CALIFORNIA DEPARTMENT OF TRANSPORTATION
OFFICE OF STRUCTURES DESIGN
COMPUTER SERVICES

BENT ANALYSIS

INSTRUCTIONS FOR USERS

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GENERAL DESCRIPTION

The Bent Analysis program will assist you in the analysis of a single story plane frame with a multi or single column concrete substructure. Input may be entered on pre-formatted panels, similar to those used by the BDS program, or may be entered by creating a file with xedit. The output of this analysis provides necessary information for design of the bent cap and columns.

The following list is a summary of some of the program's capabilities:

1. The frame members may be prismatic or non-prismatic.

2. Intermediate member hinge and cantilevers are accommodated.

3 . Sidesway may be included.

4. Reduction of the dead load negative moment due to support width may be obtained.

5. Axial forces and moments in columns due to temperature change will be reported.

6. Live load column moments will be adjusted automatically for skewed bent.

7. Live load moments and shears for a standard HS truck or a group of standard HS trucks will be automatically generated.

8. Live load moments and shears for a P truck plus a standard HS truck will be automatically generated.

9. All load factors, except impact, will be automatically multiplied.

10. Factored and unfactored moment and shear envelopes will be reported.

11. Load factor design method is used to analyze and design both reinforced concrete and prestressed concrete bent caps.

12. Provides a final stirrup design of the cap members.

13. Summary of unfactored column loads for the "YIELD" program input will be reported.

PROGRAM LIMITATIONS

Since this program is for a plane frame, the user must be aware of the analysis method limitations. Factors such as skew correction for dead load column moment, torsion, and longitudinal distribution of loads through the superstructure are not considered by this program. The limitations listed below must be observed :

1. The live load lane reaction applied as wheel lines are assumed to act directly on the cap members.

2. The maximum number of members is limited to 20, of which not more than 11 may be cap members.

3. All of the interior joints must have a column support.

4. Members must be orthogonal - caps are horizontal and columns are vertical. Work is being performed on this program to accomodate non-orthogonal members.

5. Dead load analysis will include only the loads on the ADDITIONAL DEAD LOAD form that are designated Trial No 00.

6. Live load impact is not calculated by the program and must therefore be included in the live load input.

7. Dead load and live load gamma and beta factors will be multiplied internally and automatically. Do not factor any dead loads or live loads on the input data.

8. A maximum of 10 girders per cap member is allowed.

9. Non-prestressed T bents and C bents can be accomodated. This program will not analyze or design prestressed T bents or C bents.

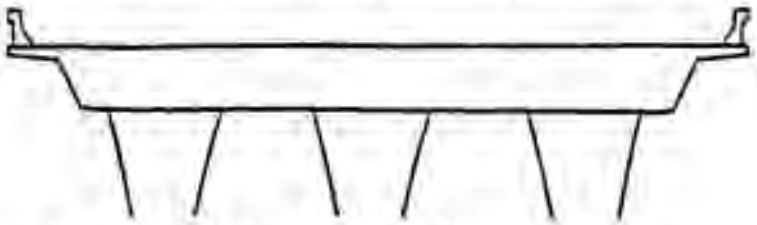
10. The distance between the wheel lines for a standard HS truck or a P truck is 6 feet.

11. The minimum clearance between two trucks is 4 feet.

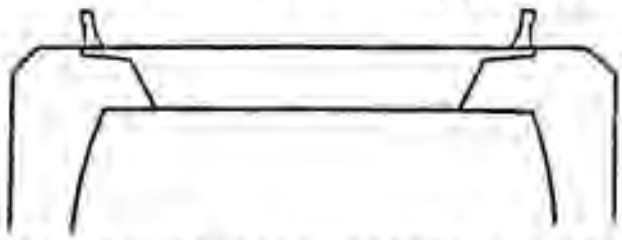
GENERAL APPLICATION

The Bent Analysis Program was developed to analyze the following types of plane-framed systems:

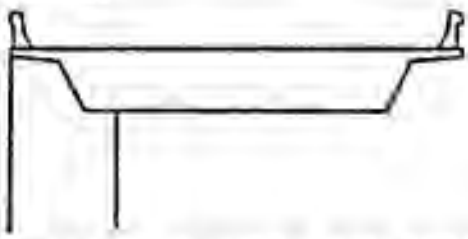
1. Multi-column bent with cantilevered overhangs



