CCEER 86-2

USER'S MANUAL FOR ISADAB AND SIBA, COMPUTER PROGRAMS FOR NONLINEAR TRANSVERSE ANALYSIS OF HIGHWAY BRIDGES SUBJECTED TO STATIC AND DYNAMIC LATERAL LOADS

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ABSTRACT

This document presents the user's manual for two computer programs for the nonlinear analysis of highway bridges subjected to horizontal forces. The programs are called ISADAB and SIBA. The former was developed in FORTRAN IV on a CYBER 730 mainframe and performs a variety of tasks ranging from static to earthquake analysis of bridges. The latter consists of a package of three programs which were developed in BASIC on a Commodore 64. The SIBA package is for only static nonlinear analysis of bridges and for the related graphical displays.

ACKNOWLEDGEMENTS

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The authors are thankful to Dr. Bruce Douglas, the director of the Center for Civil Engineering Earthquake Research for his comments and advice. Miss T. "Jeanie" Pratt and Mrs. Chris Archer are thanked for the typing and preparation of this report.

The CYBER 730 computer system operated by the computer center at the University of Nevada System was used in the course of developing ISADAB.

DISCLAIMER

Every effort was made to check the programs described in this report. The authors, however, do not assume any responsibility for the computer results and their applications.

TABLE OF CONTENTS

PART ONE

USER'S MANUAL FOR ISADAB

1.1 INTRODUCTION

Program ISADAB was developed for transverse inelastic analysis of highway bridges. The following tasks can be carried out by the program:

(a) Static analysis,

(b) Free-vibration analysis for initial displacements caused by static loads,

(c) Frequency analysis based on instantaneous stiffness during static loading, and

(d) Earthquake response analysis.

The technical background for the above analyses is provided in Ref. 1. The purpose of this report is to instruct users about input preparations. The authors assume no responsibility for the computer results although the program has been checked for many example cases and reasonable results have been obtained.

Features (b) and (d) include the storage of nodal displacement and acceleration histories on temporary files which are then used for plotting. The plotting program which is used to obtain graphs utilizes subroutines from the NCAR (National Center for Atmospheric Research) library. Because graphics programs are highly machine-dependent, the plotting program has not been discussed in this manual.

1.2 GENERAL SCOPE

Limits on different variables are specified in section 1.3 where the variables appear. The following general limitations apply to the program:

(a) The bridge is analyzed only in the transverse direction;

(b) No intermediate hinges are allowed;

(c) Only single-column piers are permitted;

(d) The bridge has to be straight or nearly straight; and

(e) In the case of earthquake response analysis, the input ground acceleration is assumed to be the same at all the pier and abutment foundations.

1.3 THE DATA PREPARATION PROCEDURE

1. Project Title (8A10)

COLUMN NO: 1-80
NOTATION: PRJ
LIMIT: 80 Characters
COMMENTS: The title of the bridge and/or project is provided on this card. The title may consist of any combination of numerical values and upper-case alphabetic symbols. The data on this card will appear in the front page of the output.

2. Units (8A10)

COLUMN NO: 1-80
NOTATION: Unit
LIMIT: 80 Characters
COMMENTS: This card allows the user to specify the units being used. All the input data should have consistent units. The output will have the same units as the input. The units involved are for force, length, and time.

3. General Information (3F10.4)

COLUMN NO: 1-10
NOTATION: E: Modulus of elasticity of concrete
LIMIT: -
COMMENTS: -

COLUMN NO: 11-20
NOTATION: G: Shear modulus of concrete
LIMIT: -
COMMENTS: -

COLUMN NO: 21-30
NOTATION: GA: Gravity acceleration
LIMIT: -
COMMENTS: -

4. Structural Information (12I5)

COLUMN NO: 1-5
NOTATION: NSPN: Number of spans in the bridge
LIMIT: 10
COMMENTS: -

COLUMN NO: 6-10
NOTATION: NDCK: Number of deck flexural types
LIMIT: 5
COMMENTS: Each deck section presents one flexural type. A bridge with the same section in all spans has only one deck flexural type even though the span lengths may vary from one span to another.

COLUMN NO: 11-15
NOTATION: NPR: Number of pier flexural types
LIMIT: 5
COMMENTS: -

COLUMN NO: 16-20
NOTATION: NSPP: Number of pile springs
LIMIT: 10
COMMENTS: Each pile foundation has one translational and one rotational spring. In some bridges, the stiffness for different pile foundations may be the same. In such cases, only two foundation springs need to be specified (one translational and one rotational).

COLUMN NO: 21-25
NOTATION: NGD: Number of deck geometry types
LIMIT: 5
COMMENTS: The span length may change in different spans of the bridge. NGD specifies the total number of deck length types in the bridge.

COLUMN NO: 26-30
NOTATION: NLD: Number of load increment sets
LIMIT: -
COMMENTS: Used in static, free-vibration, or eigen value analyses. Each load increment set presents all the load increments that are applied on the bridge simultaneously.

COLUMN NO: 31-35
NOTATION: NLT: Number of load increment groups
LIMIT: 0 through 3
COMMENTS: 0 - each load increment set is different
1 - all load increment sets are equal
2 - the loads within each NLD/2 increment set are equal
3 - the loads within each NLD/3 increment set are equal

COLUMN NO: 36-40
NOTATION: NSKP: Number of loads to be skipped in the output
LIMIT: -
COMMENTS: Used in static, free-vibration or eigen value analyses. The out put for the first and last load increments will always be printed on the output file regardless of NSKP. Note that the analysis is carried out for all the load increments regardless of the value of NSKP.

COLUMN NO: 41-45
NOTATION: IPD: Index to specify if the P-delta effect should be included in the analysis
LIMIT: -
COMMENTS: 0 - ignore P-delta effect
1 - include P-delta effect

COLUMN NO: 46-50
NOTATION: NUT: Index to specify contents of output
LIMIT: -
COMMENTS: 0 - output contains input and output information
1 - output contains input information only

COLUMN NO: 51-55
NOTATION: IEL: Index to specify if all of the abutment springs are to remain elastic
LIMIT: 0-1
COMMENTS: 0 - abutment springs are inelastic
1 - abutment springs remain elastic
Note that the spring rotating about the bridge longitudinal axis is always treated as an elastic spring regardless of IEL.

COLUMN NO: 56-60
NOTATION: MODEX: Index to specify programs made of execution
LIMIT: -
COMMENTS: 1 - static analysis
2 - static and free-vibration analysis
3 - simultaneous static and eigen value analysis
4 - earthquake response analysis

5. <u>Free Vibration Data</u>

If the program is to execute a static and free-vibration analysis (MODEX = 2) then two data cards need to be inserted at this point. If

MODEX $\neq$ 2 skip this section of input. Plotting information is written on temporary files TAPES 3 and 4.

6. Free-Vibration Information (2I5,4F10.0)

COLUMN NO: 1-5
NOTATION: NPS: Number of response points per second for plotting
LIMIT: -
COMMENTS: Good plot resolution requires 40 to 60 points per second.

COLUMN NO: 6-10
NOTATION: NPD: Number of horizontal degrees of freedom for which displacement and acceleration plots are desired
LIMIT: 2 x NSPN
COMMENTS: -

COLUMN NO: 11-20
NOTATION: DRTN: Duration of free-vibration analysis
LIMIT: -
COMMENTS: -

COLUMN NO: 21-30
NOTATION: DT: Time step for numerical integration
LIMIT: -
COMMENTS: In order to satisfy convergence and stability requirements, DT should be about 1/20 to 1/10 of the shortest period of vibration of the system.

COLUMN NO: 31-40
NOTATION: DM: Mass damping coefficient
LIMIT: -
COMMENTS: $DM = 2\,\omega_1\omega_2\,(\xi_2\,\omega_1 - \xi_1\,\omega_2)/(\omega_1^2 - \omega_2^2)$
where ξ_1 and ξ_2 = the damping ratio for the first 2 modes
ω_1 and ω_2 = the circular frequencies for the first 2 modes of vibration

COLUMN NO: 41-50
NOTATION: DS: Stiffness damping coefficient
LIMIT: -
COMMENTS: $DS = 2(\xi_1\omega_1 - \xi_2\omega_2)/(\omega_1^2 - \omega_2^2)$

7. DOFs To Be Plotted (10I5)

COLUMN NO: 1-5, 6-10, 11-15,....46-50
NOTATION: IDD(i): Horizontal DOFS for which plots are to be generated
LIMIT: -
COMMENTS: -

8. <u>Weight at Each DOF (8F10.4)</u>

COLUMN NO: 1-10, 11-20,....71-80
NOTATION: WT(i): Weight of the ith DOF
LIMIT: -
COMMENTS: WT(1) is typed in the first 10 columns, WT(2) is typed in the second 10 columns and so on.

9. <u>Deck Section Properties (3F10.4)</u>

COLUMN NO: 1-10
NOTATION: AI(i): Moment of inertia about the centroidal vertical axis for the ith deck flexural type
LIMIT: -
COMMENTS: -

COLUMN NO: 11-20
NOTATION: AJ(i): Torsional inertia for the ith deck flexural type
LIMIT: -
COMMENTS: -

COLUMN NO: 21-30
NOTATION: AS(i): Horizontal shear area of the ith deck flexural type
LIMIT: -
COMMENTS: -

10. <u>Pier Flexural Properties</u>

Two lines are needed for each pier flexural type, line (a) followed by card (b)

(a) <u>Pier Section and Length Properties (7F10.4)</u>

COLUMN NO: 1-10
NOTATION: BI(i,1): Moment of inertia of pier type i near the base
LIMIT: -
COMMENTS: -

COLUMN NO: 11-20
NOTATION: BI(1,2): Moment of inertia of pier type i elsewhere
LIMIT: -
COMMENTS: -

COLUMN NO: 21-30
NOTATION: BJ(i): Torsional inertia of pier type i
LIMIT: -
COMMENTS: -

COLUMN NO: 31-40
NOTATION: BS(i): Shear area of pier type i
LIMIT: -
COMMENTS: -

COLUMN NO: 51-60
NOTATION: TT(i): Total length of pier type i
LIMIT: -
COMMENTS: -

COLUMN NO:61-70
NOTATION: EB(i): Length of weak section at base of pier type i
LIMIT: -
COMMENTS: This parameter presents the length of plastic hinge near the column base. In pinned columns, the plastic hinge is concentrated over the height of the pin (usually a very short distance). In columns with no pinned detail at the base, EB should be set equal to one-half of the effective depth of the column section.

(b) Flexural Properties (8F10.4)

COLUMN NO: 1-10
NOTATION: CRM(i): Cracking moment at the base of pier type i
LIMIT: -
COMMENTS: -

COLUMN NO: 11-20
NOTATION: YIM(i): Yielding moment at the base of pier type i
LIMIT: -
COMMENTS: -

COLUMN NO: 21-30
NOTATION: ULM(i): Moment at a point beyond the yield point of the primary curve of pier type i
LIMIT: -
COMMENTS: This value is used only to calculate the slope of the post-yielding segment of the moment-curvature diagram; it does not impose any limit on the resistance of the member.

COLUMN NO: 31-40
NOTATION: YIC(i): Yield curvature at the base of pier type i
LIMIT: -
COMMENTS: -

COLUMN NO: 41-50
NOTATION: ULC (i): curvature at a point beyond the yield point of the primary curve for the base of pier type i
LIMIT: -
COMMENTS: The curvature must be the value of curvature corresponding to ULM (i)

COLUMN NO: 51-60
NOTATION: SC(i): unit length rotation due to bond slip corresponding to the cracking moment
LIMIT: -
COMMENTS: Procedure to calculate rotations due to bond slip is described in Ref. 2.

COLUMN NO: 61-70
NOTATION: SY(i): unit length rotation due to bond slip corresponding to the yield moment
LIMIT: -
COMMENTS: -

COLUMN NO: 71-80
NOTATION: SLI(i): unit length rotation due to bond slip corresponding to ULM (i)
LIMIT: -
COMMENTS: -

11. Pile Spring Properties (6F10.4)

Each pile foundation is idealized by one translational and one rotational spring. These springs are uncoupled. This section of input provides the primary curves associated with each foundation spring (1 line per spring). A trilinear primary curve is used. The curve has to be concave down. See Fig. 2.1.

COLUMN NO: 1-10
NOTATION: CRM(i): force/moment at break-point 1 for pile spring i
LIMIT: -
COMMENTS: -

COLUMN NO: 11-20
NOTATION: YIM(i): force/moment at break-point 2 for pile spring i
LIMIT: -
COMMENTS: -

COLUMN NO: 21-30
NOTATION: ULM(i): force/moment at break-point 3 for pile spring i
LIMIT: -
COMMENTS: This point is used only to calculate slope of the last branch. It imposes no limit on the resistance of the spring.

COLUMN NO: 31-40
NOTATION: DC(i): displacement/rotation at break-point 1 for pile spring i
LIMIT: -
COMMENTS: -

COLUMN NO: 41-50
NOTATION: DY(i): displacement/rotation of break-point 2 for pile spring i
LIMIT: -
COMMENTS: -

COLUMN NO: 51-60
NOTATION: ULC(i): displacement/rotation corresponding to ULM(i)
LIMIT: -
COMMENTS: -

12. Abutment Spring Stiffnesses (3F10.4)

Three cards are needed to define the initial stiffness of the three abutment springs.

COLUMN NO: 1-10
NOTATION: P1(i): force/moment corresponding to initial tangent stiffness of spring i
LIMIT: -
COMMENTS: -

COLUMN NO: 11-20
NOTATION: R1(i): displacement/rotation corresponding to initial tangent stiffness of spring i
LIMIT: -
COMMENTS: P1(i) and R1(i) correspond to the force and deformation coordinates of point A in Fig. 2.12 in Ref. 1.

i = 1 corresponds to the translational abutment spring.

i = 2 corresponds to the rotational abutment spring restraining deformations about the longitudinal axis of the bridge. (This spring remains elastic).

i = 3 corresponds to the rotational abutment spring restraining deformations about a vertical axis at the abutment.

