0	0	0	0	0

NOTES:

1. N = TOTAL NO. OF CANTILEVER TENDONS IN EACH WEB
2. L1 = LEVEL 1 AT 0.150 m FROM TOP WITH N1 TENDONS
3. L2 = LEVEL 2 AT 0.300 m FROM TOP WITH N2 TENDONS
4. L3 = LEVEL 3 AT 0.450 m FROM TOP WITH N3 TENDONS
5. L4 = LEVEL 4 AT 0.600 m FROM TOP WITH N4 TENDONS
6. Ycgs = [N1.L1 + N2.L2 + N3.L3 + N4.L4]/N
7. e = YT - Ycgs
8. P = N x 0.6 UTS = N x 1876.8 kN
9. SIGN CONVENTION FOR MOMENTS:
   AT TOP: +M = COMPRESSION
   -M = TENSION
   AT BOT: +M = TENSION
   -M = COMPRESSION
10. Mp + Mt = P.e + P/A x ST
11. Mp + Mb = P.e - P/A x SB

CANT JOINT NO.	STEP 1: ERECTION OF CANTILEVERS + GROUP 1 TENDONS					ALLOWABLE MOMENTS WITH 0.55f'c	
	Md STAGE 24	Mp+Mt+Md	Mp+Mb+Md	STRESS (psi) TOP	STRESS (psi) BOT	Ma(top)	Ma(bot)
1	-267000	140923	-190347	927	-1124	501991	-558879
2	-258300	149623	-181647	984	-1073	501991	-558879
3	-239800	125535	-171351	868	-1092	477561	-518209
4	-222300	101673	-162275	740	-1119	453445	-478830
5	-205600	78242	-154241	601	-1155	429639	-440756
6	-189700	68939	-144235	560	-1179	406136	-404007
7	-174600	59997	-134559	517	-1205	382930	-368598
8	-160400	51315	-125322	471	-1237	360013	-334550
9	-146900	43096	-116334	422	-1272	337377	-301883
10	-134100	35338	-107608	370	-1313	315008	-270620
11	-122000	28042	-99155	316	-1360	292893	-240784
12	-110500	21309	-90887	260	-1413	271012	-212401
13	-99720	15021	-82940	199	-1476	249341	-185500
14	-89550	8724	-75781	126	-1563	227850	-160111
15	-75230	4032	-64839	68	-1718	195533	-124596
16	-62170	9887	-52724	167	-1397	195533	-124596
17	-50360	14491	-41858	245	-1109	195533	-124596
18	-39800	17845	-32243	301	-854	195533	-124596
19	-30470	19970	-23858	337	-632	195533	-124596
20	-22380	20854	-16712	352	-443	195533	-124596
21	-15540	20488	-10817	346	-287	195533	-124596
22	-9946	18877	-6168	319	-163	195533	-124596
23	-5592	16025	-2758	271	-73	195533	-124596
24	-2484	11927	-595	201	-16	195533	-124596
25	-621	6585	324	111	9	195533	-124596
26	0	0	0	0	0	195533	-124596

NOTES:

1. Md OBTAINED FROM TIMEDEP
2. ALL MOMENTS GIVEN IN kN.m
3. STRESS AT TOP = [Mp+Mt+Md]/ST x 145 psi
4. STRESS AT BOT = [Mp+Mb+Md]/SB x 145 psi
5. ALLOWABLE STRESS = 0.55 f'c = 3300 psi
6. SIGN CONVENTION FOR STRESS:
   - TOP: + = COMPRESSION, - = TENSION
   - BOT: + = TENSION, - = COMPRESSION

APPENDIX C

SPREADSHEET MODEL FOR ESTABLISHMENT OF CONTINUITY AND FINAL STRESS CHECK

Page

APPENDIX C

SPREADSHEET MODEL FOR ESTABLISHMENT OF CONTINUITY AND FINAL STRESS CHECK (Continued)

Page

CANT---CONT JT--PT---JT	DIST X(m)	ELEMENT LENGTH DL(m)	SECTION PROPERTIES h (m)	t (m)	A (m^2)	YT (m)	YB (m)	I (m^4)	ST(m^3)	SB(m^3)
27*(1.0) 1	0.000	6.450	2.700	0.250	8.429	1.051	1.649	9.024	8.587	5.472
24 (1.1) 3	6.450	5.000	2.700	0.250	8.429	1.051	1.649	9.024	8.587	5.472
22 (1.2) 4	11.450	5.000	2.700	0.250	8.429	1.051	1.649	9.024	8.587	5.472
20 (1.3) 5	16.450	5.000	2.700	0.250	8.429	1.051	1.649	9.024	8.587	5.472
18 (1.4) 6	21.450	5.000	2.700	0.250	8.429	1.051	1.649	9.024	8.587	5.472
16 (1.5) 7	26.450	5.000	2.700	0.250	8.429	1.051	1.649	9.024	8.587	5.472
14 (1.6) 8	31.450	4.950	2.980	0.312	9.082	1.230	1.750	12.308	10.007	7.033
11 (1.7) 9	36.400	4.950	3.535	0.434	10.375	1.595	1.940	20.517	12.863	10.576
8 (1.8)10	41.350	4.950	4.090	0.556	11.668	1.970	2.120	31.149	15.812	14.693
5 (1.9)11	46.300	5.700	4.645	0.678	12.961	2.352	2.293	44.383	18.870	19.356
1*(2.0)13	52.000	10.650	5.200	0.800	14.254	2.739	2.461	60.394	22.050	24.540
8 (2.1)16	62.650	9.900	4.090	0.556	11.668	1.970	2.120	31.149	15.812	14.693
14 (2.2)18	72.550	10.000	2.980	0.312	9.082	1.230	1.750	12.308	10.007	7.033
18 (2.3)20	82.550	10.000	2.700	0.250	8.429	1.051	1.649	9.024	8.587	5.472
22 (2.4)22	92.550	11.450	2.700	0.250	8.429	1.051	1.649	9.024	8.587	5.472
27 (2.5)25	104.000	11.450	2.700	0.250	8.429	1.051	1.649	9.024	8.587	5.472
22 (2.6)28	115.450	10.000	2.700	0.250	8.429	1.051	1.649	9.024	8.587	5.472
18 (2.7)30	125.450	10.000	2.700	0.250	8.429	1.051	1.649	9.024	8.587	5.472
14 (2.8)32	135.450	9.900	2.980	0.312	9.082	1.230	1.750	12.308	10.007	7.033
8 (2.9)34	145.350	10.650	4.090	0.556	11.668	1.970	2.120	31.149	15.812	14.693
1*(3.0)37	156.000	10.650	5.200	0.800	14.254	2.739	2.461	60.394	22.050	24.540
8 (3.1)40	166.650	9.900	4.090	0.556	11.668	1.970	2.120	31.149	15.812	14.693
14 (3.2)42	176.550	10.000	2.980	0.312	9.082	1.230	1.750	12.308	10.007	7.033
18 (3.3)44	186.550	10.000	2.700	0.250	8.429	1.051	1.649	9.024	8.587	5.472
22 (3.4)46	196.550	11.450	2.700	0.250	8.429	1.051	1.649	9.024	8.587	5.472
27 (3.5)49	208.000	11.450	2.700	0.250	8.429	1.051	1.649	9.024	8.587	5.472
22 (3.6)52	219.450	10.000	2.700	0.250	8.429	1.051	1.649	9.024	8.587	5.472
18 (3.7)54	229.450	10.000	2.700	0.250	8.429	1.051	1.649	9.024	8.587	5.472
14 (3.8)56	239.450	9.900	2.980	0.312	9.082	1.230	1.750	12.308	10.007	7.033
8 (3.9)58	249.350	10.650	4.090	0.556	11.668	1.970	2.120	31.149	15.812	14.693
1*(4.0)61	260.000	5.700	5.200	0.800	14.254	2.739	2.461	60.394	22.050	24.540
5 (4.1)63	265.700	4.950	4.645	0.678	12.961	2.352	2.293	44.383	18.870	19.356
8 (4.2)64	270.650	4.950	4.090	0.556	11.668	1.970	2.120	31.149	15.812	14.693
11 (4.3)65	275.600	4.950	3.535	0.434	10.375	1.595	1.940	20.517	12.863	10.576
14 (4.4)66	280.550	5.000	2.980	0.312	9.082	1.230	1.750	12.308	10.007	7.033
16 (4.5)67	285.550	5.000	2.700	0.250	8.429	1.051	1.649	9.024	8.587	5.472
18 (4.6)68	290.550	5.000	2.700	0.250	8.429	1.051	1.649	9.024	8.587	5.472
20 (4.7)69	295.550	5.000	2.700	0.250	8.429	1.051	1.649	9.024	8.587	5.472
22 (4.8)70	300.550	5.000	2.700	0.250	8.429	1.051	1.649	9.024	8.587	5.472
24 (4.9)71	305.550	6.450	2.700	0.250	8.429	1.051	1.649	9.024	8.587	5.472
27*(5.0)73	312.000	---	2.700	0.250	8.429	1.051	1.649	9.024	8.587	5.472