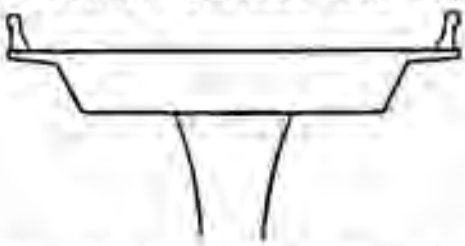
2. Single or multi-span outrigger bent



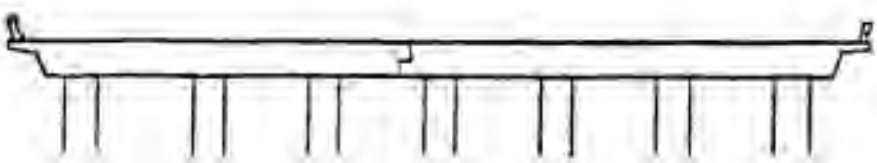
3. C bent either cantilevered or end supported (non-prestressed)



4. T bent with or without end supports (non-prestressed)



5. Multi-column bent with an internal hinge or different column end conditions



DATA PREPARATION

Data may be entered at the terminal on either pre-formatted input panels containing descriptive column headings or by creating or revising a file with XEDIT. The following is a detailed description of each input panel.

FRAME DESCRIPTION (Form A)

This input data describes the frame geometry. By itself, this data would produce a factored dead load analysis.

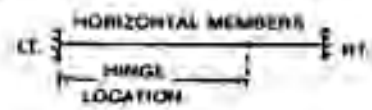
FORM NUMBER: 107310

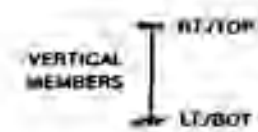
CODE		MEMBER NO.	END JOINT NO. LT	END JOINT NO. RT	END CONDITION	DIRECTION	LENGTH FT	MIN I_{cc} FT	HINGE LOC OR SUPPORT WIDTH FT	E KSI	DEAD LOAD UNIFORM KIFT	DEAD LOAD UNIT WT PCF	SKEW ANGLE (DEGREES) LT	SKEW ANGLE (DEGREES) RT	FOR FUTURE USE	CONCRETE F'c KSI	MEMBER	REVERSE	DEFLECTIONS	SIDESWAY

END CONDITION
- CANTILEVER
- PIN
- H,P ROLLER

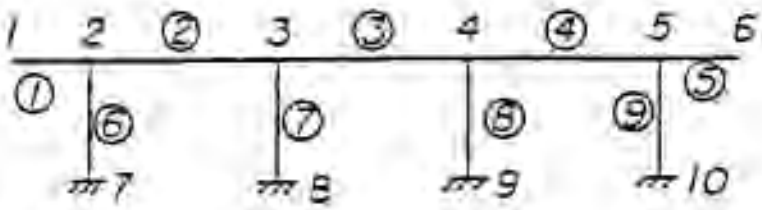
DIRECTION
C,G OR H = HORIZONTAL

Note: Member numbers must be numbered consecutively





MEMBER NUMBER must start with 1 and increase consecutively. The cap members must be numbered first (including cantilevers). Up to 20 members may be analyzed.



END JOINT NO. defines the left and right end of member joint number. Starting with 1, number the end joints of each member consecutively from the left end of Member No. 1. The bottom of a column is considered to be the left end of that member. A column top (right end) joint number is the same as that of the cap members to which the column connects. No more than three members may meet at one joint.

END CONDITION describes the degree of freedom of the member at the joint. If left blank, defaults to fixed end condition.

C = Cantilevered (unsupported)

P = Pinned (moment is released)

R = Roller (moment and horizontal force is released)

DIRECTION is assumed to be vertical unless a "G","C", or "H" is entered to indicate a girder, cap or horizontal member.

LENGTH (feet) is the cap member length measured along the centerline of the bent to the nearest 0.1 foot.

MIN. I is the minimum moment of inertia. If this entry is left blank, the required section properties must be provided by the "Section Properties by Parts" input (Form C).