13. Ramberg Osgood Parameter (3F10.0)

COLUMN NO: 1-10, 11-20, 21-30
NOTATION: GAM (i): The gamma factor for abutment spring i
LIMIT: -
COMMENTS: This parameter is used to control the shape of the Ramberg-Osgood force-deformation curve. Its effect is discussed in Ref. 1.

14. Typical Deck Element Lengths (8F10.4)

COLUMN NO: 1-10, 11-20......71-80
NOTATION: TYPT(i): length of deck geometry type i
LIMIT: -
COMMENTS: The length of each of the NGD geometry types must be input on this line.

15. Member Flexural Characteristics (16I5)

COLUMN NO: 1-5, 6-10, 11-15.......76-80
NOTATION: IFC(i): flexural characteristics of deck or pier member i
LIMIT: -
COMMENTS: The flexural type of each deck and pier member must be identified. The member numbering starts with 1 for the deck element at the left end of the bridge and proceeds chronologically alternating between deck and pier elements and ending with the deck element at the opposite end of the bridge (Fig. 2.2).

16. Member Geometry Characteristics (16I5)

COLUMN NO: 1-5, 6-10, 11-15.....76-80
NOTATION: IGC(i): geometry type of deck member i
LIMIT: -
COMMENTS: The geometry type of the i^{th} deck member starting from one end of the bridge and spanning to the other end are given here.

17. Spring Characteristics (16I5)

COLUMN NO: 1-5, 6-10, 11-15.....76-80
NOTATION: ISP(i); spring characteristics of spring i
LIMIT: -
COMMENTS: Springs 1 and 4 restrain translation at each abutment.
Springs 2 and 5 restrain rotation about the deck axis at each abutment (these springs remain elastic).
Springs 3 and 6 restrain rotation about a vertical axis at each abutment.
The spring numbering proceeds with 7 and 8 which restrain translation and rotation, respectively, of the foundation of pier 1 followed by 9 and 10 which restrain translation and rotation, respectively, of the foundation of piers 2 and so on (Fig. 2.3). The spring types begin with 1 as the first pile spring property card and proceed chronologically to the last of the abutment spring stiffness cards.

18. Load Increments (8F10.0)

Skip this part if MODEX = 1, 2, or 3. The values of nodal load increments are provided in this section. The i^{th} value within each load increment set is assumed to act at node i. The node numbering scheme is shown in Fig. 2.2 (see PART TWO of this report). Enter zero for nodes without loads.

EARTHQUAKE ANALYSIS DATA: If the program is to execute an earthquake response analysis (MODEX=4), the earthquake analysis data must be added at this point of the data file. If MODEX≠4, skip this section of input.

19. <u>Earthquake Information (8A10)</u>

COLUMN NO: 1-80
NOTATION: ENAM: title of the earthquake
LIMIT: -
COMMENTS: This card can contain alpha-numeric characters and should describe the earthquake and its intensity.

20. <u>Earthquake Analysis Control Information (4I5)</u>

COLUMN NO: 1-5
NOTATION: NPTS: number of points in the digitized earthquake record
LIMIT: 1600
COMMENTS: -

COLUMN NO: 6-10
NOTATION: NPS: number of response points to be saved per second
LIMIT: -
COMMENTS: This parameter controls the number of response points to be saved per second as well as the number of times the response is checked for new maxima each second. Typical values of NPS range from 40-60 and are related to the fundamental period of the structure.

COLUMN NO: 11-15
NOTATION: NCYC: the frequency of changing stiffness
LIMIT: -
COMMENTS: Because small time steps are used in the analysis, the changes in the structural stiffness from one step to the next may be insignificant. Furthermore, reconstruction of the structural stiffness matrix at all time steps is costly and inefficient. Therefore, stiffness is changed once at every NCYC time step. Experience indicates that the stiffness matrix should be updated about 100 times each second.

COLUMN NO: 16-20
NOTATION: IPLOT: index to specify if plots are desired
LIMIT: -
COMMENTS: 0 - no plots desired
1 - plots are desired - plotting information is written on temporary files (TAPES 3, 4, and 7).

21. <u>Earthquake Analysis Information (7F10.4)</u>

COLUMN NO: 1-10
NOTATION: DTAL: time interval of base acceleration data
LIMIT: -
COMMENTS: -

COLUMN NO: 11-20
NOTATION: DT: Time step for numerical integration
LIMIT: -
COMMENTS: Same as DT in free-vibration analysis

COLUMN NO: 21-30
NOTATION: ACCM: Factor to normalize the base acceleration
LIMIT: -
COMMENTS: -

COLUMN NO: 31-40
NOTATION: TM: Factor to scale the time axis of the base acceleration
LIMIT: -
COMMENTS: If no change in the time axis is desired set TM : 1.0

COLUMN NO: 41-50
NOTATION: SUBT: Value to be subtracted from ordinates of base acceleration points
LIMIT: -
COMMENTS: SUBT is used in the program before input is scaled by ACCM. This parameter is used to eliminate any shift in the input earthquake relative to the time axis.

COLUMN NO: 51-60
NOTATION: DM: Mass damping coefficient
LIMIT: -
COMMENTS: Same as DM in free-vibration analysis

COLUMN NO: 61-70
NOTATION: DS: Stiffness damping coefficient
LIMIT: -
COMMENTS: Same as DS in free-vibration analysis

22. <u>Base Acceleration Format Card</u> (8A10)

COLUMN NO: 1-70
NOTATION: FRMT(*): Format used in the input acceleration
LIMIT: -
COMMENTS: The format needs to be enclosed in parentheses.

23. <u>Base Acceleration Data (FRMT)</u>

COLUMN NO: As specified in data entry 22.
NOTATION: ETQ(*)
LIMIT: -
COMMENTS: -

1.4 EXAMPLES

A five-span reinforced concrete bridge located at the Rose Creek interchange was used to illustrate the features of program ISADAB. The bridge was the subject of several experimental and analytical studies which are discussed in Ref. 1. The plan view and elevation of the bridge are shown in Fig. 1.1. Other information about the bridge may be obtained from Ref. 1.

As pointed out in Sec. 1.1, ISADAB is capable of performing four types of analyses. The following sections present the input and output data for these types.

1.4.a - Static Analysis The input data for the static analysis are the same as those used in frequency analysis except for MODEX in data entry 4. The input data for frequency analysis are presented in Sect. 1.4.c. the printed output for static analysis is the same as that for the free-vibration analysis (see Sec. 1.4.b). For brevity, the input and output for static analysis are not presented herein, and the user is referred to Sec. 1.4.b and 1.4.c.

1.4.b - Free-Vibration Analysis The input and output for the free-vibration analysis of the Rose Creek bridge are shown in the following pages. Note that the free-vibration is a result of an initial displacement which is produced by static loads. In this example, the static loads are applied in thirty increments. The initial nodal displacements and accelerations before the release of the bridge are printed after the information about the last static load increment. The dynamic displacement and acceleration histories are stored in temporary tapes and plotted by another program. A sample of the plotted responses is shown in Fig. 1.2.

```
 KUSECKEEK INTERCHANGE; FREE-VIBRATION ANALYSIS;   7/17/85
 KIPS INCH
 3122.        1300.       386.4
   5     1      2     4     3    30    03    29     1    00     0     2
  40     3          5.0      0.005       0.592      0.0042
   1     2      3
  300.         703.         50.         918.         50.         918.        50.        703.
   50.         300.
52700000. 6345000.     3690.
  884700.  2979000. 1766000.       3600.        283.7        31.           .50
  19580.0    49000.    50000.    .000051      .00008     .0001250  .0007800    .000812
 1106000.  2979000. 1766000.       3600.        283.7        31.           .5
   24910.    56000.    57000.    .000051      .00008     0.000154  .00078     .000808
    90.0      198.      278.0     0.053        0.29        1.0
  278.        585.      792.      0.053        .325        1.0
   23000.0   40000.0   45000.0    .0005      0.001480     .0042
   50000.0  102000.0  115000.0    .0005       .00197      0.0038
      38.5     1.250
    9931.0   .003430
    2277.0  0.009540
       2.0       2.0       2.0
     626.     1128.      1272.
   1     1     1     1     1     1     2     2     1
   1     2     3     2     1
   5     6     7     5     6     7     1     3     2     4     2     4     1     3
       6.0       14.0        1.0        18.5        1.0        18.5        1.0        14.0
       1.0        6.0
       4.0        9.4        0.7        12.3        0.7        12.3        0.7         9.4
       0.7        4.0
       2.0        4.7        0.3         6.2        0.3         6.2        0.3        4.70
       0.3        2.0
```

PROJECT TITLE : ROSECREEK INTERCHANGE; FREE-VIBRATION ANALYSIS; 7/17/85

UNITS : KIPS INCH

NO. OF SPANS	5
NO. OF NODES	10
NO. OF ELEMENTS	9
MODULUS OF ELASTICITY	.3122E+04
SHEAR MODULUS	.1300E+04
GRAVITY ACCELERATION	.3864E+03
NO. OF LOAD INCREMENTS	30
NO. OF EQUAL LOAD GROUPS	3
NO. OF LOADS SKIPPED IN OUTPUT	29
P-DELTA INDEX	1
0= IGNORE P-DELTA	
1= INCLUDE P-DELTA	
MODE OF EXECUTION	2
1=STATIC LOADING ONLY	
2=FREE VIBRATION	
3=FREQUENCY ANALYSIS	
4=EARTHQUAKE ANALYSIS	

FREE VIBRATION DATA

DURATION OF ANALYSIS	.5000E+01
TIME INCR. FOR NUM. INTEGRATION	.5000E-02
MASS DAMPING COEFFICIENT	.5920E+00
STIFFNESS DAMPING COEFFICIENT	.4200E-02
NO. OF RESPONSE POINTS PER SEC.	40
NO. OF DOFS WITH RESPONSE PLOT	3

DOFS WITH RESPONSE PLOT

1 2 3

WEIGHTS

NODE	WEIGHT	NODE	WEIGHT	NODE	WEIGHT	NODE	WEIGHT	NODE	WEIGHT
1	.3000E+03	2	.7030E+03	3	.5000E+02	4	.9180E+03	5	.5000E+02
6	.9180E+03	7	.5000E+02	8	.7030E+03	9	.5000E+02	10	.3000E+03

TYPICAL DECK ELEMENT DIMENSIONS

ELEMENT	LENGTH
1	.6260E+03
2	.1128E+04
3	.1272E+04

TYPICAL PIER ELEMENT DIMENSIONS

ELEMENT	TOTAL	TOP END	BOTTOM END
1	.2837E+03	.3100E+02	.5000E+00
2	.2837E+03	.3100E+02	.5000E+00

TYPICAL ELEMENT PROPERIES

DECK ELEMENTS

	MOM. OF INERTIA	TORSIONAL INERTIA	SHEAR AREA
1	.5270E+08	.6345E+07	.3690E+04

PIER ELEMENTS

	MOM. OF INERT. NEAR BASE	MOM. OF INERT. ELSEWHERE	TORSIONAL INERITA	SHEAR AREA
1	.8847E+06	.2979E+07	.1766E+07	.3600E+04
2	.1106E+07	.2979E+07	.1766E+07	.3600E+04

PIER BASE MOMENT-CURVATURE

TYPE	CRACK. MOM.	YIELD MOM.	ULT. MOM.	YIELD CURV.	ULT. CURV.
1	.1958E+05	.4900E+05	.5000E+05	.510E-04	.800E-04
2	.2491E+05	.5600E+05	.5700E+05	.510E-04	.800E-04

PIER BOND SLIP ROTATION

TYPE	CRACKING	YIELDING	ULTIMATE
1	.1250E-03	.7800E-03	.8120E-03
2	.1540E-03	.7800E-03	.8080E-03

SPRING PROPERITES

TYPE	FORCE AT BREAKPOINT 1	2	3	DEFORMATION AT BREAKPOINT 1	2	3
1	.9000E+02	.1980E+03	.2780E+03	.5300E-01	.2900E+00	.1000E+01
2	.2780E+03	.5850E+03	.7920E+03	.5300E-01	.3250E+00	.1000E+01
3	.2300E+05	.4000E+05	.4500E+05	.5000E-03	.1480E-02	.4200E-02
4	.5000E+05	.1020E+06	.1150E+06	.5000E-03	.1970E-02	.3800E-02
5	.3850E+02			.1250E+01		
6	.9931E+04			.3430E-02		
7	.2277E+04			.9540E-02		

ELEMENT NO.	FLEXURE TYPE	GEOMETRY TYPE
DECK		
1	1	1
2	1	2
3	1	3
4	1	2
5	1	1
PIER		
6	1	
7	2	
8	2	
9	1	

SPRING CHARACTERISTICS

NUMBER	TYPE	NUMBER	TYPE	NUMBER	TYPE	NUMBER	TYPE
1	5	2	6	3	7	4	5
5	6	6	7	7	1	8	3
9	2	10	4	11	2	12	4
13	1	14	3				

****
L O A D I N G 1
****

LOAD INCREMENTS

DOF	INCR.	DOF	INCR.	DOF	INCR.	DOF	INCR.	DOF	INCR.
1	.6000E+01	2	.1400E+02	3	.1000E+01	4	.1850E+02	5	.1000E+01
6	.1850E+02	7	.1000E+01	8	.1400E+02	9	.1000E+01	10	.6000E+01

TOTAL LOADS

DOF	LOAD	DOF	LOAD	DOF	LOAD	DOF	LOAD	DOF	LOAD
1	.6000E+01	2	.1400E+02	3	.1000E+01	4	.1850E+02	5	.1000E+01
6	.1850E+02	7	.1000E+01	8	.1400E+02	9	.1000E+01	10	.6000E+01

DISPLACEMENTS

DOF	DISP.	DOF	DISP.	DOF	DISP.	DOF	DISP.	DOF	DISP.
1	.683218E-01	2	.516693E-01	3	.111904E-01	4	.345302E-01	5	.3697
6	.345302E-01	7	.369724E-02	8	.516693E-01	9	.111904E-01	10	.6832