NOTES:

1. CANT JT = CANTILEVER JOINT NO.
2. PT = POINT ON SPAN
3. CONT JT = CONTINUITY JOINT NO. (i)
4. X = DIST. FROM ORIGIN (AT JOINT 1)
5. DL = LENGTH OF ELEMENT (k)
6. h = DEPTH OF SECTION
7. t = THICKNESS OF BOTTOM SLAB
8. A = AREA OF SECTION
9. YT = DIST. TO N.A. FROM TOP
10. YB = DIST. TO N.A. FROM BOTTOM
11. I = MOMENT OF INERTIA ABOUT N.A.
12. ST = SECTION MODULUS AT TOP
13. SB = SECTION MODULUS AT BOTTOM

CANT---CONT JT--PT---JT	CANTILEVER TENDONS (GROUP 1) EACH WEB TOTAL N	TENDON LOCATION LEVEL L1	L2	L3	L4	Ycgs(m)	e (m)	P(kN)	Mp(kN.m)	Mp+Mt	Mp+Mb
27*(1.0) 1	0	0	0	0	0	0	0	0	0	0	0
24 (1.1) 3	2	2	0	0	0	0.150	0.901	7507	6763	14411	1889
22 (1.2) 4	4	4	0	0	0	0.150	0.901	15014	13526	28823	3778
20 (1.3) 5	6	6	0	0	0	0.150	0.901	22522	20289	43234	5668
18 (1.4) 6	8	8	0	0	0	0.150	0.901	30029	27052	57645	7557
16 (1.5) 7	10	10	0	0	0	0.150	0.901	37536	33815	72057	9446
14 (1.6) 8	12	12	0	0	0	0.150	1.080	45043	48647	98275	13765
11 (1.7) 9	15	13	2	0	0	0.170	1.425	56304	80233	150041	22840
8 (1.8)10	18	13	5	0	0	0.192	1.778	67565	120153	211712	35072
5 (1.9)11	21	13	8	0	0	0.207	2.145	78826	169070	283834	51352
1*(2.0)13	27	13	10	2	2	0.261	2.478	101347	251127	407902	76642
8 (2.1)16	18	13	5	0	0	0.192	1.778	67565	120153	211712	35072
14 (2.2)18	12	12	0	0	0	0.150	1.080	45043	48647	98275	13765
18 (2.3)20	8	8	0	0	0	0.150	0.901	30029	27052	57645	7557
22 (2.4)22	4	4	0	0	0	0.150	0.901	15014	13526	28823	3778
27 (2.5)25	0	0	0	0	0	0	0	0	0	0	0
22 (2.6)28	4	4	0	0	0	0.150	0.901	15014	13526	28823	3778
18 (2.7)30	8	8	0	0	0	0.150	0.901	30029	27052	57645	7557
14 (2.8)32	12	12	0	0	0	0.150	1.080	45043	48647	98275	13765
8 (2.9)34	18	13	5	0	0	0.192	1.778	67565	120153	211712	35072
1*(3.0)37	27	13	10	2	2	0.261	2.478	101347	251127	407902	76642
8 (3.1)40	18	13	5	0	0	0.192	1.778	67565	120153	211712	35072
14 (3.2)42	12	12	0	0	0	0.150	1.080	45043	48647	98275	13765
18 (3.3)44	8	8	0	0	0	0.150	0.901	30029	27052	57645	7557
22 (3.4)46	8	8	0	0	0	0.150	0.901	30029	27052	57645	7557
27 (3.5)49	0	0	0	0	0	0	0	0	0	0	0
22 (3.6)52	4	4	0	0	0	0.150	0.901	15014	13526	28823	3778
18 (3.7)54	8	8	0	0	0	0.150	0.901	30029	27052	57645	7557
14 (3.8)56	12	12	0	0	0	0.150	1.080	45043	48647	98275	13765
8 (3.9)58	18	13	5	0	0	0.192	1.778	67565	120153	211712	35072
1*(4.0)61	27	13	10	2	2	0.261	2.478	101347	251127	407902	76642
5 (4.1)63	21	13	8	0	0	0.207	2.145	78826	169070	283834	51352
8 (4.2)64	18	13	5	0	0	0.192	1.778	67565	120153	211712	35072
11 (4.3)65	15	13	2	0	0	0.170	1.425	56304	80233	150041	22840
14 (4.4)66	12	12	0	0	0	0.150	1.080	45043	48647	98275	13765
16 (4.5)67	10	10	0	0	0	0.150	0.901	37536	33815	72057	9446
18 (4.6)68	8	8	0	0	0	0.150	0.901	30029	27052	57645	7557
20 (4.7)69	6	6	0	0	0	0.150	0.901	22522	20289	43234	5668
22 (4.8)70	4	4	0	0	0	0.150	0.901	15014	13526	28823	3778
24 (4.9)71	2	2	0	0	0	0.150	0.901	7507	6763	14411	1889
27*(5.0)73	0	0	0	0	0	0	0	0	0	0	0

NOTES:

1. N = TOTAL NO. OF CANTILEVER TENDONS IN EACH WEB
2. L1 = LEVEL 1 AT 0.150 m FROM TOP WITH N1 TENDONS
3. L2 = LEVEL 2 AT 0.300 m FROM TOP WITH N2 TENDONS
4. L3 = LEVEL 3 AT 0.450 m FROM TOP WITH N3 TENDONS
5. L4 = LEVEL 4 AT 0.600 m FROM TOP WITH N4 TENDONS
6. Ycgs = [N1.L1 + N2.L2 + N3.L3 + N4.L4]/N
7. e = YT - Ycgs
8. P = N x 0.6 UTS = N x 1876.8 kN
9. SIGN CONVENTION FOR MOMENTS
   AT TOP: +M = COMPRESSION
   -M = TENSION
   AT BOT: +M = TENSION
   -M = COMPRESSION
10. Mp + Mt = P.e + P/A x ST
11. Mp + Mb = P.e - P/A x SB

CANT---CONT JT--PT---JT	CONTINUITY TENDONS (GROUP 2,3,4 & 5) EACH WEB													
	TOT N	TENDON LOC. LEVEL L1	L5	L6	L7	L8	Ycgs(m)	e(m)	P(kN)	Mp(kN.m)	Mp+Mt	Mp+Mb	(Mp/I)
27*(1.0) 1	3	1	0	0	0	2	0.751	0.300	11261	3381	14854	-3929	375
24 (1.1) 3	4	1	0	0	1	2	1.913	-0.862	15014	-12937	2360	-22684	-1434
22 (1.2) 4	4	1	0	0	1	2	1.913	-0.862	15014	-12937	2360	-22684	-1434
20 (1.3) 5	5	1	0	0	1	3	2.040	-0.989	18768	-18564	557	-30748	-2057
18 (1.4) 6	5	1	0	0	1	3	2.040	-0.989	18768	-18564	557	-30748	-2057
16 (1.5) 7	5	1	0	0	1	3	2.040	-0.989	18768	-18564	557	-30748	-2057
14 (1.6) 8	5	1	0	0	1	3	2.264	-1.034	18768	-19406	1272	-33940	-1577
11 (1.7) 9	4	1	0	0	1	2	2.539	-0.944	15014	-14170	4446	-29475	-691
8 (1.8)10	1	1	0	0	0	0	0.150	1.820	3754	6832	11918	2105	219
5 (1.9)11	1	1	0	0	0	0	0.150	2.202	3754	8265	13730	2660	186
1*(2.0)13	0	0	0	0	0	0	0.000	2.739	0	0	0	0	0
8 (2.1)16	1	1	0	0	0	0	0.150	1.820	3754	6832	11918	2105	219
14 (2.2)18	6	1	0	1	1	3	2.308	-1.078	22522	-24286	528	-41727	-1973
18 (2.3)20	10	1	0	1	2	6	2.250	-1.199	37536	-45011	-6769	-69379	-4988
22 (2.4)22	14	1	0	1	5	7	2.304	-1.253	52550	-65831	-12292	-99946	-7295
27 (2.5)25	15	1	0	1	5	8	2.320	-1.269	56304	-71458	-14095	-108010	-7919
22 (2.6)28	14	1	0	1	5	7	2.304	-1.253	52550	-65831	-12292	-99946	-7295
18 (2.7)30	10	1	0	1	2	6	2.250	-1.199	37536	-45011	-6769	-69379	-4988
14 (2.8)32	6	1	0	1	1	3	2.308	-1.078	22522	-24286	528	-41727	-1973
8 (2.9)34	1	1	0	0	0	0	0.150	1.820	3754	6832	11918	2105	219
1*(3.0)37	0	0	0	0	0	0	0.000	2.739	0	0	0	0	0
8 (3.1)40	1	1	0	0	0	0	0.150	1.820	3754	6832	11918	2105	219
14 (3.2)42	6	1	0	1	1	3	2.308	-1.078	22522	-24286	528	-41727	-1973
18 (3.3)44	10	1	0	1	2	6	2.250	-1.199	37536	-45011	-6769	-69379	-4988
22 (3.4)46	14	1	0	1	5	7	2.304	-1.253	52550	-65831	-12292	-99946	-7295
27 (3.5)49	15	1	0	1	5	8	2.320	-1.269	56304	-71458	-14095	-108010	-7919
22 (3.6)52	14	1	0	1	5	7	2.304	-1.253	52550	-65831	-12292	-99946	-7295
18 (3.7)54	10	1	0	1	2	6	2.250	-1.199	37536	-45011	-6769	-69379	-4988
14 (3.8)56	6	1	0	1	1	3	2.308	-1.078	22522	-24286	528	-41727	-1973
8 (3.9)58	1	1	0	0	0	0	0.150	1.820	3754	6832	11918	2105	219
1*(4.0)61	0	0	0	0	0	0	0.000	2.739	0	0	0	0	0
5 (4.1)63	1	1	0	0	0	0	0.150	2.202	3754	8265	13730	2660	186
8 (4.2)64	1	1	0	0	0	0	0.150	1.820	3754	6832	11918	2105	219
11 (4.3)65	4	1	0	0	1	2	2.539	-0.944	15014	-14170	4446	-29475	-691
14 (4.4)66	5	1	0	0	1	3	2.264	-1.034	18768	-19406	1272	-33940	-1577
16 (4.5)67	5	1	0	0	1	3	2.040	-0.989	18768	-18564	557	-30748	-2057
18 (4.6)68	5	1	0	0	1	3	2.040	-0.989	18768	-18564	557	-30748	-2057
20 (4.7)69	5	1	0	0	1	3	2.040	-0.989	18768	-18564	557	-30748	-2057
22 (4.8)70	4	1	0	0	1	2	1.913	-0.862	15014	-12937	2360	-22684	-1434
24 (4.9)71	4	1	0	0	1	2	1.913	-0.862	15014	-12937	2360	-22684	-1434
27*(5.0)73	3	1	0	0	0	2	0.751	0.300	11261	3381	14854	-3929	375