HINGE LOCATION OR SUPPORT WIDTH depends on the entry in the "Direction" field. If a "C", "G", or "H" is entered for direction, then a hinge location is defined, otherwise, a top of column support width is defined. Hinge location is given in feet from the left end of the member to the hinge centerline. The support width is ussually the column width in feet along th centerline of the bent. The support width is needed to obtai the dead load moment reduction. For prestressed bents, each side of a hinge must be treated as a separate frame.

E, the modulus of elasticity, may be input or the user may accept the built-in defaults. E defaults to 3600 KSI for cap members and 3250 ksi for column members. If the user elects to use a different E, it must be entered for cap and column members separately. Once an entry is made, E remains constant for all subsequent cap or column members until another entry is made.

DEAD LOAD (unfactored) may be applied to the input frame by two methods:

UNIFORM describes a uniform load in kips/foot.

UNIT WT. describes the weight of the material to be used in calculating dead load. To use unit weight, the member cross section must be described with either of the section property input forms. If no unit weight is given, a default value of zero is used. Both a uniform load and a unit weight may be applied simultaneously.

F'c (ksi) defines the concrete compressive strength. F'c may be entered or the user may accept the default values of 4.00 ksi for cap members and 3.25 ksi for column members. This value will be used for the prestressed concrete design but not for reinforced concrete design in which f'c must be specified on the Reinforced Concrete Data input panel. If an entry for f'c but not E has been made, the modulus of elasticity will be automatically calculated per AASHTO Article 8.7.1.

MEMBER RECALL is available for members which have identical properties. These properties include LENGTH, MIN I, END CONDITION, UNIT WEIGHT, and DEAD LOAD. The data required for the repetitive member is the member number from which data is to be obtained. If the member is to be flipped end for end enter "R" in the REVERSE column. Any other data given for the repetitive member is ignored. Data can not be recalled from a member which was generated by MEMBER RECALL.

DEFLECTIONS at the quarter points of all members will automatically be calculated for Dead Load (Trial No. 0). If they are desired at some evenly spaced points other than the quarter points, enter the number of equal spaces under DEFLECTIONS. The entry needs to be made only once and may be made in the data for any member. In addition to the above, deflections will always be calculated at hinges and at the quarter points of the longer portion of the hinged member.

If correction for SIDESWAY is desired in the Dead Load analysis (Trial No. 0), enter "S" in the SIDESWAY column. The entry needs to be made only once and may be made in the data for any member.

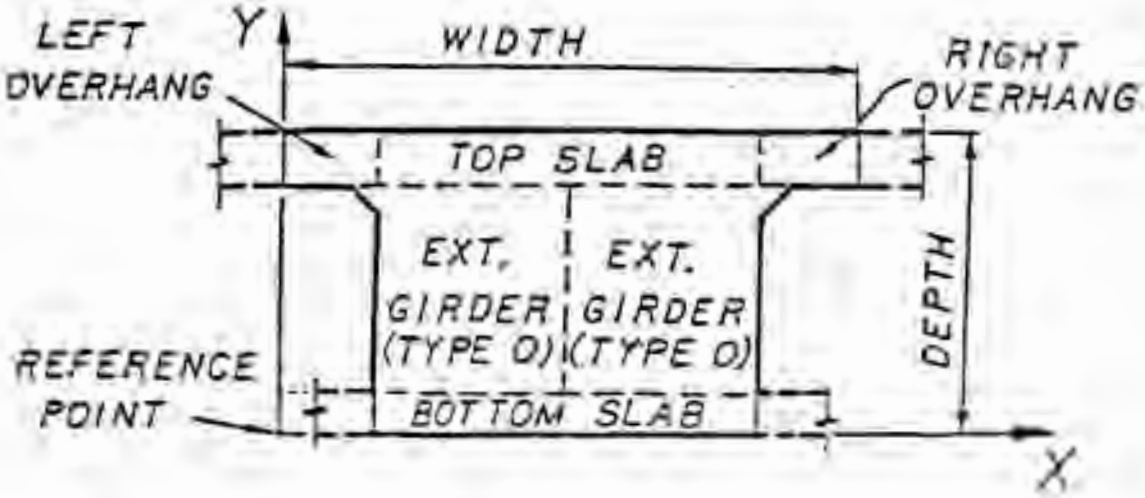
SUPERSTRUCTURE SECTIONS (Form B)

This input data describes the cross-section geometry of bent cap members. By itself this form will produce section properties. The section described by this form may be modified by submitting Section Properties by Parts with consistent member number and cross-section locations. However, to generate load factor design, the SUPERSTRUCTURE SECTIONS input must be included in the description of the bent cap sections. All dimensions are normal to the centerline of the bent.