NODAL ROTATIONS

NODE NUMBER	ROT. ABOUT HORIZ. AXIS	ROT. ABOUT VERT. AXIS
1	-.1295E-03	-.2732E-04
2	-.1579E-03	-.2271E-04
3	-.9968E-04	
4	-.1339E-03	-.7862E-05
5	-.5422E-04	
6	-.1339E-03	.7862E-05
7	-.5422E-04	
8	-.1579E-03	.2271E-04
9	-.9968E-04	
10	-.1295E-03	.2732E-04

DECK FORCES

ELEMENT NUMBER	LEFT END HORIZ. SHEAR	LEFT END MOMENT	RIGHT END MOMENT	LEFT END TORQUE
1	.3896E+01	.6522E+01	.2432E+04	.3748E+03
2	-.1069E+00	-.2226E+04	.2105E+04	-.1758E+03
3	.5675E-12	-.2034E+04	.2034E+04	-.5062E-10
4	.1069E+00	-.2105E+04	.2226E+04	.1758E+03
5	-.3896E+01	-.2432E+04	-.6522E+01	-.3748E+03

PIER FORCES

PIER NO.	TOP SHEAR	TOP MOMENT	BOT. MOMENT	TOP TORQUE
1	.1810E+02	.5506E+03	.4585E+04	-.2063E+03
2	.1849E+02	-.1758E+03	.5422E+04	-.7143E+02
3	.1849E+02	-.1758E+03	.5422E+04	.7143E+02
4	.1810E+02	.5506E+03	.4585E+04	.2063E+03

PIER DUCTILITIES

PIER NO.	DUCTILITY
1	.5850E-01
2	.6470E-01
3	.6470E-01
4	.5850E-01

ABUTMENT SPRING FORCES

SPRING NO.	1	2	3	4	5	6
FORCE/MOM.	.2001E+01	-.3748E+03	-.6503E+01	.2001E+01	-.3748E+03	.6503E+01

FORCES AT PIER FOOTINGS

PIER NUMBER	HORIZONTAL FORCE	MOMENT
1	.1900E+02	-.4585E+04
2	.1939E+02	-.5422E+04
3	.1939E+02	-.5422E+04
4	.1900E+02	-.4585E+04

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   L O A D I N G   30
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LOAD INCREMENTS

DOF	INCR.	DOF	INCR.	DOF	INCR.	DOF	INCR.	DOF	INCR.
1	.2000E+01	2	.4700E+01	3	.3000E+00	4	.6200E+01	5	.3000E+00
6	.6200E+01	7	.3000E+00	8	.4700E+01	9	.3000E+00	10	.2000E+01

TOTAL LOADS

DOF	LOAD	DOF	LOAD	DOF	LOAD	DOF	LOAD	DOF	LOAD
1	.1200E+03	2	.2810E+03	3	.2000E+02	4	.3700E+03	5	.2000E+02
6	.3700E+03	7	.2000E+02	8	.2810E+03	9	.2000E+02	10	.1200E+03

DISPLACEMENTS

DOF	DISP.	DOF	DISP.	DOF	DISP.	DOF	DISP.	DOF	DISP.
1	.435742E+01	2	.370568E+01	3	.970324E+00	4	.281946E+01	5	.2128
6	.281946E+01	7	.212832E+00	8	.370568E+01	9	.970324E+00	10	.4357

NODAL ROTATIONS

NODE NUMBER	ROT. ABOUT HORIZ. AXIS	ROT. ABOUT VERT. AXIS
1	-.8006E-02	-.1053E-02
2	-.9765E-02	-.9780E-03
3	-.8596E-02	
4	-.1005E-01	-.4552E-03
5	-.4965E-02	
6	-.1005E-01	.4552E-03
7	-.4965E-02	
8	-.9765E-02	.9780E-03
9	-.8596E-02	
10	-.8006E-02	.1053E-02

DECK FORCES

ELEMENT NUMBER	LEFT END HORIZ. SHEAR	LEFT END MOMENT	RIGHT END MOMENT	LEFT END TORQUE
1	.6342E+02	.2292E+03	.3947E+05	.2318E+05
2	.8095E+02	-.3059E+05	.1219E+06	.2103E+04
3	.2073E-10	-.1178E+06	.1178E+06	-.2160E-08
4	-.8095E+02	-.1219E+06	.3059E+05	-.2103E+04
5	-.6342E+02	-.3947E+05	-.2292E+03	-.2318E+05

PIER FORCES

PIER NO.	TOP SHEAR	TOP MOMENT	BOT. MOMENT	TOP TORQUE
1	.2702E+03	.2108E+05	.5349E+05	-.8885E+04
2	.4594E+03	.2103E+04	.1265E+06	-.4136E+04
3	.4594E+03	.2103E+04	.1265E+06	.4136E+04
4	.2702E+03	.2108E+05	.5349E+05	.8885E+04

PIER DUCTILITIES

PIER NO.	DUCTILITY
1	.1196E+01
2	.3718E+01
3	.3718E+01
4	.1196E+01

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ABUTMENT SPRING FORCES

SPRING NO.	1	2	3	4	5	6
FORCE/MOM.	.5517E+02	-.2318E+05	-.2283E+03	.5517E+02	-.2318E+05	.2283E+03

FORCES AT PIER FOOTINGS

PIER NUMBER	HORIZONTAL FORCE	MOMENT
1	.2747E+03	-.5308E+05
2	.4584E+03	-.1233E+06
3	.4584E+03	-.1233E+06
4	.2747E+03	-.5308E+05

INITIAL ACCELERATIONS

DOF	ACC.	DOF	ACC.	DOF	ACC.	DOF	ACC.	DOF	ACC.
1	-.3289E+00	2	-.2118E+00	3	.4401E+00	4	-.9193E-01	5	-.1497E+01
6	-.9193E-01	7	-.1497E+01	8	-.2118E+00	9	.4401E+00	10	-.3289E+00

ALL DATA PROCESSED

14.35.45.UCLP, AA, B04L1 , 0.704KLNS.

1.4.c - Frequency Analysis The vibration frequencies and mode shapes of the Rose Creek bridge were calculated using ISADAB. The calculations are made based on the instantaneous stiffness of the system and follow the application of static loads. To determine the initial frequencies and mode shapes of the bridge, the analysis needs to be performed for one load increment which is sufficiently small to avoid any nonlinearity in the system. (Note that some of the abutment springs are nonlinear even for very small amplitudes. Parameter IEL on data line four may be used to force these springs to remain elastic.)

The Rose Creek bridge was subjected to thirty load increments, and the frequencies and mode shapes were calculated for one in every four load increments. The input and output are shown in the next pages. For brevity, the output for only two load increments is shown. Note that the frequencies have decreased from load increment one to four indicating a reduction in the stiffness of the bridge.

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   ROSECREEK INTERCHANGE; FREQUENCY ANALYSIS;   7/17/85                          9
  KIPS INCH
   3122.        1300.       386.4
     5     1      2     4     3    30    03    02      1   00      0     3
    300.         703.         50.        918.          50.        918.        50.       703.
     50.         300.
 52700000. 6345000.     3690.
   584700.  2979000. 1766000.        3600.         283.7        31.          .50
   19580.0    49000.      50000.    .000051       .00008      .0001250 .0007800    .000812
  1106000.  2979000. 1766000.       3600.          283.7        31.          .5
    24910.    56000.      57000.    .000051      .00008     0.000154 .00078       .000808
     90.0      198.       278.0      0.053         0.29        1.0
  275.         585.       792.       0.053         .325        1.0
   23000.0   40000.0    45000.0     .0005        0.001480     .0042
   55000.0  102000.0   115000.0     .0005         .00197      0.0038
      38.5     1.250
    4931.0   .003430
    2277.0  0.009540
       2.0       2.0          2.0
     625.     1128.      1272.
   1     1      1     1      1     1     2     2     1
   1     2      3     2      1
   5     5      7     5      6     7     1     3     2     4     2     4     1     3
       5.0      14.0         1.0         18.5         1.0          18.5          1.0        14.0
       1.0       6.0
       4.0       9.4         0.7         12.3         0.7          12.3          0.7         9.4
       0.7       4.0
       2.0       4.7         0.3          6.2         0.3           6.2          0.3        4.70
       0.3       2.0
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PROJECT TITLE : ROSECREEK INTERCHANGE; FREQUENCY ANALYSIS; 7/17/85

UNITS : KIPS INCH

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NO. OF SPANS                              5
NO. OF NODES                             10
NO. OF ELEMENTS                           9
MODULUS OF ELASTICITY                 .3122E+04
SHEAR MODULUS                         .1300E+04
GRAVITY ACCELERATION                  .3864E+03
NO. OF LOAD INCREMENTS                   30
NO. OF EQUAL LOAD GROUPS                  3
NO. OF LOADS SKIPPED IN OUTPUT            2
P-DELTA INDEX                             1
   0= IGNORE P-DELTA
   1= INCLUDE P-DELTA
MODE OF EXECUTION                         3
   1=STATIC LOADING ONLY
   2=FREE VIBRATION
   3=FREQUENCY ANALYSIS
   4=EARTHQUAKE ANALYSIS
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WEIGHTS

NODE	WEIGHT	NODE	WEIGHT	NODE	WEIGHT	NODE	WEIGHT	NODE	WEIGHT
1	.3000E+03	2	.7030E+03	3	.5000E+02	4	.9180E+03	5	.5000E+02
6	.9180E+03	7	.5000E+02	8	.7030E+03	9	.5000E+02	10	.3000E+03

TYPICAL DECK ELEMENT DIMENSIONS

ELEMENT	LENGTH
1	.6260E+03
2	.1128E+04
3	.1272E+04

TYPICAL PIER ELEMENT DIMENSIONS

ELEMENT	TOTAL	TOP END	BOTTOM END
1	.2837E+03	.3100E+02	.500CE+00
2	.2837E+03	.3100E+02	.5000E+00

TYPICAL ELEMENT PROPERIES

DECK ELEMENTS

	MOM. OF INERTIA	TORSIONAL INERTIA	SHEAR AREA
1	.5270E+08	.6345E+07	.3690E+04

	MOM. OF INERT. NEAR BASE	MOM. OF INERT. ELSEWHERE	TORSIONAL INERITA	SHEAR AREA
1	.8847E+06	.2979E+07	.1766E+07	.3600E+04
2	.1106E+07	.2979E+07	.1766E+07	.3600E+04

PIER BASE MOMENT-CURVATURE

TYPE	CRACK. MOM.	YIELD MOM.	ULT. MOM.	YIELD CURV.	ULT. CURV.
1	.1958E+05	.4900E+05	.5000E+05	.510E-04	.800E-04
2	.2491E+05	.5600E+05	.5700E+05	.510E-04	.800E-04

PIER BOND SLIP ROTATION

TYPE	CRACKING	YIELDING	ULTIMATE
1	.1250E-03	.7800E-03	.8120E-03
2	.1540E-03	.7800E-03	.8080E-03

SPRING PROPERITES

TYPE	FORCE AT BREAKPOINT 1	2	3	DEFORMATION AT BREAKPOINT 1	2	3
1	.9000E+02	.1980E+03	.2780E+03	.5300E-01	.2900E+00	.1000E+01
2	.2780E+03	.5850E+03	.7920E+03	.5300E-01	.3250E+00	.1000E+01
3	.2300E+05	.4000E+05	.4500E+05	.5000E-03	.1480E-02	.4200E-02
4	.5000E+05	.1020E+06	.1150E+06	.5000E-03	.1970E-02	.3800E-02
5	.3850E+02			.1250E+01		
6	.9931E+04			.3430E-02		
7	.2277E+04			.9540E-02		

ELEMENT CHARACTERISTICS

ELEMENT NO.	FLEXURE TYPE	GEOMETRY TYPE
DECK		
1	1	1
2	1	2
3	1	3
4	1	2
5	1	1
PIER		
6	1	
7	2	
8	2	
9	1	

SPRING CHARACTERISTICS

NUMBER	TYPE	NUMBER	TYPE	NUMBER	TYPE	NUMBER	TYPE
1	5	2	6	3	7	4	5
5	6	6	7	7	1	8	3
9	2	10	4	11	2	12	4
13	1	14	3				

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L O A D I N G 1

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LOAD INCREMENTS

DOF	INCR.	DOF	INCR.	DOF	INCR.	DOF	INCR.	DOF	INCR.
1	.6000E+01	2	.1400E+02	3	.1000E+01	4	.1850E+02	5	.1000E+01
6	.1850E+02	7	.1000E+01	8	.1400E+02	9	.1000E+01	10	.6000E+01

TOTAL LOADS

DOF	LOAD	DOF	LOAD	DOF	LOAD	DOF	LOAD	DOF	LOAD
1	.6000E+01	2	.1400E+02	3	.1000E+01	4	.1850E+02	5	.1000E+01
6	.1850E+02	7	.1000E+01	8	.1400E+02	9	.1000E+01	10	.6000E+01

DISPLACEMENTS

DOF	DISP.	DOF	DISP.	DOF	DISP.	DOF	DISP.	DOF	DISP.
1	.683218E-01	2	.516693E-01	3	.111904E-01	4	.345302E-01	5	.369
6	.345302E-01	7	.369724E-02	8	.516693E-01	9	.111904E-01	10	.683

FREQUENCIES (HZ.)