NOTES:

1. N = TOTAL NO. OF CONTINUITY TENDONS IN EACH WEB
2. L1 = LEVEL 1 AT 0.150 m FROM TOP WITH N1 TENDONS
3. L5 = LEVEL 5 AT (h-L4) m FROM TOP WITH N5 TENDONS
4. L6 = LEVEL 6 AT (h-L3) m FROM TOP WITH N6 TENDONS
5. L7 = LEVEL 7 AT (h-L2) m FROM TOP WITH N7 TENDONS
6. L8 = LEVEL 8 AT (h-L1) m FROM TOP WITH N8 TENDONS
7. Ycgs = [N1.L1 + N5.L5 + N6.L6 + N7.L7 + N8.L8]/N
8. e = YT - Ycgs
9. P = N x 0.6UTS = Nx1876.8 kN
10. SIGN CONVENTION FOR MOMENTS
    AT TOP: +M = COMPRESSION
    -M = TENSION
    AT BOT: +M = TENSION
    -M = COMPRESSION
11. Mp + Mt = P.e + P/A x ST
12. Mp + Mb = P.e - P/A x SB

CANT---CONT JT--PT---JT	STEP 2: SPAN 1 CONTINUITY + GROUP 2 TENDONS Ms (kN.m)	Md (TIMEDEP)	STEP 1+2 Mt*+Md	Mb*+Md	STRESS (psi) AT TOP	AT BOT
27*(1.0) 1	0	0	14854	-3929	251	-104
24 (1.1) 3	0	-2303	14468	-23098	244	-612
22 (1.2) 4	0	-9781	21401	-28687	361	-760
20 (1.3) 5	0	-22230	21561	-47311	364	-1254
18 (1.4) 6	0	-39660	18542	-62851	313	-1665
16 (1.5) 7	0	-62060	10553	-83362	178	-2209
14 (1.6) 8	0	-89490	10057	-109665	146	-2261
11 (1.7) 9	0	-122000	32487	-128635	366	-1764
8 (1.8)10	0	-160500	63130	-123323	579	-1217
5 (1.9)11	0	-205800	91765	-151788	705	-1137
1*(2.0)13	0	-267300	140602	-190658	925	-1127
8 (2.1)16	0	-160600	63030	-123423	578	-1218
14 (2.2)18	0	-89580	9223	-117542	134	-2423
18 (2.3)20	0	-39780	11096	-101602	187	-2692
22 (2.4)22	0	-9945	6586	-106113	111	-2812
27 (2.5)25	0	0	---	---	---	---
22 (2.6)28	---	---	---	---	---	---
18 (2.7)30	---	---	---	---	---	---
14 (2.8)32	---	---	---	---	---	---
8 (2.9)34	---	---	---	---	---	---
1*(3.0)37	---	---	---	---	---	---
8 (3.1)40	---	---	---	---	---	---
14 (3.2)42	---	---	---	---	---	---
18 (3.3)44	---	---	---	---	---	---
22 (3.4)46	---	---	---	---	---	---
27 (3.5)49	---	---	---	---	---	---
22 (3.6)52	---	---	---	---	---	---
18 (3.7)54	---	---	---	---	---	---
14 (3.8)56	---	---	---	---	---	---
8 (3.9)58	---	---	---	---	---	---
1*(4.0)61	---	---	---	---	---	---
5 (4.1)63	---	---	---	---	---	---
8 (4.2)64	---	---	---	---	---	---
11 (4.3)65	---	---	---	---	---	---
14 (4.4)66	---	---	---	---	---	---
16 (4.5)67	---	---	---	---	---	---
18 (4.6)68	---	---	---	---	---	---
20 (4.7)69	---	---	---	---	---	---
22 (4.8)70	---	---	---	---	---	---
24 (4.9)71	---	---	---	---	---	---
27*(5.0)73	---	---	---	---	---	---

NOTES:
1. NO SECONDARY MOMTS. OCCUR DURING SPAN 1 CONTINUITY
2. Mt* = TOTAL P/S MOMT AT TOP (DUE TO CANTILEVER + CONTINUITY TENDONS)
3. Mt* = (Mp+Mt)cantilever + (Mp+Mt)continuity
4. Mb* = TOTAL P/S MOMT AT BOT (DUE TO CANTILEVER + CONTINUITY TENDONS)
5. Mb* = (Mp+Mb)cantilever + (Mp+Mb)continuity
6. STRESS AT TOP = (Mt*+Md)/ST x 145 psi
7. STRESS AT BOT = (Mb*+Md)/SB x 145 psi
8. ALLOWABLE STRESS: fc = 0.55 f'c = 3300 psi

CANT---CONT JT--PT---JT	STEP 3: SPAN 2 CONTINUITY + GROUP 3 TENDONS Arm @37 Q(m)	Mp/I x DL.Q	Mf/I	Mf/I x DL.Q	Ms	Md (TIMEDEP)	TOTAL MOMT (TENDON+SELF) Mt*+Md	Mb*+Md	STRESS (psi) AT TOP	AT BOT
27*(1.0) 1	---	---	---	---	0	0	14854	-3929	251	-104
24 (1.1) 3	---	---	---	---	6764	-3772	19763	-17803	334	-472
22 (1.2) 4	---	---	---	---	12007	-12390	30800	-19289	520	-511
20 (1.3) 5	---	---	---	---	17251	-25980	35061	-33810	592	-896
18 (1.4) 6	---	---	---	---	22494	-44550	36146	-45248	610	-1199
16 (1.5) 7	---	---	---	---	27737	-68080	32271	-61645	545	-1634
14 (1.6) 8	---	---	---	---	32981	-96660	35868	-83855	520	-1729
11 (1.7) 9	---	---	---	---	38171	-130300	62358	-98764	703	-1354
8 (1.8)10	---	---	---	---	43362	-170000	96992	-89461	889	-883
5 (1.9)11	---	---	---	---	48553	-216400	129718	-113835	997	-853
1*(2.0)13	98.675	115240	0.017	24	54531	-279200	183233	-148027	1205	-875
8 (2.1)16	88.400	-767451	0.029	41	48946	-168100	104477	-81977	958	-809
14 (2.2)18	78.450	-2730489	0.065	56	43756	-93160	49399	-77366	716	-1595
18 (2.3)20	68.450	-4203850	0.078	50	38512	-39340	50048	-62650	845	-1660
22 (2.4)22	57.725	-5027756	0.068	41	33269	-5477	44323	-68376	748	-1812
27 (2.5)25	46.275	-4030479	0.055	26	27265	8866	22036	-71879	372	-1905
22 (2.6)28	35.550	-2183300	0.043	13	21262	-2870	34922	-77776	590	-2061
18 (2.7)30	25.550	-889280	0.033	6	16018	-34450	32445	-80254	548	-2127
14 (2.8)32	15.600	-135433	0.016	1	10775	-86000	23578	-103187	342	-2127
8 (2.9)34	5.325	6219	0.003	0	5584	-158700	70514	-115939	647	-1144
1*(3.0)37	-5.325	-6219	0.000	---	0	-267400	140502	-190758	924	-1127
8 (3.1)40	---	---	---	---	0	-160600	63030	-123423	578	-1218
14 (3.2)42	---	---	---	---	0	-89590	9213	-117552	134	-2424
18 (3.3)44	---	---	---	---	0	-39790	11086	-101612	187	-2693
22 (3.4)46	---	---	---	---	0	-9947	35406	-102336	598	-2712
27 (3.5)49	---	---	---	---	0	---	---	---	---	---
22 (3.6)52	---	---	---	---	0	---	---	---	---	---
18 (3.7)54	---	---	---	---	0	---	---	---	---	---
14 (3.8)56	---	---	---	---	0	---	---	---	---	---
8 (3.9)58	---	---	---	---	0	---	---	---	---	---
1*(4.0)61	---	---	---	---	0	---	---	---	---	---
5 (4.1)63	---	---	---	---	0	---	---	---	---	---
8 (4.2)64	---	---	---	---	0	---	---	---	---	---
11 (4.3)65	---	---	---	---	0	---	---	---	---	---
14 (4.4)66	---	---	---	---	0	---	---	---	---	---
16 (4.5)67	---	---	---	---	0	---	---	---	---	---
18 (4.6)68	---	---	---	---	0	---	---	---	---	---
20 (4.7)69	---	---	---	---	0	---	---	---	---	---
22 (4.8)70	---	---	---	---	0	---	---	---	---	---
24 (4.9)71	---	---	---	---	0	---	---	---	---	---
27*(5.0)73	---	---	---	---	0	---	---	---	---	---
	SUM =	-19852798		259 Mf						