The MEMBER NO. and CROSS SECTION LOCATION identify and locate the section from the left end of the member. Both must be repeate on each line used to describe the section.

RECALL may be used to recall section data previously entered at another location.

REF. PT. COORD. (X,Y) provides the reference point coordinates for each section described. The default location is at the lower left corner of the section as shown in the example below.



WIDTH and DEPTH of the section must be given. The depth must be measured from the reference point.

TOP and BOTTOM SLAB THICKNESS must be given. Since these values are to be combined with girders to form a solid cap section, any thickness may be used.

INTERIOR and EXTERIOR GIRDERS may be combined in any manner that forms a solid cap section. Exterior girders must be Type D.

OVERHANGS can be used to define the effective portion of the deck slab contributing to the bent cap strength.

STORE numbers must be entered for members to be recalled.

SECTION PROPERTIES BY PARTS (Form C)

This input data describes a section of a prismatic member or multiple sections of a non-prismatic member. By itself this form will produce section properties. This data is normally used to supplement the FRAME DESCRIPTION data and/or the SUPERSTRUCTURE SECTIONS data. Use this form to describe the column sections.

FORM NUMBER: 207312

		MEMBER NO	CROSS SEC LOC X	RECALL	SIGN	PART CODE	PART DIMENSION		REF PT. COORD.		ANY SHAPE			STORE SEC
							VERTICAL + OR DEPTH D	HOR W	Z	Y	AREA	I_{zz}	S	

MEMBER NO, and CROSS SECTION LOCATION identify and locate the section from the left end of the member in feet. Each cross section description within a given member must have a separate location (discontinuities in cross sections must be separated by at least 0.1 feet.)

RECALL may be used to recall previously stored section properties.

SIGN is used to subtract a given part from a cross section or to build a section with negative properties.

Sections are built by adding or subtracting the parts shown. Be certain reference points match among parts.

PART CODE identifies the shape of the figure being defined. If no part code is given, the part code is assumed to be 26. Part code 27 is used to define the depth of the cross section. The depth is always required to calculate member stresses.

PART DIMENSION defines the vertical and horizontal dimensions for each section part. Vertical and horizontal dimensions are required input if part codes 1 thru 25 are used. For vertical members or columns, the vertical dimension will be the width of these members.

REFERENCE POINT COORDINATE system is identical to that used in the SUPERSTRUCTURE SECTIONS data. When describing column sections, the Y axis is parallel to the centerline of the bent cap.

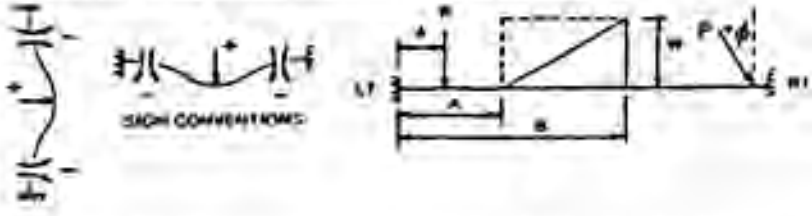
ANY SHAPE may be used to define any shape with known properties when using part code 26. Area, Ixx, depth, and the Y coordinate of the center of gravity must be given.

ADDITIONAL DEAD LOAD (Form D)

This input data describes the unfactored additional dead loads which the bent cap will carry. If you wish to combine this load with other dead load, the trial no. must be set to zero.

FORM NUMBER: 507316

CODE		TRIAL NO	MEMBER NO	LOADS				FEMS		DEFLECTIONS	SIDESWAY	ANGLE Φ (DEGREES)
				W or P	CODE	A	B	LEFT	RIGHT			



TRIAL NO. designates separate loading conditions for a single problem. For BENT ANALYSIS, Trial No. 00 is taken to be added dead load which supplements the dead load given in the bent description. The added loads could be barrier railing, wearing surface, signs and / or utility loads.