MODE	FREQ.	MODE	FREQ.	MODE	FREQ.	MODE	FREQ.	MODE	FREQ.
1	.1856E+01	2	.1906E+01	3	.2695E+01	4	.4144E+01	5	.7370E+01
6	.8179E+01	7	.2091E+02	8	.2092E+02	9	.3426E+02	10	.3482E+02

NORMALIZED MODE SHAPE VECTORS

MODE ****** 1	MODE ****** 2	MODE ****** 3	MODE ****** 4	MODE ****** 5
.6369E+01	.5725E+01	-.6682E+00	-.1023E+01	.3628E+01
.3922E+01	.3474E+01	.9413E-01	.3749E+00	-.2914E+01
.8989E+00	.7859E+00	-.2170E-01	.5249E-01	-.8380E+00
.1000E+01	.1000E+01	.1000E+01	.1000E+01	.1000E+01
.1026E+00	.7438E-01	.1226E+00	.1487E+00	.1703E+00
-.1000E+01	.1000E+01	.1000E+01	-.1000E+01	.1000E+01
-.1026E+00	.7438E-01	.1226E+00	-.1487E+00	.1703E+00
-.3922E+01	.3474E+01	.9413E-01	-.3749E+00	-.2914E+01
-.8989E+00	.7859E+00	-.2170E-01	-.5249E-01	-.8380E+00
-.6369E+01	.5725E+01	-.6682E+00	.1023E+01	.3628E+01

6	7	8	9	10
.1700E+01	.6141E+00	.6253E+00	.1892E-01	.2203E-01
-.1504E+01	-.6896E+01	-.6538E+01	-.2372E+00	-.1795E+00
-.4665E+00	.3773E+03	.3530E+03	.4356E+01	.3044E+01
.1000E+01	.1000E+01	.1000E+01	.1000E+01	.1000E+01
.1787E+00	.1155E+02	.9460E+01	-.1458E+03	-.1173E+03
-.1000E+01	.1000E+01	-.1000E+01	-.1000E+01	-.1000E+01
-.1787E+00	.1155E+02	-.9460E+01	-.1458E+03	.1173E+03
.1504E+01	-.6896E+01	.6538E+01	-.2372E+00	.1795E+00
.4665E+00	.3773E+03	-.3530E+03	.4356E+01	-.3044E+01
-.1700E+01	.6141E+00	-.6253E+00	.1892E-01	-.2203E-01

NODAL ROTATIONS

NODE NUMBER	ROT. ABOUT HORIZ. AXIS	ROT. ABOUT VERT. AXIS
1	-.1295E-03	-.2732E-04
2	-.1579E-03	-.2271E-04
3	-.9968E-04	
4	-.1339E-03	-.7862E-05
5	-.5422E-04	
6	-.1339E-03	.7862E-05
7	-.5422E-04	
8	-.1579E-03	.2271E-04
9	-.9968E-04	
10	-.1295E-03	.2732E-04

DECK FORCES

ELEMENT NUMBER	LEFT END HORIZ. SHEAR	LEFT END MOMENT	RIGHT END MOMENT	LEFT END TORQUE
1	.3896E+01	.6522E+01	.2432E+04	.3748E+03
2	-.1069E+00	-.2226E+04	.2105E+04	-.1758E+03
3	.5675E-12	-.2034E+04	.2034E+04	-.5062E-10
4	.1069E+00	-.2105E+04	.2226E+04	.1758E+03
5	-.3896E+01	-.2432E+04	-.6522E+01	-.3748E+03

PIER FORCES

PIER NO.	TOP SHEAR	TOP MOMENT	BOT. MOMENT	TOP TORQUE
1	.1810E+02	.5506E+03	.4585E+04	-.2063E+03
2	.1849E+02	-.1758E+03	.5422E+04	-.7143E+02
3	.1849E+02	-.1758E+03	.5422E+04	.7143E+02
4	.1810E+02	.5506E+03	.4585E+04	.2063E+03

PIER DUCTILITIES

PIER NO.	DUCTILITY
1	.5850E-01
2	.6470E-01
3	.6470E-01
4	.5850E-01

ABUTMENT SPRING FORCES

SPRING NO.	1	2	3	4	5	6
FORCE/MOM.	.2001E+01	-.3748E+03	-.6503E+01	.2001E+01	-.3748E+03	.6503E+01

FORCES AT PIER FOOTINGS

PIER NUMBER	HORIZONTAL FORCE	MOMENT
1	.1900E+02	-.4585E+04
2	.1939E+02	-.5422E+04
3	.1939E+02	-.5422E+04
4	.1900E+02	-.4585E+04

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L O A D I N G 4
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LOAD INCREMENTS

DOF	INCR.	DOF	INCR.	DOF	INCR.	DOF	INCR.	DOF	INCR.
1	.6000E+01	2	.1400E+02	3	.1000E+01	4	.1850E+02	5	.1000E+01
6	.1850E+02	7	.1000E+01	8	.1400E+02	9	.1000E+01	10	.6000E+01

TOTAL LOADS

DOF	LOAD	DOF	LOAD	DOF	LOAD	DOF	LOAD	DOF	LOAD
1	.2400E+02	2	.5600E+02	3	.4000E+01	4	.7400E+02	5	.4000E+01
6	.7400E+02	7	.4000E+01	8	.5600E+02	9	.4000E+01	10	.2400E+02

DISPLACEMENTS

DOF	DISP.	DOF	DISP.	DOF	DISP.	DOF	DISP.	DOF	DISP.
1	.278949E+00	2	.209341E+00	3	.453922E-01	4	.138132E+00	5	.1475
6	.138132E+00	7	.147526E-01	8	.209341E+00	9	.453922E-01	10	.2789

FREQUENCIES (HZ.)

MODE	FREQ.	MODE	FREQ.	MODE	FREQ.	MODE	FREQ.	MODE	FREQ.
1	.1824E+01	2	.1875E+01	3	.2690E+01	4	.4137E+01	5	.7365E+01
6	.8176E+01	7	.2091E+02	8	.2092E+02	9	.3426E+02	10	.3482E+02

NORMALIZED MODE SHAPE VECTORS

MODE ****** 1	MODE ****** 2	MODE ****** 3	MODE ****** 4	MODE ****** 5
.6535E+01	.6170E+01	-.6464E+00	-.1015E+01	.3610E+01
.3991E+01	.3695E+01	.1073E+00	.3809E+00	-.2913E+01
.9150E+00	.8385E+00	-.1853E-01	.5398E-01	-.8377E+00
.1000E+01	.1000E+01	.1000E+01	.1000E+01	.1000E+01
.1018E+00	.7124E-01	.1224E+00	.1486E+00	.1703E+00
-.1000E+01	.1000E+01	.1000E+01	-.1000E+01	.1000E+01
-.1018E+00	.7124E-01	.1224E+00	-.1486E+00	.1703E+00
-.3991E+01	.3695E+01	.1073E+00	-.3809E+00	-.2913E+01
-.9150E+00	.8385E+00	-.1853E-01	-.5398E-01	-.8377E+00
-.6535E+01	.6170E+01	-.6464E+00	.1015E+01	.3610E+01
6	**7**	**8**	**9**	**10**
.1693E+01	.6138E+00	.6249E+00	.1891E-01	.2203E-01
-.1503E+01	-.6896E+01	-.6538E+01	-.2372E+00	-.1795E+00
-.4662E+00	.3773E+03	.3530E+03	.4356E+01	.3044E+01
.1000E+01	.1000E+01	.1000E+01	.1000E+01	.1000E+01
.1787E+00	.1155E+02	.9460E+01	-.1458E+03	-.1173E+03
-.1000E+01	.1000E+01	-.1000E+01	.1000E+01	-.1000E+01
-.1787E+00	.1155E+02	-.9460E+01	-.1458E+03	.1173E+03
.1503E+01	-.6896E+01	.6538E+01	-.2372E+00	.1795E+00
.4662E+00	.3773E+03	-.3530E+03	.4356E+01	-.3044E+01
-.1693E+01	.6138E+00	-.6249E+00	.1891E-01	-.2203E-01

NODAL ROTATIONS

NODE NUMBER	ROT. ABOUT HORIZ. AXIS	ROT. ABOUT VERT. AXIS
1	-.5240E-03	-.1142E-03
2	-.6392E-03	-.9474E-04
3	-.4038E-03	
4	-.5361E-03	-.3257E-04
5	-.2169E-03	
6	-.5361E-03	.3257E-04
7	-.2169E-03	
8	-.6392E-03	.9474E-04
9	-.4038E-03	
10	-.5240E-03	.1142E-03

DECK FORCES

ELEMENT NUMBER	LEFT END HORIZ. SHEAR	LEFT END MOMENT	RIGHT END MOMENT	LEFT END TORQUE
1	.1646E+02	.2703E+02	.1028E+05	.1517E+04
2	-.6182E+00	-.9418E+04	.8721E+04	-.7542E+03
3	.1355E-11	-.8425E+04	.8425E+04	-.2475E-09
4	.6182E+00	-.8721E+04	.9418E+04	.7542E+03
5	-.1646E+02	-.1028E+05	-.2703E+02	-.1517E+04

PIER FORCES

PIER NO.	TOP SHEAR	TOP MOMENT	BOT. MOMENT	TOP TORQUE
1	.7349E+02	.2271E+04	.1858E+05	-.8608E+03
2	.7378E+02	-.7542E+03	.2169E+05	-.2959E+03
3	.7378E+02	-.7542E+03	.2169E+05	.2959E+03
4	.7349E+02	.2271E+04	.1858E+05	.8608E+03

PIER DUCTILITIES

PIER NO.	DUCTILITY
1	.2370E+00
2	.2588E+00
3	.2588E+00
4	.2370E+00

ABUTMENT SPRING FORCES

SPRING NO.	1	2	3	4	5	6
FORCE/MOM.	.7233E+01	-.1517E+04	-.2695E+02	.7233E+01	-.1517E+04	.2695E+02

FORCES AT PIER FOOTINGS

PIER NUMBER	HORIZONTAL FORCE	MOMENT
1	.7708E+02	-.1858E+05
2	.7738E+02	-.2169E+05
3	.7738E+02	-.2169E+05
4	.7708E+02	-.1858E+05

1.4.d - Earthquake Analysis The Rose Creek bridge was analyzed for the first ten seconds of the north-south component of the 1940 El Centro record. Only part of the input earthquake record is shown in the input. The output from the computer analysis includes horizontal displacement and acceleration maxima, maximum nodal rotations, and maximum component forces. The displacement and acceleration histories are also stored on temporary tapes and plotted using a plotting program. Figure 1.3 shows a sample of plotted response histories.

```
ROSECREEK INTERCHANGE; EARTHQUAKE RESPONSE ANALYSIS;   7/18/85                     16
KIPS INCH
 3122.      1300.      386.4
   5    1     2    4     3    30     03    02      1   00     0    4
  300.       703.        50.        918.        50.         918.        50.       703.
   50.       300.
52700000. 6345000.   3690.
 664700.   2979000. 1766000.      3600.        283.7        31.         .50
 19580.0    49000.     50000.    .000051      .00008     .0001250  .0007800   .000812
1106000.  2979000. 1766000.      3600.        283.7        31.         .5
  24910.    56000.     57000.    .000051     .00008     0.000154  .00078     .000808
   90.0      198.      278.0      0.053        0.29        1.0
  278.       585.      792.       0.053        .325        1.0
  23000.0   40000.0    45000.0    .0005       0.001480     .0042
  50000.0  102000.0   115000.0    .0005       .00197      0.0038
     33.5     1.250
   9931.0   .003430
   2277.0  0.009540
      2.0       2.0         2.0
    626.     1128.     1272.
    1    1    1    1    1    1    2    2    1
    1    2    3    2    1
    5    6    7    5    6    7    1    3    2    4    2    4    1    3
EL CENTRO NS 1940;   0.40
 500    50     5    1
     0.02      0.005    0.04523      1.0       0.0      0.592     0.0042
(10F8.0)
     -14.    -108.    -101.     -88.     -95.    -120.    -142.    -128.    -110.     -85.
     -85.    -131.    -176.    -194.    -162.    -144.    -108.     -82.     -42.     -66.
    -131.    -190.    -196.     -66.      30.     141.     -49.    -128.    -144.    -203.
    -260.    -325.    -306.    -172.    -197.    -163.    -164.     -67.      25.     150.
     236.     252.     336.     463.     492.     419.     359.     271.     235.     339.
     412.     530.     639.     732.     652.     599.     400.     400.      63.    -515.
    -787.    -603.    -484.    -250.     -59.     134.     308.     499.     710.     995.
    1219.    1529.    1449.    1155.     935.     892.     926.     839.     901.     993.
    1209.     328.   -1475.   -2066.   -1989.   -2034.   -1816.   -1725.   -1752.   -1753.
   -1605.   -1630.   -1347.   -1087.    -782.    -429.     -17.     360.     785.    1164.
    1598.    1960.    2412.    2729.    3036.    3200.    3417.    2821.    2324.   -1196.
   -2373.   -1640.   -1865.   -1095.    -753.    -173.     113.     533.     595.    1136.
    1757.     576.   -2631.   -1547.   -1729.   -1012.    -579.     237.    -670.   -1930.
   -1641.   -1685.   -1481.   -1231.   -1001.    -751.    -523.    -271.     -44.     186.
     -95.    -433.    -838.    -951.    -716.    -599.    -334.    -108.     135.     420.
     673.     -97.    -372.     -40.      11.     344.     565.     883.    1130.    1363.
     219.     241.     683.     689.    1318.    1353.    2040.    -931.   -1308.    -692.
    -546.      72.     675.   -1067.   -1488.   -1071.   -1162.    -762.    -559.    -215.
    -126.    -674.    -324.    -337.    -109.      17.     299.     488.     608.     222.
     -32.    -245.      77.     211.     568.     826.    1206.    1478.    1737.     421.
      29.     259.     293.     -55.    -147.     143.     206.     499.     645.     957.
    1128.    1447.    1629.    1945.    1856.    1984.    1769.    1250.   -1207.    -542.
    -334.    -311.   -1118.   -1661.   -2464.   -2025.   -1835.   -1317.    -960.    -325.
     154.     816.    1319.    1818.     -58.    -169.     285.     447.     983.    1424.
    1653.    2456.    1685.   -1380.    -999.   -1089.    -907.    -469.   -1250.   -2111.
   -1617.   -1692.   -1306.   -1111.    -773.    -510.    -544.   -1200.   -1209.   -1158.
   -1145.    -717.    -546.      64.    -804.   -1634.    -859.    -961.    -396.    -147.
     319.     648.     876.     472.     198.     -27.     292.     445.     785.    1033.
    1352.    1606.    1861.    1281.     640.     204.     314.     373.     496.     235.
     -64.    -168.    -113.    -229.    -248.    -157.     -69.     147.     379.     579.
     255.     -41.    -428.    -133.      95.     230.    -129.     -50.      80.     210.
     380.     510.     157.     -32.    -111.       5.      76.      35.     -95.     -36.
     -16.      36.      85.     -56.    -304.    -421.    -244.    -236.    -177.    -129.
     -16.     203.    -108.     -91.     -34.    -106.    -111.     -99.      -2.      73.
     235.     355.     705.     779.     184.    -263.    -124.     -42.     159.      48.
    -219.    -467.    -428.    -216.     -43.     159.     320.     419.     123.    -160.
    -204.     -62.    -206.    -137.     -55.      53.     134.     266.     232.      79.
      -8.     200.     435.     492.     191.      92.     -22.     -21.      52.      93.
     255.     368.     525.     541.     425.     398.     559.     756.     365.     411.
      98.    -204.    -249.    -405.    -413.    -471.    -433.    -458.     -57.     178.
    -208.    -492.    -530.    -362.    -405.    -308.    -316.    -265.    -265.    -269.
    -345.    -309.    -217.     -78.      87.     281.     310.     358.     341.     358.
```