NOTES:

1. FOR CALCULATION OF SECONDARY MOMENT AT SUPPORT B, SEE PAGE C14.
2. ARM ABOUT JOINT 37: Qk = 156.0 - (Xi + Xi+1)/2 ... where k = element no., i = joint no. ; Xi = distance from joint 1
3. AVG. Mp/I = [(Mp/I)i + (Mp/I)i+1]/2 ...used to find moment of area about joint 37
4. (Mf)i = (156.0 - Xi)/104 x Mf ... with secondary FEM (Mf) applied at joint 13
5. AVG. Mf/I = [(Mf/I)i + (Mf/I)i+1]/2 ...used to find moment of area about joint 37
6. SPAN 1: (Ms)i = Xi/52.0 x MB ... where MB = secondary momt at support B (see p. 14)
7. SPAN 2: (Ms)i = (156.0 - Xi)/104.0 x MB

CANT---CONT JT--PT---JT	STEP 4: SPAN 3 CONTINUITY + GROUP 4 TENDONS Arm @61 Q(m)	Mp/I x DL.Q	Mf/I	Mf/I x DL.Q	Ms	Md	TOTAL MOMT (TENDON+SELF) Mt*+Md	Mb*+Md	STRESS (psi) AT TOP	AT BOT
27*(1.0) 1	---	---	---	---	0	0	14854	-3929	251	-104
24 (1.1) 3	---	---	---	---	-2471	-2406	18658	-18908	315	-501
22 (1.2) 4	---	---	---	---	-4387	-9964	28839	-21250	487	-563
20 (1.3) 5	---	---	---	---	-6302	-22500	32239	-36633	544	-971
18 (1.4) 6	---	---	---	---	-8218	-40000	32478	-48916	548	-1296
16 (1.5) 7	---	---	---	---	-10134	-62480	27737	-66179	468	-1754
14 (1.6) 8	---	---	---	---	-12049	-90000	30478	-89244	442	-1840
11 (1.7) 9	---	---	---	---	-13946	-122600	56112	-105010	633	-1440
8 (1.8)10	---	---	---	---	-15842	-161200	89950	-96504	825	-952
5 (1.9)11	---	---	---	---	-17739	-206600	121779	-121774	936	-912
1*(2.0)13	---	---	---	---	-19923	-268200	174310	-156950	1146	-927
8 (2.1)16	---	---	---	---	-13331	-158700	100546	-85908	922	-848
14 (2.2)18	---	---	---	---	-7203	-85250	50106	-76659	726	-1580
18 (2.3)20	---	---	---	---	-1014	-32940	55435	-57264	936	-1517
22 (2.4)22	---	---	---	---	5176	-5859	49116	-63582	829	-1685
27 (2.5)25	---	---	---	---	12262	12030	37463	-56453	633	-1496
22 (2.6)28	---	---	---	---	19349	-1432	55710	-56989	941	-1510
18 (2.7)30	---	---	---	---	25539	-34520	57913	-54785	978	-1452
14 (2.8)32	---	---	---	---	31728	-87570	53737	-73028	779	-1506
8 (2.9)34	---	---	---	---	37856	-161800	105270	-81183	965	-801
1*(3.0)37	98.675	115240	0.017	24	44448	-272000	180350	-150910	1186	-892
8 (3.1)40	88.400	-767451	0.029	41	39896	-164100	99426	-87027	912	-859
14 (3.2)42	78.450	-2730489	0.065	56	35665	-92080	42388	-84377	614	-1740
18 (3.3)44	68.450	-4203850	0.078	50	31391	-39510	42757	-69941	722	-1853
22 (3.4)46	57.725	-5027756	0.068	41	27117	-6338	66133	-71610	1117	-1898
27 (3.5)49	46.275	-4030479	0.055	26	22224	7208	15337	-78578	259	-2082
22 (3.6)52	35.550	-2183300	0.043	13	17330	-5311	28550	-84149	482	-2230
18 (3.7)54	25.550	-889280	0.033	6	13057	-37580	26353	-86346	445	-2288
14 (3.8)56	15.600	-135433	0.016	1	8783	-89260	18326	-108439	266	-2236
8 (3.9)58	5.325	6219	0.003	0	4552	-160400	67782	-118672	622	-1171
1*(4.0)61	0.000	0	0.000	0	0	-267400	140502	-190758	924	-1127
5 (4.1)63	---	---	---	---	0	-205900	91665	-151888	704	-1138
8 (4.2)64	---	---	---	---	0	-160600	63030	-123423	578	-1218
11 (4.3)65	---	---	---	---	0	-122100	32387	-128735	365	-1765
14 (4.4)66	---	---	---	---	0	-89580	9967	-109755	144	-2263
16 (4.5)67	---	---	---	---	0	-62160	10453	-83462	177	-2212
18 (4.6)68	---	---	---	---	0	-39780	18422	-62971	311	-1669
20 (4.7)69	---	---	---	---	0	-22380	21411	-47461	362	-1258
22 (4.8)70	---	---	---	---	0	-9947	21235	-28853	359	-765
24 (4.9)71	---	---	---	---	0	-2487	14284	-23282	241	-617
27*(5.0)73	---	---	---	---	0	---	---	---	---	---
	SUM =	-19846579		259 Mf						

NOTES:

1. ARM ABOUT JOINT 61: Qk = 260.0 - (Xi + Xi+1)/2 ...where k = element no., i = joint no. ; Xi = dist. from joint 1
2. AVG. Mp/I = [(Mp/I)i + (Mp/I)i+1]/2 ...used to find moment of area about joint 61
3. (Mf)i = (260.0 - Xi)/104.0 x Mf ... with secondary FEM (Mf) applied at joint 37
4. AVG. Mf/I = [(Mf/I)i + (Mf/I)i+1]/2 ...used to find moment of area about joint 61
5. SPAN 1: (Ms)i = Xi/52.0 x MB ... where MB = secondary momt at support B (see p. 15)
6. SPAN 2: (Ms)i = (52.0 + L'2 - Xi)/L'2 x MB
7. SPAN 3: (Ms)i = (260.0 - Xi)/104.0 x MC ... where MC = secondary momt at support C.