MEMBER NO. defines the member to which the added dead load is applied.

W or P are the unfactored uniform loads W (kips/ft.) and concentrated loads P (kips)

CODE is used to indicate the loading type:

- L = max. W on left
- R = max. W on right
- U = uniform load
- P = concentrated load

A and B are used to define the loading locations. If the dimensions A and B entered are greater than the member length, the member length will be used.

FEMs are the unfactored fixed end moments in ft-kips given by the user.

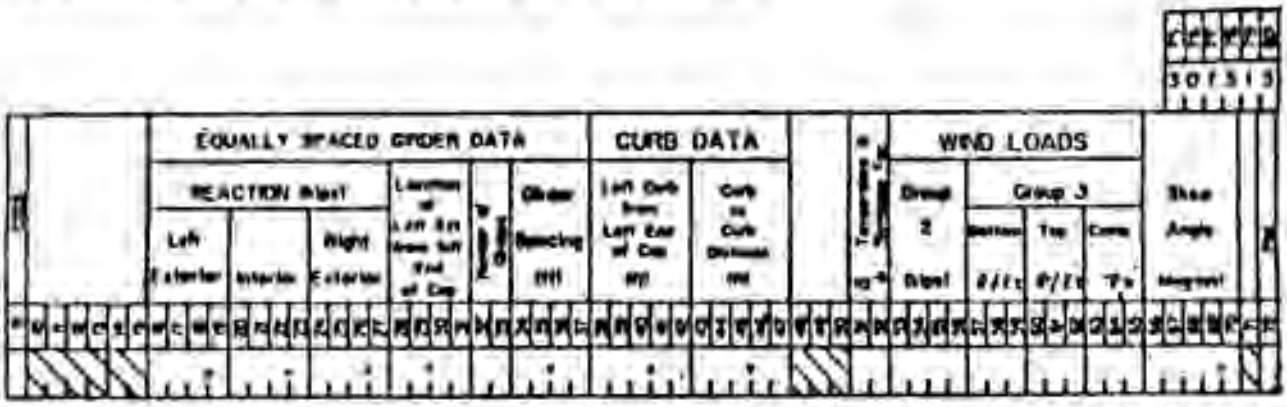
SIDESWAY may be considered by placing an 'S' in this column.

ANGLE ϕ DEGREES defines the load angle in degrees. Default equals zero.

COMMENTS of up to 12 characters per line may be made in columns 56 thru 67. Caution: if a single comment covers more than one line, the comment lines may print out of order.

UNIFORM GIRDER DATA (Form M)

This input data describes the equally spaced girder data (including girder dead load reaction), curb data, thermal expansion coefficient, wind loads, and skew angle.



EQUALLY SPACED GIRDER DATA defines the unfactored dead load reactions for left exterior, interior, and right exterior girders in kips (may be obtained from the BDS Analysis), the total number of girders on the bent (10 girders maximum), the distance of the left exterior girder centerline from the left end of the bent cap, and the girder spacing. All these dimensions are measured normal to the roadway.

CURB DATA defines the distance from the left end of the bent cap to the inside face of the left curb or sidewalk and the curb to curb or the sidewalk to sidewalk distance. Both dimensions are measured normal to the roadway.

TEMPERATURE AND SHRINKAGE FACTOR should be obtained from Article 3.16 of the AASHTO Bridge Design Specifications, or as otherwise specified for your job. The default value for this program is 0.00021.

WIND LOADS (unfactored) will apply along the centerline of the bent cap. The Group 2 wind load will be in kips applied horizontally at both ends of the column and the Group 3 wind load will be in pounds per foot applied horizontally along the column.

SKEW ANGLE of the bent cap is given to 0.01 degree clockwise positive. The skew angle is used for the coordinate transformation of the girder locations, live load lane and wheel line locations, and the column live load moments from bridge frame coordinates to bent frame coordinates.