PROJECT TITLE : ROSECREEK INTERCHANGE; EARTHQUAKE RESPONSE ANALYSIS; 7/18/

UNITS : KIPS INCH

~~NO. OF SPANS~~	5
NO. OF NODES	10
NO. OF ELEMENTS	9
MODULUS OF ELASTICITY	.3122E+04
~~SHEAR MODULUS~~	.1300E+04
GRAVITY ACCELERATION	.3864E+03
NO. OF LOAD INCREMENTS	30
NO. OF EQUAL LOAD GROUPS	3
~~NO. OF LOADS SKIPPED IN OUTPUT~~	2
P-DELTA INDEX	1
0= IGNORE P-DELTA	
1= INCLUDE P-DELTA	
~~MODE OF EXECUTION~~	4
1=STATIC LOADING ONLY	
2=FREE VIBRATION	
3=FREQUENCY ANALYSIS	
~~4=EARTHQUAKE ANALYSIS~~	

EARTHQUAKE ANALYSIS DATA

DURATION OF ANALYSIS	.1000E+02
TIME INCR. FOR NUM. INTEGRATION	.5000E-02
~~MASS DAMPING COEFFICIENT~~	.5920E+00
STIFFNESS DAMPING COEFFICIENT	.4200E-02
NO. OF RESPONSE POINTS PER SEC.	50
NO. OF CYCLES BEFORE CHECKING FOR A CHANGE IN STIFFNESS	5

EARTHQUAKE DATA

BASE MOTION : EL CENTRO NS 1940; 0.4G

NO. OF DATA POINTS	500
TIME INTERVAL FOR THE DATA	.2000E-01
SCALE FACTOR FOR ACCELERATION	.4523E-01
SCALE FACTOR FOR TIME	.1000E+01
SHIFT OF TIME AXIS	0.

WEIGHTS

NODE	WEIGHT	NODE	WEIGHT	NODE	WEIGHT	NODE	WEIGHT	NODE	WEIGHT
1	.3000E+03	2	.7030E+03	3	.5000E+02	4	.9180E+03	5	.5000E+02
6	.9180E+03	7	.5000E+02	8	.7030E+03	9	.5000E+02	10	.3000E+03

TYPICAL DECK ELEMENT DIMENSIONS

ELEMENT	LENGTH
1	.6260E+03
2	.1128E+04
3	.1272E+04

TYPICAL PIER ELEMENT DIMENSIONS

ELEMENT	TOTAL	TOP END	BOTTOM END
1	.2837E+03	.3100E+02	.5000E+00
2	.2837E+03	.3100E+02	.5000E+00

TYPICAL ELEMENT PROPERIES

DECK ELEMENTS

	MOM. OF INERTIA	TORSIONAL INERTIA	SHEAR AREA
1	.5270E+08	.6345E+07	.3690E+04

PIER ELEMENTS

	MOM. OF INERT. NEAR BASE	MOM. OF INERT. ELSEWHERE	TORSIONAL INERITA	SHEAR AREA
1	.8847E+06	.2979E+07	.1766E+07	.3600E+04
2	.1106E+07	.2979E+07	.1766E+07	.3600E+04

PIER BASE MOMENT-CURVATURE

TYPE	CRACK. MOM.	YIELD MOM.	ULT. MOM.	YIELD CURV.	ULT. CURV.
1	.1958E+05	.4900E+05	.5000E+05	.510E-04	.800E-04
2	.2491E+05	.5600E+05	.5700E+05	.510E-04	.800E-04

PIER BOND SLIP ROTATION

TYPE	CRACKING	YIELDING	ULTIMATE
1	.1250E-03	.7800E-03	.8120E-03
2	.1540E-03	.7800E-03	.8080E-03

SPRING PROPERITES

TYPE	FORCE AT BREAKPOINT 1	2	3	DEFORMATION AT BREAKPOINT 1	2	3
1	.9000E+02	.1980E+03	.2780E+03	.5300E-01	.2900E+00	.1000E+01
2	.2780E+03	.5850E+03	.7920E+03	.5300E-01	.3250E+00	.1000E+01
3	.2300E+05	.4000E+05	.4500E+05	.5000E-03	.1480E-02	.4200E-02
4	.5000E+05	.1020E+06	.1150E+06	.5000E-03	.1970E-02	.3800E-02
5	.3850E+02			.1250E+01		
6	.9931E+04			.3430E-02		
7	.2277E+04			.9540E-02		

ELEMENT CHARACTERISTICS

ELEMENT NO.	FLEXURE TYPE	GEOMETRY TYPE
DECK		
1	1	1
2	1	2
3	1	3
4	1	2
5	1	1
PIER		
6	1	
7	2	
8	2	
9	1	

SPRING CHARACTERISTICS

NUMBER	TYPE	NUMBER	TYPE	NUMBER	TYPE	NUMBER	TYPE
1	5	2	6	3	7	4	5
5	6	6	7	7	1	8	3
9	2	10	4	11	2	12	4
13	1	14	3				

****
R E S P O N S E   M A X I M A
****

MAXIMUM DISPLACEMENTS

DOF	DISP.	DOF	DISP.	DOF	DISP.	DOF	DISP.	DOF	DISP.
1	-.5314E+01	2	.4120E+01	3	-.1577E+01	4	.2755E+01	5	.2067E+00
6	-.2755E+01	7	.2067E+00	8	.4120E+01	9	-.1577E+01	10	-.5314E+01

MAXIMUM ACCELERATIONS (G)

DOF	ACC.	DOF	ACC.	DOF	ACC.	DOF	ACC.	DOF	ACC.
1	.8119E+00	2	.4954E+00	3	.7367E+00	4	.3864E+00	5	.4041E+00
6	.3864E+00	7	.4041E+00	8	.4954E+00	9	.7367E+00	10	.8119E+00

MAXIMUM NODAL ROTATIONS

NODE NUMBER	ROT. ABOUT HORIZ. AXIS	ROT. ABOUT VERT. AXIS
1	-.8758E-02	.2903E-02
2	-.1068E-01	.2695E-02
3	-.9536E-02	
4	-.9905E-02	.1252E-02
5	-.4780E-02	
6	-.9905E-02	-.1252E-02
7	-.4780E-02	
8	-.1068E-01	-.2695E-02
9	-.9536E-02	
10	-.8758E-02	-.2903E-02

MAXIMUM DECK FORCES

ELEMENT NUMBER	LEFT END HORIZ. SHEAR	LEFT END MOMENT	RIGHT END MOMENT	LEFT END TORQUE
1	-.1807E+03	-.5665E+03	-.1126E+06	.2536E+05
2	-.2211E+03	.8839E+05	-.3352E+06	.2059E+05
3	.5214E-08	.3238E+06	-.3238E+06	.9218E-06
4	.2211E+03	.3352E+06	-.8839E+05	-.2059E+05
5	.1807E+03	.1126E+06	.5665E+03	-.2536E+05

MAXIMUM PIER FORCES

PIER NO.	TOP SHEAR	TOP MOMENT	BOT. MOMENT	TOP TORQUE
1	.3108E+03	-.3548E+05	.5436E+05	.2448E+05
2	.4186E+03	.2059E+05	.1240E+06	.1137E+05
3	.4186E+03	.2059E+05	.1240E+06	-.1137E+05
4	.3108E+03	-.3548E+05	.5436E+05	-.2448E+05

MAXIMUM PIER DUCTILITIES

PIER NO.	DUCTILITY
1	.1234E+01
2	.3621E+01
3	.3621E+01
4	.1234E+01

MAXIMUM ABUTMENT SPRING FORCES

SPRING NO.	1	2	3	4	5	6
FORCE/MOM.	-.6230E+02	-.2536E+05	.5568E+03	-.6230E+02	-.2536E+05	-.5568E+03

MAXIMUM FORCES AT PIER FOOTINGS

PIER NUMBER	HORIZONTAL FORCE	MOMENT
1	-.3389E+03	-.5401E+05
2	.4451E+03	-.1217E+06
3	.4451E+03	-.1217E+06
4	-.3389E+03	-.5401E+05

NUMBER OF ITERATIONS = 2001

ALL DATA PROCESSED

14.28.26.UCLP, AA, 804L1 , 0.576KLNS.

PART TWO

USER'S MANUAL FOR SIBA SERIES

2.1 Introduction

The SIBA programs were developed for the static nonlinear analysis of highway bridges subjected to horizontal forces. The analytical procedure for the model is described in Ref. 1 and Appendix A. The purpose of this manual is to outline the procedure to run the programs.

Three programs are used to perform different tasks as described in Appendix A. The program SIBA-1 is the analysis module, while the program SIBA-2 is used to print the input and output. Program SIBA-3 is used for the graphical presentation of selected input data. The programs were developed in BASIC on a Commodore 64 microcomputer.

Limits applicable to different parameters are included in the input description (see sec. 2.2). The following limits should also be considered:

1. Only straight or nearly straight bridges are allowed;
2. Only single-column piers can be analyzed by the program; and
3. No intermediate hinges are allowed on the deck although, through appropriate stiffness properties assigned to the abutment springs, the deck-abutment connection may be modeled as a hinge.
4. The bridge is analyzed only for transverse loads.

The bridge is modeled as a collection of elements (deck or column) and boundary springs as shown in Fig. 1 in Appendix A.

2.2 SIBA-1

The program entitled SIBA-1 performs the inelastic analysis of statically loaded highway bridges in the transverse direction. All analysis calculations are made in this program only. Input to SIBA-1 is provided interactively or through a data file created by the program in a previous run. If the bridge is being analyzed for the first time, the data has to be given in the interactive mode.The following sections show the information requested by the computer program. Each question is followed by the variable name associated with the particular piece of data. Program SIBA-2 (the program to print output) takes its input from the sequential file most recently executed on SIBA-1. The input to SIBA-3 is provided by the file generated by SIBA-1.

The data are prepared in blocks. The computer will prompt the user after each block of data with the following question.

ARE THE ABOVE DATA CORRECT? Y=Yes, N=No (CK$)

A yes reply will continue with the interactive input of data.

A no reply will send the user back to the beginning of that section to re-enter the data.

(1) DATA FILE NAME? (F$)

Any alphanumeric string may be used to call up previous input or to identify new data.

(2) DOES THIS FILE EXIST ON THE DISKETTE? Y=Yes, N=No (E$)

A negative response allows the creation of a new data file under the name given in (1). A positive response calls up the data file stored under the name given in (1) for analysis or for modification followed by analysis.

(3) INPUT MODE: I=INTERACTIVE, D=DATA FILE (IM$)

The interactive mode is chosen to prompt the user for the data necessary to create a new file. If the user specifies the DATA FILE mode, the screen will prompt with the following question.

IS DATA MODIFICATION DESIRED? Y=Yes, N=No (X$)

A "Y" response allows the user to scan data from an old file and make changes to observe the resulting variation in bridge response. The following information cannot be modified in this section:

- Units,
- Number of spans,
- Number of typical deck lengths,
- Typical deck element lengths, and
- Deck element length types.

An "N" response allows the user to analyze the data as is.

(4) PROJECT TITLE? (P$)

Any alphanumeric string of less than thirty-five characters may be used. This title is not processed but merely serves as a heading for the output.

(5) UNITS? (U$)

Units of force and displacement are displayed in the output for the user's information. This information is not processed although data must be prepared with consistent units.

(6) MODULUS OF ELASTICITY? (E)

Input the modulus of elasticity of the bridge material. For cases in which the modulus of elasticity of the piers is different from that of the deck, the user should use his/her judgment in selecting the proper value. In bridges with relatively soft deck-to-abutment connections, transverse response is controlled by the stiffness of the piers. Therefore, the E value should be close to the modulus of elasticity of the pier material.

(7) SHEAR MODULUS? (G)

The shear modulus is used in stiffness calculations for both the deck and the piers. As is the case with the modulus of elasticity, the pier material characteristics dominate the transverse response when soft deck-to-abutment connections exist.

(8) NUMBER OF SPANS? (SP)

The maximum number of spans allowed is six.

(9) NUMBER OF TYPICAL DECK CROSS SECTIONS? (DE)

Input the number of deck section types. Different deck elements having the same cross section constitute one deck section type. There can be up to five deck section types.

(10) NUMBER OF PIER TYPES? (PT)

Input the number of pier flexural types. Different column elements having the same cross section and the same length are considered to be the one-column flexural type. There can be up to five pier types.

(11) NUMBER OF FOUNDATION SPRING TYPES? (FS)

The number of abutment springs is fixed to three. The number of pier foundation spring types is entered here and must not exceed seven.

(12) <u>NUMBER OF TYPICAL DECK LENGTHS?</u> (DG)

The length of the deck may vary for different spans of the bridge. Each different span length presents one deck length type. Up to six types are allowed.

(13) <u>NUMBER OF LOAD INCREMENTS?</u> (NL)

Input the total number of load increments.

(14) <u>NUMBER OF LOAD TYPES</u> (NT)

A load increment set is defined as the collection of the loads applied to different nodes simultaneously.

0 = each load increment set is different.

1 = all load increments sets are the same.

2 = load increment sets are broken into two groups of NL/2 with the increments in each group having equal magnitudes.