CANT---CONT JT--PT---JT	STEP 5: SPAN 4 CONTINUITY + GROUP 5 TENDONS							TOTAL MOMT (TENDON+SELF)		STRESS (psi	
	Arm @73 Q (m)	Mp/I x DL.Q	Mf/I	Mf/I x DL.Q	Ms	TOTAL Ms	Md	Mt*+Md	Mb*+Md	AT TOP	AT BOT
27*(1.0) 1	---	---	---	---	0	0	0	14854	-3929	251	-104
24 (1.1) 3	---	---	---	---	158	4450	-2260	18961	-18605	320	-493
22 (1.2) 4	---	---	---	---	280	7900	-9706	29377	-20712	496	-549
20 (1.3) 5	---	---	---	---	402	11350	-22130	33011	-35861	557	-950
18 (1.4) 6	---	---	---	---	524	14800	-39520	33482	-47912	565	-1270
16 (1.5) 7	---	---	---	---	646	18250	-61880	28983	-64932	489	-1721
14 (1.6) 8	---	---	---	---	769	21700	-89290	31957	-87765	463	-1809
11 (1.7) 9	---	---	---	---	890	25115	-121800	57802	-103320	652	-1417
8 (1.8)10	---	---	---	---	1011	28530	-160300	91860	-94593	842	-934
5 (1.9)11	---	---	---	---	1131	31946	-205500	124010	-119542	953	-896
1*(2.0)13	---	---	---	---	1271	35879	-267000	176781	-154479	1163	-913
8 (2.1)16	---	---	---	---	837	36452	-157800	102282	-84171	938	-831
14 (2.2)18	---	---	---	---	433	36985	-84600	51189	-75576	742	-1558
18 (2.3)20	---	---	---	---	26	37524	-32550	55850	-56848	943	-1506
22 (2.4)22	---	---	---	---	-382	38063	-450	54143	-58555	914	-1552
27 (2.5)25	---	---	---	---	-848	38679	11870	36455	-57461	616	-1523
22 (2.6)28	---	---	---	---	-1315	39296	-1884	53943	-58756	911	-1557
18 (2.7)30	---	---	---	---	-1723	39835	-35230	55481	-57218	937	-1516
14 (2.8)32	---	---	---	---	-2130	40373	-88530	50647	-76118	734	-1569
8 (2.9)34	---	---	---	---	-2534	40906	-163000	101537	-84917	931	-838
1*(3.0)37	---	---	---	---	-2968	41480	-273500	175882	-155377	1157	-918
8 (3.1)40	---	---	---	---	-1834	38062	-163800	97892	-88561	898	-874
14 (3.2)42	---	---	---	---	-780	34885	-89990	43698	-83067	633	-1713
18 (3.3)44	---	---	---	---	285	31676	-36890	45662	-67037	771	-1776
22 (3.4)46	---	---	---	---	1349	28467	-3582	70238	-67505	1186	-1789
27 (3.5)49	---	---	---	---	2568	24792	10120	20817	-73098	352	-1937
22 (3.6)52	---	---	---	---	3787	21117	-2238	35410	-77288	598	-2048
18 (3.7)54	---	---	---	---	4852	17908	-34370	34414	-78284	581	-2074
14 (3.8)56	---	---	---	---	5916	14699	-86300	27202	-99563	394	-2053
8 (3.9)58	---	---	---	---	6970	11522	-158900	76252	-110202	699	-1088
1*(4.0)61	49.150	26087	0.017	5	8104	8104	-267400	148606	-182654	977	-1079
5 (4.1)63	43.825	43989	0.020	5	7216	7216	-205900	98880	-144673	760	-1084
8 (4.2)64	38.875	-45348	0.026	6	6444	6444	-160600	69474	-116979	637	-1154
11 (4.3)65	33.925	-190376	0.034	7	5673	5673	-122000	38159	-122962	430	-1686
14 (4.4)66	28.950	-263004	0.049	8	4901	4901	-89530	14919	-104804	216	-2161
16 (4.5)67	23.950	-246350	0.056	6	4122	4122	-62090	14645	-79270	247	-2101
18 (4.6)68	18.950	-194920	0.046	4	3343	3343	-39680	21865	-59529	369	-1577
20 (4.7)69	13.950	-121743	0.035	2	2564	2564	-22250	24104	-44767	407	-1186
22 (4.8)70	8.950	-64155	0.024	1	1784	1784	-9795	23172	-26916	391	-713
24 (4.9)71	3.225	-11013	0.014	0	1005	1005	-2311	15465	-22101	261	-586
27*(5.0)73	---	---	0.000	---	0	0	0	14854	-3929	251	-104
	SUM =	-1066836		43 Mf							

NOTES:

1. ARM ABOUT JOINT 73: Qk = 312.0 - (Xi + Xi+1)/2
2. AVG. Mp/I = [(Mp/I)i + (Mp/I)i+1]/2 ...used to find moment of area about joint 73
3. (Mf)i = (312.0 - Xi)/52.0 x Mf ... with secondary FEM (Mf) applied at joint 61
4. AVG. Mf/I = [(Mf/I)i + (Mf/I)i+1]/2 ...used to find moment of area about joint 73
5. SPAN 1: (Ms)i = Xi/52.0 x MB ... where MB = secondary momt at support B (see p. 16)
6. SPAN 2: (Ms)i = (52.0 + L'2 - Xi)/L'2 x MB
7. SPAN 3: (Ms)i = (156.0 + L'3 - Xi)/L'3 x MC ... where MC = secondary momt at support C
8. SPAN 4: (Ms)i = (312.0 - Xi)/52.0 x MD ... where MD = secondary momt at support D

THERMAL ANALYSIS

S1 (m^2) = 4.644 $E\alpha\Delta T$ = 6443

CANT---CONT JT--PT---JT	S2 (m^3)	Np/AxST	Np/AxSB	Mp	Ms	THERMAL TOP	MOMT BOT	THERMAL STRESSES TOP (psi)	BOT (psi)
27*(1.0) 1	4.045	-30486	19426	-26063	0	-1218	-6637	-21	-176
24 (1.1) 3	4.045	-30486	19426	-26063	5450	4232	-1187	71	-31
22 (1.2) 4	4.045	-30486	19426	-26063	9675	8457	3038	143	80
20 (1.3) 5	4.045	-30486	19426	-26063	13900	12682	7263	214	192
18 (1.4) 6	4.045	-30486	19426	-26063	18120	16902	11483	285	304
16 (1.5) 7	4.045	-30486	19426	-26063	22350	21132	15713	357	416
14 (1.6) 8	4.876	-32969	23173	-31418	26570	26659	18325	386	378
11 (1.7) 9	6.571	-37100	30502	-42339	30760	34204	18923	386	259
8 (1.8)10	8.313	-40550	37681	-53564	34940	42707	19057	392	188
5 (1.9)11	10.087	-43566	44687	-64994	39120	52148	18813	401	141
1*(2.0)13	11.884	-46288	51517	-76573	43940	63153	18884	415	112
8 (2.1)16	8.313	-40550	37681	-53564	41630	49397	25747	453	254
14 (2.2)18	4.876	-32969	23173	-31418	39480	39569	31235	573	644
18 (2.3)20	4.045	-30486	19426	-26063	37320	36102	30683	610	813
22 (2.4)22	4.045	-30486	19426	-26063	35150	33932	28513	573	756
27 (2.5)25	4.045	-30486	19426	-26063	32660	31442	26023	531	690
22 (2.6)28	4.045	-30486	19426	-26063	30180	28962	23543	489	624
18 (2.7)30	4.045	-30486	19426	-26063	28000	26782	21363	452	566
14 (2.8)32	4.876	-32969	23173	-31418	25830	25919	17585	376	363
8 (2.9)34	8.313	-40550	37681	-53564	23680	31447	7797	288	77
1*(3.0)37	11.884	-46288	51517	-76573	21370	40583	-3686	267	-22
8 (3.1)40	8.313	-40550	37681	-53564	23680	31447	7797	288	77
14 (3.2)42	4.876	-32969	23173	-31418	25830	25919	17585	376	363
18 (3.3)44	4.045	-30486	19426	-26063	28010	26792	21373	452	566
22 (3.4)46	4.045	-30486	19426	-26063	30180	28962	23543	489	624
27 (3.5)49	4.045	-30486	19426	-26063	32660	31442	26023	531	690
22 (3.6)52	4.045	-30486	19426	-26063	35140	33922	28503	573	755
18 (3.7)54	4.045	-30486	19426	-26063	37310	36092	30673	609	813
14 (3.8)56	4.876	-32969	23173	-31418	39480	39569	31235	573	644
8 (3.9)58	8.313	-40550	37681	-53564	41360	49127	25477	451	251
1*(4.0)61	11.884	-46288	51517	-76573	43950	63163	18894	415	112
5 (4.1)63	10.087	-43566	44687	-64994	39130	52158	18823	401	141
8 (4.2)64	8.313	-40550	37681	-53564	34950	42717	19067	392	188
11 (4.3)65	6.571	-37100	30502	-42339	30760	34204	18923	386	259
14 (4.4)66	4.876	-32969	23173	-31418	26580	26669	18335	386	378
16 (4.5)67	4.045	-30486	19426	-26063	22350	21132	15713	357	416
18 (4.6)68	4.045	-30486	19426	-26063	18130	16912	11493	286	305
20 (4.7)69	4.045	-30486	19426	-26063	13900	12682	7263	214	192
22 (4.8)70	4.045	-30486	19426	-26063	9677	8459	3040	143	81
24 (4.9)71	4.045	-30486	19426	-26063	5452	4234	-1185	71	-31
27*(5.0)73	4.045	-30486	19426	-26063	0	-1218	-6637	-21	-176

NOTES:

1. S1 = 12.9x0.360 = 4.644 m^2 ... constant
2. S2 = S1 x e = S1(YT-0.360/2) = S1(YT-0.180) m^3
3. $E\alpha\Delta T$ = 32 378 800 x 0.000010 x 19.9 = 6443
4. Np = ($E\alpha\Delta T$) S1 ... constant
5. Mp = ($E\alpha\Delta T$) S2 ... varies with S2
6. EQUIVALENT THERMAL MOMENTS:
   Mtop = ($E\alpha\Delta T$) x ST - Np/A x ST + Mp + Ms
   Mbot = Np/A x SB - Mp + Ms
7. SIGN CONVENTION FOR MOMENTS
   AT TOP: +M = COMPRESSION
   -M = TENSION
   AT BOT: +M = TENSION
   -M = COMPRESSION