NON-UNIFORM GIRDER SPACING DATA (Form O)

This input data describes number of girders, reactions of girder or girders, and locations of girders for a structure having different girder spacings and reactions. The Equally Spaced Girder Data on the UNIFORM GIRDER DATA (Form N) must be left blank, but the Curb Data on Form N is required. The maximum number of girders allowed is 10 per cap member.

SEQUENCE NUMBER	NUMBER OF GIRDERS	GIRDER REACTION (KIPS)	GIRDER LOCATION OR SPACING (FT)
16 17	18 19	20 21 22 23 24	25 26 27 28
0 1	0 1	. . . . .	. . . .
0 2	.	. . . . .	. . . .

75	76	77	78	79	80
4	0	7	3	1	4

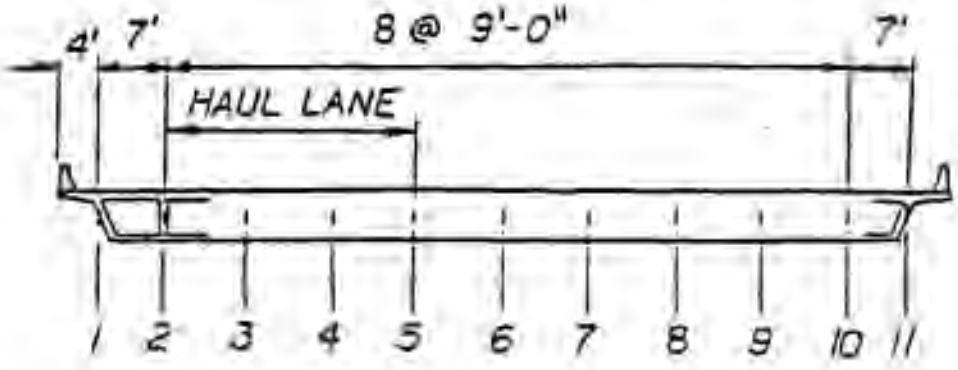
SEQUENCE NUMBERS are pre-printed. Use as many as you need consecutively from 1. Enter the girder numbers from left to right across the bent cap. The first entry, Sequence No. 1, specifies the location of the leftmost girder from the left end of the bent cap.

NUMBER OF GIRDERS is pre-printed for the leftmost girder. The remaining girders may be specified individually or in groups for girders with equal reactions and spacing. The number of girders to be specified, either individually or in groups is entered for the NUMBER OF GIRDERS.

GIRDER REACTION defines the unfactored girder reaction from dead load in kips. A change in girder reaction requires a new entry. The dead load effects of utilities may also be included in the bent analysis, simply by treating them as part of girders or individual girders.

GIRDER LOCATION OR SPACING defines the girder locations. The first entry specifies the location of the leftmost girder from the left end of the bent cap. For individual girder entries give the distance from the last entered girder. Enter the girder spacing for girders having equal spaci and reactions; the program will place the girders at equal spaces begining with the previously entered girder. The girder locations and spacing are measured normal to the roadway. See example on the following page.

NON-UNIFORM GIRDER DATA EXAMPLE



F	F	F	F	F	8
4	0	7	3	1	4

Sequence Number		Number of Girders		Girder Reaction (kips)					Girder Location or Spacing (ft)			
16	17	18	19	20	21	22	23	24	25	26	27	28
0	1	0	1	2	0	0	0		4	0	0	
0	2		1	2	1	0	0		7	0	0	
0	3		3	2	1	0	0		9	0	0	
0	4		5	2	0	0	0		9	0	0	
0	5		1	2	0	0	0		7	0	0	
0	6											
0	7											
0	8											

LIVE LOAD LANE REACTION (Form P)

This input data describes the maximum unfactored live load reaction at the bent due to one truck lane (including impact), for both standard HS truck and special P truck.

			LIVE LOAD REACTIONS PER TRUCK (LANE)											
			STANDARD HS TRUCK						SPECIAL P LOADS					
			MAXIMUM AXIAL FORCE			MAXIMUM LONGITUDINAL MOMENT			MAXIMUM AXIAL FORCE			MAXIMUM LONGITUDINAL MOMENT		
			AXIAL	MOMENT		AXIAL	MOMENT		AXIAL	MOMENT		AXIAL	MOMENT	
			(kips)	TOP	BOTTOM	(kips)	TOP	BOTTOM	(kips)	TOP	BOTTOM	(kips)	TOP	BOTTOM

The MAXIMUM AXIAL FORCE and associated MOMENT and the MAXIMUM LONGITUDINAL MOMENT and associated AXIAL force due to one lane of both STANDARD HS TRUCK and SPECIAL P TRUCK may be obtained from the BDS program or by other means of structural analysis.