3 = load increment sets are broken into three groups of NL/3 with the increments in each set having equal magnitudes.

(15) <u>NUMBER OF LOAD INCREMENTS SKIPPED?</u> (SD)

Cases in which the NL (number of load increments) is relatively large produce an output, listing results for all the load increments, that may be lengthy and unnecessary. The parameter SD allows the user to print the output for the first of each SD+1 load increment. Note that skipping some of the load increments in the output does not affect the analysis. The bridge is always analyzed for the NL increments. Regardless of the value of SD, outputs for the first and last load increments are printed on the output file.

(16) TYPE OF OUTPUT? (NU)

0 = input and output.

1 = input only.

2 = output only.

This entry allows the user to obtain a printed copy of the input to check before performing the analysis.

(17) INFORMATION FOR TYPICAL DECK CROSS SECTIONS: MOMENT OF INERTIA, TORSIONAL INERTIA, SHEAR AREA FOR TYPE I (AI(I), AJ(I), AS(I))

The moment of inertia is taken about the centroidal vertical axis for the ith deck section type. The torsional moment of inertia and horizontal shear are are also input for the ith deck section type.

(18) INFORMATION FOR TYPICAL PIER ELEMENTS:

The columns in the program are modeled as three-segment elements (see Ref. 1). The bottom segment is used to idealize pinned connections. Normally, the length of this segment is small (less than one inch). The second segment is the part from the bottom of the deck to the top of the pin, if any. If the connection of the footing is moment resistant, the properties of the first segment should be set equal to that of the second segment. Note that the length of the first segment, parameter EB(I), is used as the length of the column plastic hinge near the base.

The third segment is the column section from the bottom of the deck to the deck centroid. The program assumes that the section is infinitely rigid.

a) <u>MOMENT OF INERTIA NEAR BASE?</u> (BI(I,1))

b) <u>MOMENT OF INERTIA ELSEWHERE?</u> (BI(I,2))

c) <u>TORSIONAL INERTIA?</u> (BJ(I))

d) <u>SHEAR AREA, TOTAL LENGTH?</u> (BS(I), TT(I))

e) <u>TOP RIGID END LENGTH?</u> (ET(I))

f) <u>BOTTOM SEGMENT LENGTH?</u> (EB(I))

g) <u>CRACKING MOMENT, YIELD MOMENT, ULTIMATE MOMENT?</u>
(CR(I), YI(I), UL(I))

The value of ultimate moment is used only to calculate the slope of the postyielding segment of the moment-curvature relationship. It does not impose any limit on the ductility capacity of the member.

h) <u>YIELD CURVATURE, ULTIMATE CURVATURE?</u> (YC(I), UC(I))

The value given for ultimate curvature is a point beyond the yield point of the primary curve for pier type i. It must correspond to UL(I).

i) <u>BOND SLIP ROTATION AT CRACKING?</u> (SC(I))

The procedure to calculate rotations due to bond slip is described in Ref. 2. The value provided here is the bond slip rotation corresponding to the cracking moment divided by the total length of the pier. This division is necessary to conform to the way the program is written. In many cases, the bond slip rotation at cracking may be negligible.

j) <u>BOND SLIP ROTATION AT YIELDING?</u> (SY(I))

k) <u>BOND SLIP ROTATION AT ULTIMATE?</u> (SU(I))

(19) INFORMATION FOR TYPICAL FOUNDATION AND ABUTMENT SPRINGS:

The primary force-deformation relationship for these springs is represented by a trilinear diagram (Fig. 2.1). The data for points one through three are provided in this section. Note that point three does not set an ultimate value. It only sets the slope for the third segment.

a) FORCE/MOMENT AT BREAK POINTS 1, 2, AND 3 FOR TYPE I?

(CR(I)), YI(I), UL(I))

b) DISPLACEMENT/ROTATION AT BREAK POINTS 1, 2, AND 3 FOR TYPE I?

(DC(I), DY(I), UC(I))

(20) TYPICAL DECK ELEMENT LENGTHS, TYPE I (TY(I))

Enter the length of each of the DG deck length types (see data entry 12).

(21) DECK AND PIER ELEMENT FLEXURAL TYPES, ELEMENT I (IC(I))

The deck cross section types (see data entry 9) and pier types (see data entry 10) are provided in this section. Element numbering is shown in Fig. 2.2.

(22) DECK ELEMENT LENGTH TYPE, ELEMENT I (IG(I))

Input the length type of each deck element. Span numbers proceed from left to right.

(23) FOUNDATION AND ABUTMENT SPRING TYPES, SPRING I (IP(I))

Typical spring types, as specified in section 19, are assigned to the abutment and foundation springs. The numbering of springs is established in Fig. 2.3. The first three springs are assigned to the left abutment springs, and the second three springs are assigned to those at the right abutment. The pile foundation spring numbers start from seven and eight for the left most bent and increase in moving from the left to the right.

(24) LOAD INCREMENT AT NODE I? (DL(I))

The values of nodal load increments are provided in this section. The ith value within each load increment set is assumed to act at node i. The numbering of nodes is restricted to the pattern shown in Fig. 2.2. Enter zero for unloaded nodes.

When the execution is complete, the screen will display a statement indicating that all data have been processed.

2.3 SIBA-2

The program entitled SIBA-2 provides the user with a hard copy of the input and output data. After all data have been processed by SIBA-1, load and run SIBA-2. No further input is necessary. SIBA-2 reads its data directly from the sequential file most recently created by SIBA-1.

2.4 SIBA-3

This program is used for graphical display and to check general input information. Different colors are used to highlight different data. Upon execution, SIBA-3 asks the data file name for the bridge to be checked. The file name constitutes the only interactive input data provided to SIBA-3. The output consists of several screens as described below. Let NSPN = the number of spans.

SCREEN 1 - The first screen is used to plot bridge elevation, element and node numbers, span lengths, and pier heights.

SCREENS 2 AND NSPN + 2 - These screens show the bridge deck at the abutments, the load, and the load magnitude for the first load increment.

SCREENS 3 THROUGH NSPN + 1 - These screens show the bridge transverse section at different bents. The loads and their magnitudes are also displayed at the deck and foundation levels. The load magnitudes are for the first load increment set.

2.5 Example

A four-span symmetric bridge was used to illustrate SIBA-1 and SIBA-2. The bridge was analyzed for twenty equal load increments. To obtain realistic response, the properties for the bridge were chosen from an actual bridge although some simplifications were made. For the sake of brevity, the output for only five of the load increments is shown. The input and output are presented starting on the next page.

SIBA-C64 PROGRAM SERIES

TO PERFORM

INELASTIC STATIC ANALYSIS

OF LATERALLY-LOADED BRIDGES

NATIONAL SCIENCE FOUNDATION

RESEARCH GRANTS CEE-81-08124

AND CEE-84-12576

DEVELOPED BY

RENEE A. LAWVER

MEHDI SAIIDI

CENTER FOR CIVIL ENGINEERING

EARTHQUAKE RESEARCH

UNIVERSITY OF NEVADA-RENO

PROJECT TITLE: 4SPAN 5/29/86

UNITS: KIP-INCH

****
INPUT
****

NO.OF SPANS	4
NO. OF NODES	8
NO. OF ELEMENTS	7
MODULUS OF ELASTICITY	3400
SHEAR MODULUS	1360
NO. OF LOAD INCREMENTS	20
NO. OF EQUAL LOAD GROUPS	1
NO. OF LOADS SKIPPED IN OUTPUT	0

**************** TYPICAL DECK ELEMENT DIMENSIONS ****************

ELEMENT	LENGTH
1	626
2	1128

**************** TYPICAL PIER ELEMENT DIMENSIONS ****************

ELEMENT	TOTAL	TOP END	BOTTOM END
1	280	31	1
2	280	31	1

**************** TYPICAL ELEMENT PROPERTIES **********************

DECK ELEMENTS

	MOMENT OF INERTIA	TORSIONAL INERTIA	SHEAR AREA
1	4000000	1000000	2000

PIER ELEMENTS

	MOMENT OF INERTIA NEAR BASE	MOMENT OF INERTIA ELSEWHERE	TORSIONAL INERTIA	SHEAR AREA
1	900000	3500000	750000	3000
2	1100000	3500000	750000	3000

2

**************** PIER BASE MOMENT-CURVATURE **********************

TYPE	CRACKING MOMENT	YIELD MOMENT	ULTIMATE MOMENT
1	22000	48000	50000
2	28000	60000	65000

TYPE	YIELD CURVATURE	ULTIMATE CURVATURE
1	4.2E-05	1E-04
2	4E-05	1E-04

**************** PIER BOND SLIP ROTATION ************************

TYPE	CRACKING	YIELDING	ULTIMATE
1	0	3.58E-05	4E-05
2	0	3.58E-05	4E-05

**************** SPRING PROPERTIES ******************************

TYPE	FORCE AT BREAKPOINT		
	1	2	3
1	280	600	800
2	40000	100000	110000
3	90	200	280
4	45000	105000	115000
5	23	50	60
6	1000	2440	4000
7	1200	2900	3000

TYPE	DEFORMATION AT BREAKPOINT		
	1	2	3
1	.05	.3	1
2	5E-04	2E-03	4E-03
3	.05	.3	1
4	5.2E-04	2.2E-03	4.2E-03
5	.05	.5	2
6	2E-03	8.38E-03	.03
7	.03	.09	1

3

*************** ELEMENT CHARACTERISTICS ************************

DECK	ELEMENT NUMBER	FLEXURE TYPE	LENGTH TYPE
	1	1	1
	2	1	2
	3	1	2
	4	1	1

PIER	ELEMENT NUMBER	FLEXURE TYPE
	5	1
	6	2
	7	1

************** SPRING CHARACTERISTICS ************************

NUMBER	TYPE
1	5
2	6
3	7
4	5
5	6
6	7
7	1
8	2
9	3
10	4
11	1
12	2

4

```
************************************************************************
                              OUTPUT
************************************************************************
```

```
***************
  LOADING     1
***************
```

DOF	LOAD INCREMENT	TOTAL LOAD	DISPLACEMENT
1	6	6	.0135425556
2	14	14	.0257598642
3	1	1	2.68053482E-03
4	18	18	.0377020089
5	1	1	.0102882549
6	14	14	.0257598641
7	1	1	2.68053482E-03
8	6	6	.0135425556

*************** NODAL ROTATIONS ********************************

NODE NUMBER	ROTATION ABOUT HORIZONTAL AXIS	ROTATION ABOUT VERTICAL AXIS
1	-7.64795596E-05	2.05156923E-05
2	-9.40811054E-05	1.72459224E-05
3	-4.88344753E-05	
4	-1.12261174E-04	-3.67379738E-14
5	-5.61766634E-05	
6	-9.4081105E-05	-1.72459224E-05
7	-4.88344752E-05	
8	-7.64795595E-05	-2.05156923E-05

*************** DECK FORCES ************************************

ELEMENT NUMBER	LEFT END HORIZONTAL SHEAR	LEFT END MOMENT	RIGHT END MOMENT	LEFT END TORQUE
1	-.229575595	-.820629239	-142.893694	38.2397801
2	-.240570583	72.2477519	-343.61137	21.9192321
3	.240570586	343.611372	-72.2477502	-21.9192324
4	.229575589	142.893697	.820622027	-38.2397798

5

*************** PIER FORCES ***********************************

PIER NUMBER	TOP SHEAR	TOP MOMENT	BOTTOM MOMENT	TOP TORQUE
1	14.010995	16.3205689	3906.75803	70.6459473
2	17.5188588	43.8384588	4861.44203	-1.50492905E-07
3	14.0109951	16.3205812	3906.75802	-70.6459473

*************** PIER DUCTILITIES ********************************

PIER NUMBER	DUCTILITY
1	.0703967285
2	.0722740641
3	.0703967284

*************** ABUTMENT SPRING FORCES **************************

SPRING NUMBER	FORCE/MOMENT
1	6.22957558
2	-38.2397798
3	.820627693
4	6.22957558
5	-38.2397797
6	-.82062769

*************** FORCES AT PIER FOOTINGS *************************

PIER NUMBER	HORIZONTAL FORCE	MOMENT
1	15.010995	-3906.75802
2	18.5188588	-4861.44202
3	15.010995	-3906.75801

```
***************
  LOADING    5
***************
```

DOF	LOAD INCREMENT	TOTAL LOAD	DISPLACEMENT
1	6	30	.117450895
2	14	70	.13547144
3	1	5	.0140901129
4	18	90	.183071602
5	1	5	.0498669185
6	14	70	.135471425
7	1	5	.0140901117
8	6	30	.117450981

*************** NODAL ROTATIONS ********************************

NODE NUMBER	ROTATION ABOUT HORIZONTAL AXIS	ROTATION ABOUT VERTICAL AXIS
1	-4.01976757E-04	2.30675293E-05
2	-4.94490484E-04	4.16212806E-05
3	-2.569301E-04	
4	-5.46001244E-04	-1.58344449E-11
5	-2.72811833E-04	
6	-4.94490395E-04	-4.16210965E-05
7	-2.56930109E-04	
8	-4.01975125E-04	-2.30672973E-05

*************** DECK FORCES ***********************************

ELEMENT NUMBER	LEFT END HORIZONTAL SHEAR	LEFT END MOMENT	RIGHT END MOMENT	LEFT END TORQUE
1	1.28486394	-.922286175	805.24711	200.988287
2	-2.61976789	-975.732042	-1979.36614	62.1051718
3	2.61977883	1979.36971	975.740812	-62.1052785
4	-1.28484707	-805.242862	.928594112	-200.991641

7

*************** PIER FORCES ************************************

PIER NUMBER	TOP SHEAR	TOP MOMENT	BOTTOM MOMENT	TOP TORQUE
1	73.9046321	138.882882	20554.4141	170.496812
2	84.7604533	124.210413	23608.7165	-6.4863991E-05
3	73.9046261	138.886611	20554.4087	-170.496058