CANT---CONT JT--PT---JT	APPLIED MOMENTS SUMMARY (kN.m) DEAD LOAD MOMENTS FINAL STG	360d	3600d	THERMAL MOMTS TOP	BOT	SDL(ft-k) (BEAMANL)	SDL	LL+I(ft-k) HS20,DF=1.0 (BEAMANL)	LL+I HS30 DF=3.0
27*(1.0) 1	0	0	0	-1218	-6637	0	0	0	0
24 (1.1) 3	-2260	-421	123	4232	-1187	1005	1363	720	4391
22 (1.2) 4	-9706	-6441	-5475	8457	3038	1267	1717	1286	7848
20 (1.3) 5	-22130	-17440	-16050	12682	7263	785	1065	1701	10382
18 (1.4) 6	-39520	-33400	-31590	16902	11483	-439	-596	1970	12020
16 (1.5) 7	-61880	-54340	-52110	21132	15713	-2407	-3264	-2287	-13958
14 (1.6) 8	-89290	-80320	-77660	26659	18325	-5118	-6939	-2745	-16749
11 (1.7) 9	-121800	-111400	-108300	34204	18923	-8571	-11623	-3202	-19540
8 (1.8)10	-160300	-148500	-145000	42707	19057	-12768	-17314	-3661	-22337
5 (1.9)11	-205500	-192300	-188400	52148	18813	-17708	-24012	-4305	-26266
1*(2.0)13	-267000	-252200	-247800	63153	18884	-23391	-31719	-5282	-32232
8 (2.1)16	-157800	-144500	-140300	49397	25747	-11170	-15146	-3018	-18417
14 (2.2)18	-84600	-72750	-68680	39569	31235	-1921	-2604	-1373	-8376
18 (2.3)20	-32550	-22140	-18230	36102	30683	4356	5907	1280	7808
22 (2.4)22	-450	8509	12270	33932	28513	7661	10388	1970	12021
27 (2.5)25	11870	19170	22760	31442	26023	7993	10838	2383	14542
22 (2.6)28	-1884	3765	7178	28962	23543	5352	7258	2328	14206
18 (2.7)30	-35230	-31020	-27760	26782	21363	-260	-353	1809	11040
14 (2.8)32	-88530	-85770	-82660	25919	17585	-8846	-11995	-2417	-14747
8 (2.9)34	-163000	-161700	-158700	31447	7797	-20403	-27667	-3882	-23689
1*(3.0)37	-273500	-273700	-270900	40583	-3686	-34933	-47370	-6090	-37158
8 (3.1)40	-163800	-160600	-158400	31447	7797	-20403	-27667	-3882	-23689
14 (3.2)42	-89990	-83620	-81950	25919	17585	-8846	-11995	-2417	-14747
18 (3.3)44	-36890	-27310	-26200	26792	21373	-260	-353	1809	11040
22 (3.4)46	-3582	9198	9757	28962	23543	5352	7258	2328	14206
27 (3.5)49	10120	26570	26500	31442	26023	7993	10838	2383	14542
22 (3.6)52	-2238	17900	17210	33922	28503	7661	10388	1970	12021
18 (3.7)54	-34370	-11000	-12230	36092	30673	4356	5907	1280	7808
14 (3.8)56	-86300	-59710	-61480	39569	31235	-1921	-2604	-1373	-8376
8 (3.9)58	-158900	-129100	-131400	49127	25477	-11170	-15146	-3018	-18417
1*(4.0)61	-267400	-234200	-237100	63163	18894	-23391	-31719	-5282	-32232
5 (4.1)63	-205900	-176300	-178900	52158	18823	-17708	-24012	-4305	-26266
8 (4.2)64	-160600	-134200	-136500	42717	19067	-12768	-17314	-3661	-22337
11 (4.3)65	-122000	-98790	-100800	34204	18923	-8571	-11623	-3202	-19540
14 (4.4)66	-89530	-69440	-71180	26669	18335	-5118	-6939	-2745	-16749
16 (4.5)67	-62090	-45190	-46660	21132	15713	-2407	-3264	-2287	-13958
18 (4.6)68	-39680	-25980	-27170	16912	11493	-439	-596	1970	12020
20 (4.7)69	-22250	-11750	-12660	12682	7263	785	1065	1701	10382
22 (4.8)70	-9795	-2481	-3116	8459	3040	1267	1717	1286	7848
24 (4.9)71	-2311	1810	1451	4234	-1185	1005	1363	720	4391
27*(5.0)73	0	0	0	-1218	-6637	0	0	0	0

NOTES:

1. MOMTS FOR FINAL STAGE, AT 360 DAYS AND AT 3600 DAYS OBTAINED FROM TIMEDEP
2. THERMAL MOMENTS FROM PAGE C8
3. SDL (SUPERIMPOSED DEAD LOAD) MOMENTS OBTAINED FROM BEAMANL IN FT-KIPS AND CONVERTED TO kN.m (1 FT-K = 1.356 kN.m)
4. LL+I MOMTS OBTAINED FROM BEAMANL IN FT-KIP FOR HS20 AASHTO TRUCK WITH DISTRIBUTION FACTOR (DF) OF 1.0. FROM AASHTO, DF = W/7 WHEELS PER LANE (W = WIDTH OF GIRDER IN FT.). WITH W = 12.9 m = 42.321 FT., DF = (42.321/7)/2 = 3.0 AXLES PER LANE. HENCE DESIGN LL+I M (for HS30) = M (ft-k from BEAMANL) x 1.356 x 1.50 x 3.0 kN.m

CANT---CONT JT--PT---JT	TOTAL TENDON MOMTS		STEP 6: SELF + THERMAL MOMTS (TEND+APPL) STRESS (psi)				STEP 7: SELF+THERMAL+SDL MOMTS (TEND+APPL) STRESS (psi)			
	TOP(Mt^*)	BOT(Mb^*)	Mt^*+Mapp	Mb^*+Mapp	AT TOP	AT BOT	Mt^*+Mapp	Mb^*+Mapp	AT TOP	AT BOT
27* (1.0) 1	14854	-3929	13636	-10566	230	-280	13636	-10566	230	-280
24 (1.1) 3	21221	-16345	23193	-19792	392	-524	24556	-18430	415	-488
22 (1.2) 4	39083	-11006	37833	-17674	639	-468	39551	-15957	668	-423
20 (1.3) 5	55141	-13731	45693	-28598	772	-758	46757	-27533	790	-730
18 (1.4) 6	73002	-8392	50384	-36429	851	-965	49788	-37025	841	-981
16 (1.5) 7	90863	-3052	50115	-49220	846	-1304	46851	-52484	791	-1391
14 (1.6) 8	121247	1525	58616	-69441	849	-1432	51676	-76380	749	-1575
11 (1.7) 9	179602	18480	92006	-84397	1037	-1157	80383	-96020	906	-1316
8 (1.8)10	252160	65707	134568	-75536	1234	-745	117254	-92850	1075	-916
5 (1.9)11	329510	85958	176159	-100730	1354	-755	152146	-124742	1169	-934
1* (2.0)13	443781	112521	239934	-135595	1578	-801	208215	-167314	1369	-989
8 (2.1)16	260082	73629	151679	-58424	1391	-577	136533	-73571	1252	-726
14 (2.2)18	135789	9024	90758	-44342	1315	-914	88153	-46946	1277	-968
18 (2.3)20	88400	-24298	91952	-26166	1553	-693	97859	-20259	1652	-537
22 (2.4)22	54593	-58105	88075	-30043	1487	-796	98463	-19655	1663	-521
27 (2.5)25	24585	-69331	67896	-31438	1146	-833	78734	-20600	1329	-546
22 (2.6)28	55827	-56872	82905	-35213	1400	-933	90162	-27956	1522	-741
18 (2.7)30	90711	-21988	82263	-35855	1389	-950	81909	-36208	1383	-959
14 (2.8)32	139177	12412	76565	-58534	1109	-1207	64571	-70529	936	-1454
8 (2.9)34	264537	78083	132984	-77120	1220	-761	105317	-104787	966	-1034
1* (3.0)37	449382	118123	216465	-159064	1423	-940	169095	-206433	1112	-1220
8 (3.1)40	261692	75239	129339	-80764	1186	-797	101672	-108431	932	-1070
14 (3.2)42	133688	6923	69617	-65482	1009	-1350	57622	-77477	835	-1597
18 (3.3)44	82552	-30147	72454	-45664	1223	-1210	72101	-46017	1217	-1219
22 (3.4)46	73820	-63923	99200	-43962	1675	-1165	106458	-36704	1798	-973
27 (3.5)49	10697	-83218	52259	-47076	882	-1247	63097	-36238	1065	-960
22 (3.6)52	37648	-75050	69332	-48786	1171	-1293	79720	-38398	1346	-1018
18 (3.7)54	68784	-43914	70506	-47612	1191	-1262	76413	-41705	1290	-1105
14 (3.8)56	113502	-13263	66771	-68328	968	-1409	64167	-70932	930	-1462
8 (3.9)58	235152	48698	125379	-84725	1150	-836	110233	-99871	1011	-986
1* (4.0)61	416006	84746	211769	-163760	1393	-968	180050	-195478	1184	-1155
5 (4.1)63	304780	61227	151039	-125850	1161	-943	127026	-149863	976	-1123
8 (4.2)64	230074	43621	112191	-97912	1029	-966	94878	-115226	870	-1137
11 (4.3)65	160159	-962	72363	-104040	816	-1426	60741	-115663	685	-1586
14 (4.4)66	104449	-15274	41587	-86469	603	-1783	34648	-93409	502	-1926
16 (4.5)67	76735	-17180	35777	-63558	604	-1684	32513	-66821	549	-1771
18 (4.6)68	61545	-19849	38777	-48036	655	-1273	38181	-48632	645	-1289
20 (4.7)69	46354	-22517	36786	-37505	621	-994	37851	-36440	639	-966
22 (4.8)70	32967	-17121	31631	-23877	534	-633	33348	-22160	563	-587
24 (4.9)71	17776	-19790	19699	-23286	333	-617	21062	-21924	356	-581
27* (5.0)73	14854	-3929	13636	-10566	230	-280	13636	-10566	230	-280