The current Bent Analysis program assumes that the live loads act directly on the cap member. Reactions per wheel line are assumed to be half the "LANE REACTION". The wheel lines are placed 6 feet apart normal to the roadway within 12 foot lanes. The program determines the number of lanes and location of lane lines along the cap members for each live load condition and applies live load reductions when three or more lanes are used.

Prestress Data (Form G)

This input data describes the prestressing cable paths to be incorporated in the bent cap to resist the input loads. The prestressing may be part length and/or multiple tendon.

| UPDATE | | | | | CABLE PATH | | | | | | | | SPECIFICATIONS | | | | | | | |

PATH NO. is a number or letter used to identify the various cable paths in a multiple tendon prestressing frame. The effects of the multiple paths in the same trial and frame are all added together. When multiple paths are defined, only one path may have an unknown jacking force.

MEMBER NO. is the number for which prestress information is being input. The member number is the same as is shown on the Frame Description input.

LLT, LLP, and LRT are the vertical offsets from the top of deck to the C.G. of the cable path as shown on the sketch.

XLT and XRT are the horizontal distances from the end of span to the ends of the cable path.

U is the friction curvature coefficient. If left blank, the default value of 0.20 will be used.

K is the friction wobble coefficient per foot of stressing steel. If left blank, the default value of 0.0 will be used.

Separate values of U and K may be input for each span.

f_s is the ultimate strength of the prestressing steel in kips per square inch. If left blank, a default value of 270 ksi will be used. Only one value may be input for each cable path.

% JACK is the maximum allowable temporary jacking stress expressed as a percent of the ultimate strength of the prestressing steel. If left blank, a default value of 75% will be used. Only one value may be input for each cable path. If both end stressing is requested, the same value for % jack is used at each end.

END is the input to request jacking location. Enter "L" for left end jacking, enter "R" for right end jacking, and enter "B" for both end jacking. If left blank, a default value of "B" will be used. Only one choice may be entered for each cable path.

ANCHOR SET (LT. and RT.) is the length, in eighths of an inch, of the anchor set. If one end jacking is requested, no anchor set entry is needed for the non-jacked end. Only one value for anchor set left, and one value for anchor set right may be entered per cable path. If left blank, a built-in default value of ⅜" will be used. Caution: when using short cable paths, the ⅜" seating loss may be excessive.

ALLOWABLE TENSION is the given value of the maximum allowable tension stress for which the frame is to be designed. Two methods of input are provided. If a "Y" is placed in the SPEC input field, the allowable tension will be calculated using the AASHTO specification ($6\sqrt{f'c}$). If an entry is made in the % field, the allowable tension is the entered % times $6\sqrt{f'c}$. Only one choice is allowed and only one entry is allowed per cable path. If left blank, the program will design for no tension.

P-JACK is the input prestress force in kips. If a value for P-JACK is input for all paths in a given trial and frame, then the program only analyzes the structure and reports the effects. If multiple path prestressing is described, all the values of P-JACK except one must be given. The path with no P-JACK value will have its prestress force designed by the program based on full DL + added DL + LL + I.

LOW LAX steel may be used by placing a "Y" or "L" in the LOW LAX input field.

f'c is the required concrete strength. This value is used as the basis for calculating the allowable concrete tension. If left blank, the built-in default concrete strength of 4.00 ksi will be used.

% SHORTENING is the percent of theoretical elastic shortening to be included in the prestressing calculations based on the final prestress force coefficients. Only those frames with columns affected by shortening will be considered. If left blank, a default value of 100% will be used. To eliminate shortening, enter a zero. To obtain any other even 10% increment, enter its multiple of 10%.

LOSSES (ksi) are the losses due to creep and shrinkage. If lef blank, a built-in default value of 32 ksi for normal prestress steel and 20 ksi for Low Lax steel will be used.