*************** PIER DUCTILITIES ********************************

PIER NUMBER	DUCTILITY
1	.37037449
2	.350985959
3	.370374392

*************** ABUTMENT SPRING FORCES **************************

SPRING NUMBER	FORCE/MOMENT
1	27.0470537
2	-583.386249
3	.922701172
4	27.0470589
5	-583.384209
6	-.922691694

*************** FORCES AT PIER FOOTINGS ************************

PIER NUMBER	HORIZONTAL FORCE	MOMENT
1	78.9046323	-20554.408
2	89.7604534	-23608.7163
3	78.9046259	-20554.4087

****
LOADING 10
****

DOF	LOAD INCREMENT	TOTAL LOAD	DISPLACEMENT
1	6	60	1.97801895
2	14	140	2.14306194
3	1	10	.0264043127
4	18	180	2.2867698
5	1	10	.242027478
6	14	140	2.14308462
7	1	10	.0264044655
8	6	60	1.97807497

*************** NODAL ROTATIONS ***********************************

NODE NUMBER	ROTATION ABOUT HORIZONTAL AXIS	ROTATION ABOUT VERTICAL AXIS
1	-6.98466844E-03	2.81367116E-04
2	-7.65973259E-03	2.23475554E-04
3	-4.61106671E-04	
4	-7.45567803E-03	2.60231387E-09
5	-5.75668899E-04	
6	-7.65981289E-03	-2.23418963E-04
7	-4.61118384E-04	
8	-6.9847412E-03	-2.81314989E-04

*************** DECK FORCES ***************************************

ELEMENT NUMBER	LEFT END HORIZONTAL SHEAR	LEFT END MOMENT	RIGHT END MOMENT	LEFT END TORQUE
1	-4.05419427	-11.2547803	-2526.67083	1466.59303
2	-1.91834507	1612.4081	-3776.30134	-246.023236
3	1.91965637	3776.42139	-1611.049	246.120057
4	4.05464933	2526.91031	11.3001719	-1466.60944

9

*************** PIER FORCES ***********************************

PIER NUMBER	TOP SHEAR	TOP MOMENT	BOTTOM MOMENT	TOP TORQUE
1	137.864151	1712.60104	36110.1535	915.442026
2	176.162001	-492.142479	48286.3783	.0106600809
3	137.865008	1712.73189	36110.2639	-915.210211

*************** PIER DUCTILITIES ********************************

PIER NUMBER	DUCTILITY
1	.723983074
2	.786325338
3	.723985637

*************** ABUTMENT SPRING FORCES **************************

SPRING NUMBER	FORCE/MOMENT
1	59.8534597
2	-3023.56593
3	11.2546846
4	59.8538331
5	-3023.5723
6	-11.2525995

*************** FORCES AT PIER FOOTINGS *************************

PIER NUMBER	HORIZONTAL FORCE	MOMENT
1	147.864151	-36888.5337
2	174.49209	-46988.1749
3	147.865007	-36889.4707

****
LOADING 15
****

DOF	LOAD INCREMENT	TOTAL LOAD	DISPLACEMENT
1	6	90	9.0363729
2	14	210	9.86075006
3	1	15	.0379032172
4	18	270	10.5625926
5	1	15	.735836715
6	14	210	9.86117136
7	1	15	.0379048363
8	6	90	9.03726513

*************** NODAL ROTATIONS ********************************

NODE NUMBER	ROTATION ABOUT HORIZONTAL AXIS	ROTATION ABOUT VERTICAL AXIS
1	-.0336558311	1.40921611E-03
2	-.0352172779	1.10767653E-03
3	-7.85567944E-04	
4	-.035306969	9.20660388E-08
5	-1.16024589E-03	
6	-.035218765	-1.10686717E-03
7	-7.857744532E-04	
8	-.0336577829	-1.40848761E-03

*************** DECK FORCES *************************************

ELEMENT NUMBER	LEFT END HORIZONTAL SHEAR	LEFT END MOMENT	RIGHT END MOMENT	LEFT END TORQUE
1	-21.1098891	-56.3758034	-13158.4148	3392.28062
2	-8.36790527	8634.35664	-18073.3538	108.138198
3	8.38299993	18074.3291	-8618.30515	-106.345236
4	21.1159155	13162.0579	56.5052147	-3391.27089

*************** PIER FORCES ************************************

PIER NUMBER	TOP SHEAR	TOP MOMENT	BOTTOM MOMENT	TOP TORQUE
1	197.258018	3282.84349	50728.9122	4537.47013
2	253.249105	214.489751	67792.23	.37713799
3	197.26709	3284.93721	50729.143	-4534.15469

*************** PIER DUCTILITIES ********************************

PIER NUMBER	DUCTILITY
1	1.23179678
2	1.29289302
3	1.23181639

*************** ABUTMENT SPRING FORCES **************************

SPRING NUMBER	FORCE/MOMENT
1	106.909153
2	-9789.77108
3	56.3686445
4	106.915101
5	-9789.99275
6	-56.3395042

*************** FORCES AT PIER FOOTINGS *************************

PIER NUMBER	HORIZONTAL FORCE	MOMENT
1	212.258017	-51422.7178
2	249.80991	-67865.9245
3	212.267083	-51429.7813

****
LOADING 20
****

DOF	LOAD INCREMENT	TOTAL LOAD	DISPLACEMENT
1	6	120	21.1552578
2	14	280	23.6726233
3	1	20	.0434369862
4	18	360	25.678238
5	1	20	1.44801923
6	14	280	23.6744085
7	1	20	.0434431472
8	6	120	21.1589905

*************** NODAL ROTATIONS ***********************************

NODE NUMBER	ROTATION ABOUT HORIZONTAL AXIS	ROTATION ABOUT VERTICAL AXIS
1	-.0813900639	4.33622792E-03
2	-.0845394423	3.30829933E-03
3	-9.45266725E-04	
4	-.0867644308	3.89228591E-07
5	-1.61515328E-03	
6	-.0845457447	-3.30494167E-03
7	-9.45941634E-04	
8	-.0813991146	-4.33322517E-03

*************** DECK FORCES ***************************************

ELEMENT NUMBER	LEFT END HORIZONTAL SHEAR	LEFT END MOMENT	RIGHT END MOMENT	LEFT END TORQUE
1	-71.902452	-173.473056	-44837.4619	6842.09999
2	-15.1495833	31338.239	-48426.9689	2682.61015
3	15.2090408	48429.4064	-31273.6083	-2675.01151
4	71.9274264	44852.9904	173.578552	-6836.12936

*************** PIER FORCES ************************************

PIER NUMBER	TOP SHEAR	TOP MOMENT	BOTTOM MOMENT	TOP TORQUE
1	223.247121	4152.49665	57136.2107	13552.0695
2	329.641395	5357.6391	84038.9227	1.59443037
3	223.281647	4161.14581	57137.012	-13538.3153

*************** PIER DUCTILITIES ********************************

PIER NUMBER	DUCTILITY
1	1.77603972
2	1.90357095
3	1.77610779

*************** ABUTMENT SPRING FORCES **************************

SPRING NUMBER	FORCE/MOMENT
1	187.701719
2	-32264.8724
3	173.449117
4	187.726604
5	-32267.3349
6	-173.329007

*************** FORCES AT PIER FOOTINGS *************************

PIER NUMBER	HORIZONTAL FORCE	MOMENT
1	243.247123	-57810.669
2	331.202198	-84112.617
3	243.281624	-57837.6654

****
RUN COMPLETED
****

REFERENCES

1. Saiidi, M., J.D. Hart, and B.M. Douglas, "Inelastic Static and Dynamic Analysis of Short R/C Bridges Subjected to Lateral Loads," Civil Engineering Department, Report No., CCEER-84-3, University of Nevada Reno, July 1984.

2. Sozen, M.A., "Hysteresis in Structural Elements," Applied Mechanics in Earthquake Engineering, MMD-V.8, American Society of Mechanical Engineers, New York, November 1974, pp. 63-73.