NOTES:
1. Mt^* = (Mp+Mt)cantilever + (Mp+Mt)continuity ... total tendon momt at top
2. Mb^* = (Mp+Mb)cantilever + (Mp+Mb)continuity ... total tendon momt at bottom
3. Mapp = TOTAL APPLIED MOMENTS FOR EACH STEP FROM MOMENT SUMMARY
4. STRESS AT TOP = (Mt^* + Mapp)/ST x 145 psi
5. STRESS AT BOT = (Mb^* + Mapp)/SB x 145 psi

CANT---CONT JT--PT---JT	STEP 8: SELF+THERMAL+SDL+(LL+I) MOMTS (TEND+APPL) Mt*+Mapp	Mb*+Mapp	STRESS (psi) AT TOP	AT BOT	STEP 9: SELF(360d)+THERMAL+SDL+(LL+I MOMTS (TEND+APPL) Mt*+Mapp	Mb*+Mapp	STRESS (psi) AT TOP	AT BOT
27*(1.0) 1	13636	-10566	230	-280	13636	-10566	230	-280
24 (1.1) 3	28947	-14038	489	-372	30786	-12199	520	-323
22 (1.2) 4	47398	-8109	800	-215	50663	-4844	855	-128
20 (1.3) 5	57140	-17151	965	-454	61830	-12461	1044	-330
18 (1.4) 6	61808	-25005	1044	-663	67928	-18885	1147	-500
16 (1.5) 7	32894	-66441	555	-1761	40434	-58901	683	-1561
14 (1.6) 8	34927	-93129	506	-1920	43897	-84159	636	-1735
11 (1.7) 9	60842	-115561	686	-1584	71242	-105161	803	-1442
8 (1.8)10	94916	-115188	870	-1137	106716	-103388	979	-1020
5 (1.9)11	125880	-151009	967	-1131	139080	-137809	1069	-1032
1*(2.0)13	175983	-199545	1157	-1179	190783	-184745	1255	-1092
8 (2.1)16	118117	-91987	1083	-908	131417	-78687	1205	-777
14 (2.2)18	79777	-55322	1156	-1141	91627	-43472	1328	-896
18 (2.3)20	105667	-12451	1784	-330	116077	-2041	1960	-54
22 (2.4)22	110484	-7634	1866	-202	119443	1325	2017	35
27 (2.5)25	93276	-6059	1575	-161	100576	1241	1698	33
22 (2.6)28	104369	-13749	1762	-364	110018	-8100	1858	-215
18 (2.7)30	92949	-25169	1569	-667	97159	-20959	1641	-555
14 (2.8)32	49823	-85276	722	-1758	52583	-82516	762	-1701
8 (2.9)34	81627	-128477	749	-1268	82927	-127177	760	-1255
1*(3.0)37	131937	-243591	868	-1439	131737	-243791	866	-1440
8 (3.1)40	77983	-132121	715	-1304	81183	-128921	744	-1272
14 (3.2)42	42875	-92224	621	-1901	49245	-85854	714	-1770
18 (3.3)44	83140	-34978	1404	-927	92720	-25398	1566	-673
22 (3.4)46	120664	-22498	2037	-596	133444	-9718	2253	-258
27 (3.5)49	77639	-21696	1311	-575	94089	-5246	1589	-139
22 (3.6)52	91741	-26377	1549	-699	111879	-6239	1889	-165
18 (3.7)54	84221	-33896	1422	-898	107591	-10526	1817	-279
14 (3.8)56	55791	-79309	808	-1635	82381	-52719	1194	-1087
8 (3.9)58	91816	-118288	842	-1167	121616	-88488	1115	-873
1*(4.0)61	147818	-227710	972	-1345	181018	-194510	1190	-1149
5 (4.1)63	100760	-176129	774	-1319	130360	-146529	1002	-1098
8 (4.2)64	72540	-137564	665	-1358	98940	-111164	907	-1097
11 (4.3)65	41200	-135203	464	-1854	64410	-111993	726	-1535
14 (4.4)66	17899	-110158	259	-2271	37989	-90068	550	-1857
16 (4.5)67	18556	-80779	313	-2141	35456	-63879	599	-1693
18 (4.6)68	50201	-36612	848	-970	63901	-22912	1079	-607
20 (4.7)69	48233	-26057	814	-690	58733	-15557	992	-412
22 (4.8)70	41196	-14312	696	-379	48510	-6998	819	-185
24 (4.9)71	25453	-17532	430	-465	29574	-13411	499	-355
27*(5.0)73	13636	-10566	230	-280	13636	-10566	230	-280

NOTES:

1. ALL SERVICE LOADS APPLIED AT 360 DAYS
2. ALLOWABLE STRESS AT SERVICE LOADS = 0.4 f'c = 2400 psi
3. SIGN CONVENTION FOR MOMENTS:

   AT TOP: +M = COMPRESSION
   -M = TENSION

   AT BOT: +M = TENSION
   -M = COMPRESSION

CANT---CONT JT--PT---JT	STEP 10: SELF(3600d)+THERMAL+SDL+(LL+I) MOMTS (TEND+APPL) Mt*+Mapp	Mb*+Mapp	STRESS (psi) AT TOP	AT BOT
27*(1.0) 1	13636	-10566	230	-280
24 (1.1) 3	31330	-11655	529	-309
22 (1.2) 4	51629	-3878	872	-103
20 (1.3) 5	63220	-11071	1067	-293
18 (1.4) 6	69738	-17075	1178	-452
16 (1.5) 7	42664	-56671	720	-1502
14 (1.6) 8	46557	-81499	675	-1680
11 (1.7) 9	74342	-102061	838	-1399
8 (1.8)10	110216	-99888	1011	-986
5 (1.9)11	142980	-133909	1099	-1003
1*(2.0)13	195183	-180345	1284	-1066
8 (2.1)16	135617	-74487	1244	-735
14 (2.2)18	95697	-39402	1387	-812
18 (2.3)20	119987	1869	2026	50
22 (2.4)22	123204	5086	2080	135
27 (2.5)25	104166	4831	1759	128
22 (2.6)28	113431	-4687	1915	-124
18 (2.7)30	100419	-17699	1696	-469
14 (2.8)32	55693	-79406	807	-1637
8 (2.9)34	85927	-124177	788	-1225
1*(3.0)37	134537	-240991	885	-1424
8 (3.1)40	83383	-126721	765	-1251
14 (3.2)42	50915	-84184	738	-1736
18 (3.3)44	93830	-24288	1584	-644
22 (3.4)46	134003	-9159	2263	-243
27 (3.5)49	94019	-5316	1588	-141
22 (3.6)52	111189	-6929	1877	-184
18 (3.7)54	106361	-11756	1796	-312
14 (3.8)56	80611	-54489	1168	-1123
8 (3.9)58	119316	-90788	1094	-896
1*(4.0)61	178118	-197410	1171	-1166
5 (4.1)63	127760	-149129	982	-1117
8 (4.2)64	96640	-113464	886	-1120
11 (4.3)65	62400	-114003	703	-1563
14 (4.4)66	36249	-91808	525	-1893
16 (4.5)67	33986	-65349	574	-1732
18 (4.6)68	62711	-24102	1059	-639
20 (4.7)69	57823	-16467	976	-436
22 (4.8)70	47875	-7633	808	-202
24 (4.9)71	29215	-13770	493	-365
27*(5.0)73	13636	-10566	230	-280

NOTES:

1. ALL TIME-DEPENDENT REDISTRIBUTION OF MOMENTS IS COMPLETE BY 3600 DAYS (10 YEARS).
2. ALLOWABLE STRESS = 0.4 f'c = 2400 psi
3. SIGN CONVENTION FOR MOMENTS:
   AT TOP: +M = COMPRESSION
           -M = TENSION
   AT BOT: +M = TENSION
           -M = COMPRESSION

CANT---CONT JT--PT---JT	ALLOWABLE MOMENTS WITH 0.55f'c Ma(top)	Ma(bot)	ALLOWABLE MOMENTS WITH 0.4f'c Ma(top)	Ma(bot)
27*(1.0) 1	195533	-124596	142206	-90615
24 (1.1) 3	195533	-124596	142206	-90615
22 (1.2) 4	195533	-124596	142206	-90615
20 (1.3) 5	195533	-124596	142206	-90615
18 (1.4) 6	195533	-124596	142206	-90615
16 (1.5) 7	195533	-124596	142206	-90615
14 (1.6) 8	227848	-160145	165708	-116469
11 (1.7) 9	292898	-240810	213017	-175135
8 (1.8)10	360032	-334558	261841	-243315
5 (1.9)11	429677	-440733	312493	-320533
1*(2.0)13	502071	-558786	365142	-406390
8 (2.1)16	360032	-334558	261841	-243315
14 (2.2)18	227848	-160145	165708	-116469
18 (2.3)20	195533	-124596	142206	-90615
22 (2.4)22	195533	-124596	142206	-90615
27 (2.5)25	195533	-124596	142206	-90615
22 (2.6)28	195533	-124596	142206	-90615
18 (2.7)30	195533	-124596	142206	-90615
14 (2.8)32	227848	-160145	165708	-116469
8 (2.9)34	360032	-334558	261841	-243315
1*(3.0)37	502071	-558786	365142	-406390
8 (3.1)40	360032	-334558	261841	-243315
14 (3.2)42	227848	-160145	165708	-116469
18 (3.3)44	195533	-124596	142206	-90615
22 (3.4)46	195533	-124596	142206	-90615
27 (3.5)49	195533	-124596	142206	-90615
22 (3.6)52	195533	-124596	142206	-90615
18 (3.7)54	195533	-124596	142206	-90615
14 (3.8)56	227848	-160145	165708	-116469
8 (3.9)58	360032	-334558	261841	-243315
1*(4.0)61	502071	-558786	365142	-406390
5 (4.1)63	429677	-440733	312493	-320533
8 (4.2)64	360032	-334558	261841	-243315
11 (4.3)65	292898	-240810	213017	-175135
14 (4.4)66	227848	-160145	165708	-116469
16 (4.5)67	195533	-124596	142206	-90615
18 (4.6)68	195533	-124596	142206	-90615
20 (4.7)69	195533	-124596	142206	-90615
22 (4.8)70	195533	-124596	142206	-90615
24 (4.9)71	195533	-124596	142206	-90615
27*(5.0)73	195533	-124596	142206	-90615

NOTES:
1. ALL MOMENTS GIVEN IN kN.m
2. Ma(top) = fc(allow) x ST
3. Ma(bot) = fc(allow) x SB
4. f'c = 41.4 MPa = 6000 psi

SECONDARY MOMENTS (SPAN 2 CONTINUITY)

Secondary FEM (Mf) to eliminate rotation of support B:

```
    259 Mf  =  -( -19852798 )
        Mf  =         76588 kN.m
```

Moment distribution of secondary FEM with variable I:

```
        MB  =     0.712 x Mf
   i.e. MB  =         54531   kN.m
```

SECONDARY MOMENTS (SPAN 3 CONTINUITY)

Secondary FEM (Mf) to eliminate rotation of support C:

259 Mf=-(-19846579) i.e. Mf = 76564 kN.m. ... to momt. distb. table below

Secondary Moments at supports: MB = -19923 kN.m MC = 44448 kN.m

Inflection point in span 2: L'2 = ¦MB¦/(¦MB¦+¦MC¦) x 104.0 = 32.188 m from support B

MOMENT DISTRIBUTION (SPAN 3 CONTINUITY)

	A	B	B	C	C	D
COF	0.768	0.450	0.619	0.619	0.619	0.619
k	4.640	7.930	6.410	6.410	6.410	6.410
SPAN	52.000 m		104.000 m		104.000 m	
k/L	0.089	0.153	0.062	0.062	0.062	0.062
DF	1.000	0.712	0.288	0.500	0.500	1.000
FEM				0	76564 <*****	
			-23697	-38282	-38282	-23697
	7594	16876	6821	---------	---------	23697
	-7594	----------	---------	4222	14668	---------
	----------	-5832	-5846	-9445	-9445	-5846
	3743	8317	3362	---------	---------	5846
	-3743	----------	---------	2081	3619	---------
	----------	-2874	-1764	-2850	-2850	-1764
	1487	3303	1335	---------	---------	1764
	-1487	----------	---------	826	1092	---------
	----------	-1142	-594	-959	-959	-594
	556	1236	500	---------	---------	594
	-556	----------	---------	309	368	---------
	----------	-427	-209	-338	-338	-209
	204	453	183	---------	---------	209
	-204	----------	---------	113	130	---------
	----------	-157	-75	-122	-122	-75
	74	165	67	---------	---------	75
	-74	----------	---------	41	47	---------
	----------	-57	-27	-44	-44	-27
	27	60	24	---------	---------	27
	-27	----------	---------	15	17	---------
	----------	-21	-10	-16	-16	-10
		22	9	---------	---------	10
SUM	0	19923	-19923	-44448	44448	0

NOTES:

1. SECONDARY FEM (Mf) OBTAINED FROM AREA-MOMENT METHOD.
2. CARRY OVER FACTORS (COF) AND STIFFNESS FACTORS (k) OBTAINED FROM PCA HANDBOOK OF FRAME CONSTANTS WITH STRAIGHT HAUNCH.
3. MOMENTS AT SUPPORTS (MB AND MC) USED TO DETERMINE INFLECTION POINTS FOR CALCULATION OF SECONDARY MOMENTS IN SPAN BY LINEAR INTERPOLATION.

SECONDARY MOMENTS (SPAN 4 CONTINUITY)

Secondary FEM (Mf) to eliminate rotation of support D:
43 Mf=-(-1066836)   i.e.   Mf = 24554 kN.m ... to moment distribution table below
Secondary Momts at supports: MB = 1271 kN.m   MC = -2968 kN.m   MD = 8104 kN.m
Inflection points in span 2 and 3:   L'2 = ¦MB¦/(¦MB¦+¦MC¦)x104.0 = 31.182 m from support B
L'3 = ¦MC¦/(¦MC¦+¦MD¦)x104.0 = 27.877 m from support C

MOMENT DISTRIBUTION (SPAN 4 CONTINUITY)

	A		B		C		D	E
COF	0.768	0.450	0.619	0.619	0.619	0.619	0.450	0.768
	=========	=========	=========	=========	=========	=========	=========	=========
k	4.640	7.930	6.410	6.410	6.410	6.410	7.930	4.640
SPAN	52.000 m		104.000 m		104.000 m		52.000 m	
k/L	0.089	0.153	0.062	0.062	0.062	0.062	0.153	0.089
	---------	---------	---------	---------	---------	---------	---------	---------
DF	1.000	0.712	0.288	0.500	0.500	0.288	0.712	1.000
FEM						0	24554 <*****	
					-4375	-7067	-17487	-7869
			1354	2187	2187	---------	---------	7869
	-434	-964	-390	---------	---------	1354	6043	---------
	434	---------	---------	-175	-1318	-2129	-5268	-2371
	---------	333	462	747	747	---------	---------	2371
	-255	-566	-229	---------	---------	462	1821	---------
	255	---------	---------	-103	-407	-657	-1626	-732
	---------	196	158	255	255	---------	---------	732
	-113	-252	-102	---------	---------	158	562	---------
	113	---------	---------	-46	-128	-207	-513	-231
	---------	87	54	87	87	---------	---------	231
	-45	-100	-41	---------	---------	54	177	---------
	45	---------	---------	-18	-41	-66	-164	-74
	---------	35	18	30	30	---------	---------	74
	-17	-38	-15	---------	---------	18	57	---------
	17	---------	---------	-7	-13	-22	-54	-24
	---------	13	6	10	10	---------	---------	24
	-6	-14	-6	---------	---------	6	19	---------
	6	---------	---------	-3	-4	-7	-18	-8
	---------	5	2	3	3	---------	---------	8
	-2	-5	-2	---------	---------	2	6	---------
	2	---------	---------	-1	-1	-2	-6	-3
	---------			1	1	---------	---------	3
=====	=========	=========	=========	=========	=========	=========	=========	=========
SUM	0	-1271	1271	2968	-2968	-8104	8104	0

NOTES:

1. SECONDARY FEM (Mf) OBTAINED FROM AREA-MOMENT METHOD.
2. CARRY OVER FACTORS (COF) AND STIFFNESS FACTORS (k) OBTAINED FROM PCA HANDBOOK OF FRAME CONSTANTS WITH STRAIGHT HAUNCH.
3. MOMENTS AT SUPPORTS (MB, MC AND MD) USED TO DETERMINE INFLECTION POINTS FOR CALCULATION OF SECONDARY MOMENTS IN SPAN BY LINEAR INTERPOLATION.