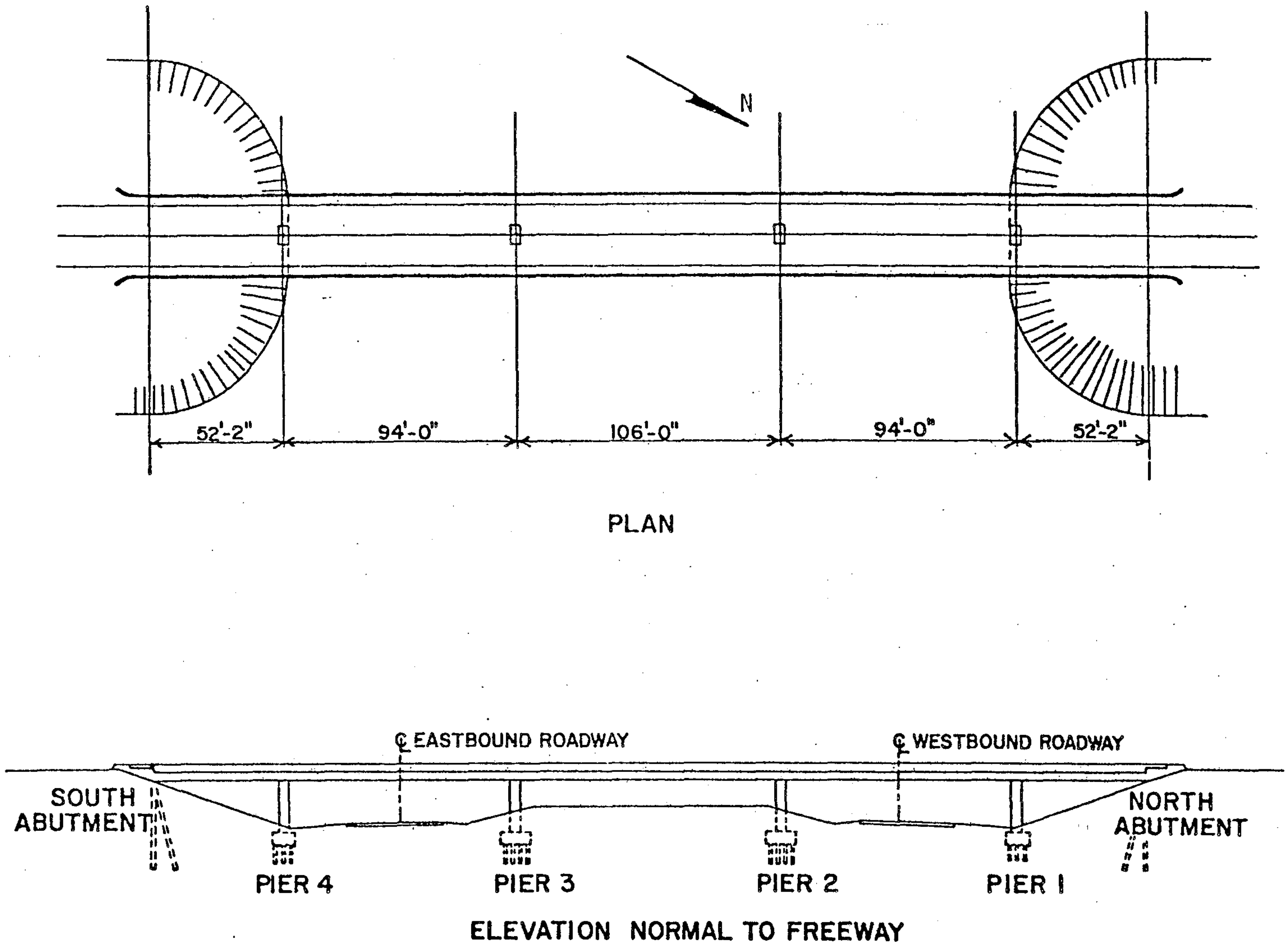


Fig. 1.1 Plan View and Elevation for the Rose Creek Bridge

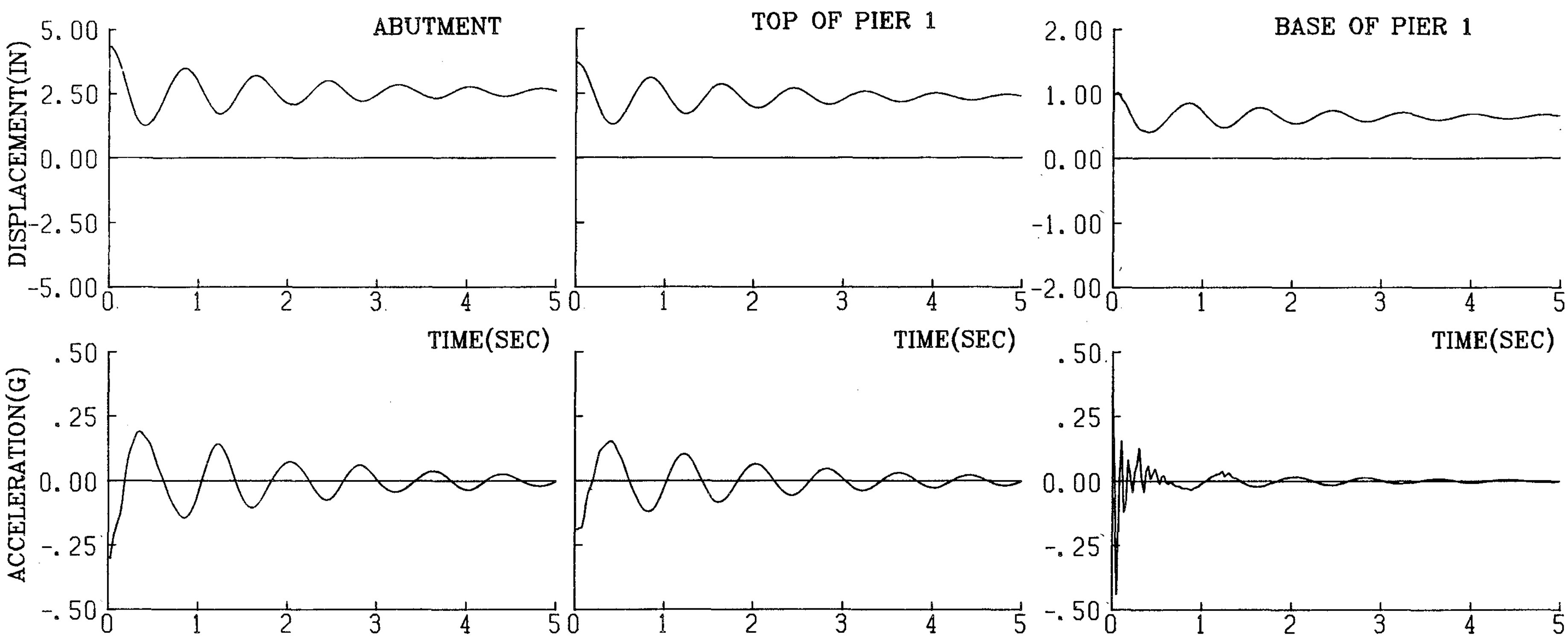


Fig. 1.2 Sample Free-Vibration Response Histories for the Rose Creek Bridge

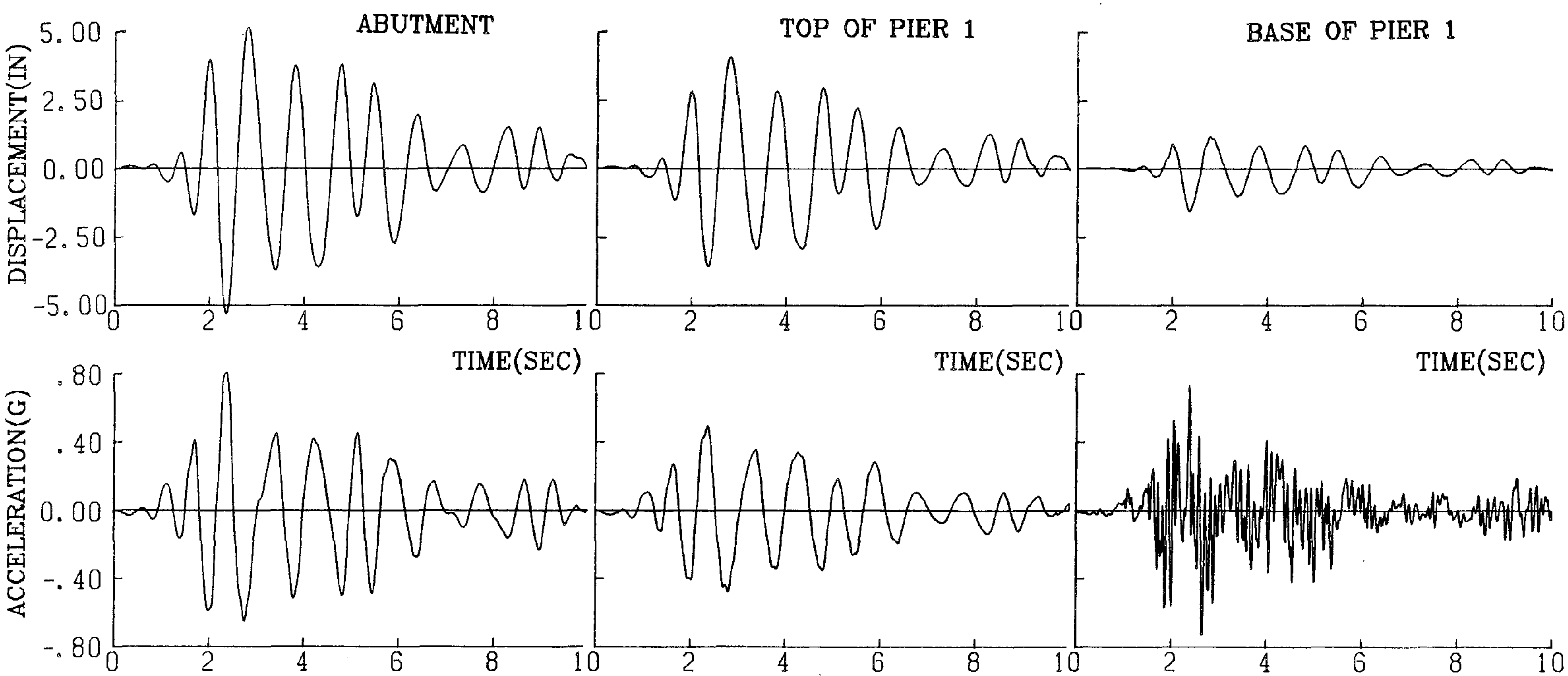


Fig. 1.3 Sample Seismic Response Histories for the Rose Creek Bridge

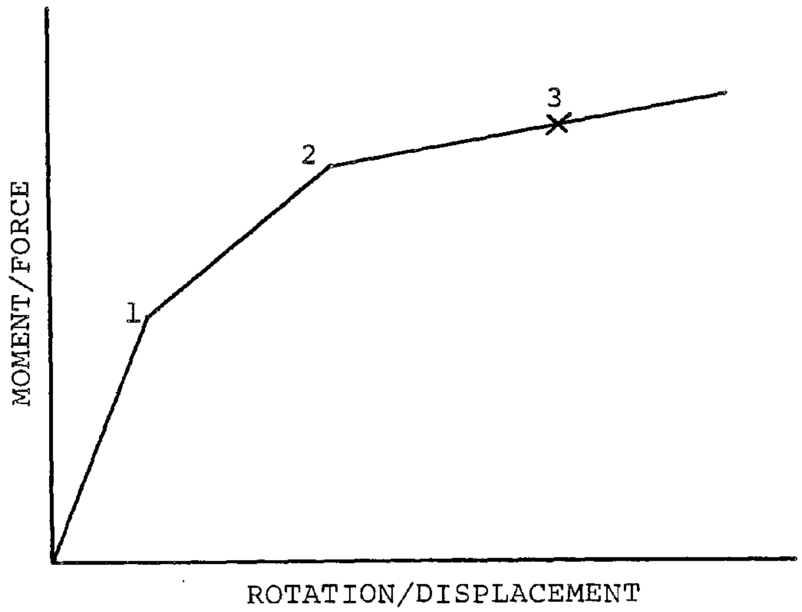
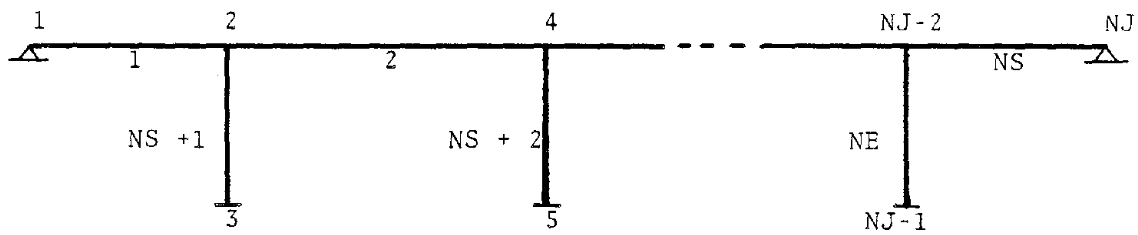


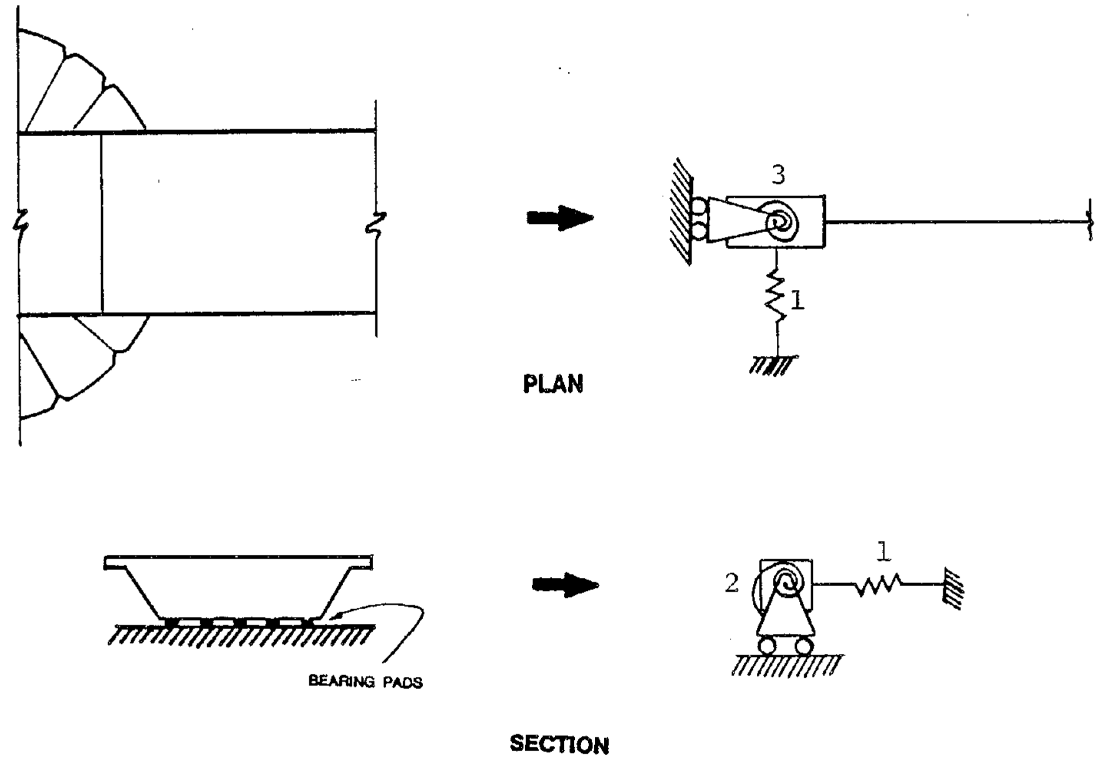
Fig. 2.1 Primary Force-Deformation Relationship for Foundation and Abutment Springs.



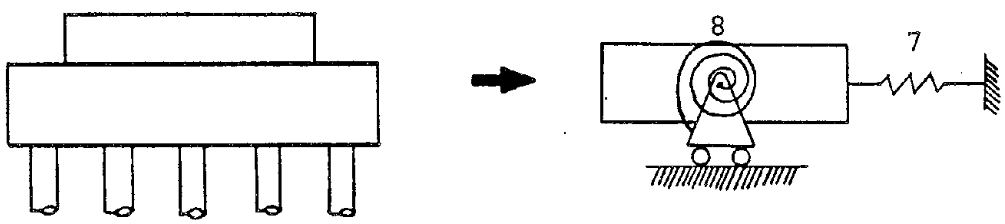
NJ = Number of joints
NE = Number of elements
NS = Number of spans

Fig. 2.2 Node and Element Numbering Scheme.

2.1



(a) Left Abutment



(b) Left Pier Base

Fig. 2.3 Boundary Spring Numbering Scheme.

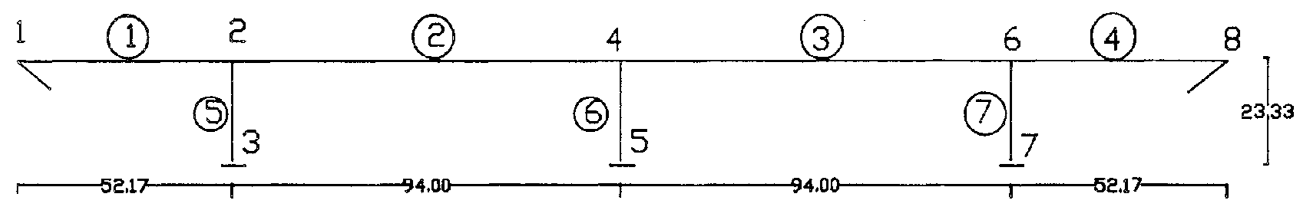


Fig. 2.4 Example Bridge.

INELASTIC STATIC ANALYSIS OF LATERALLY-LOADED BRIDGES ON A LOW-COST MICROCOMPUTER

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ABSTRACT

A relatively simple analytical model for inelastic lateral load analysis of short, symmetric highway bridges is presented. The nonlinear components include bridge boundary elements. The primary task is performed in a program named SIBA-C64-1 which was developed on a Commodore 64 in BASIC V2. Two numerical examples, a 2-span and a 5-span bridge, are presented and the application of the model in interpreting the response is discussed. It is concluded that the program presented, and similar programs which utilize advanced analytical techniques, should enable design engineers to move toward more realistic design of structures.

INTRODUCTION

The ultimate behavior of structural systems subjected to extreme lateral loads, particularly loads due to earthquakes, has been of considerable interest to researchers, designers, and agencies responsible for the preparation of design codes. To study the response as the structure is loaded beyond the elastic stage, inelastic analytical models become necessary. Inelastic models, however, have not been utilized to a significant extent in design offices for the reasons described herein. As a result, many seismic codes include the effects of the nonlinear behavior implicitly, allowing the practicing engineer to use the more familiar elastic analytical models.

The primary reasons for the limited utilization of inelastic models are (a) inelastic models are usually very complex and are beyond the level of undergraduate engineering training; (b) many of the available inelastic models have not been evaluated rigorously to establish their reliability in predicting the response of "real" structures; and (c) the necessary software to implement inelastic models ordinarily requires a main frame computer which may not be available to many designers. Attempts have been made to address the aforementioned difficulties for reinforced concrete building structures; and, as a result, relatively simple models have been developed and implemented on low-cost microcomputers (1). In the area of bridge engineering, "finite-element type" programs have been developed for use on main frame computers; however, no simple yet realistic microcomputer models are available.

The purpose of this paper is to describe the microcomputer version of a recently developed (2), relatively simple, inelastic model for static lateral load analysis of symmetric, straight highway bridges. Further simplifications were made in the new version. The program was developed in BASIC V2 on a Commodore 64.

STRUCTURAL MODELING

The model was developed for analysis of fully or approximately symmetric highway bridges to limit the number of degrees of freedom and, hence, to reduce the amount of matrix operations. A schematic view of the bridge model is shown in Fig. 1. At the abutments, three nonlinear springs were assumed: one translational and the other two rotational. Deck and pier elements were idealized as line members, with nonlinearity allowed only at the base of pier elements. The pier foundation effect was represented by two nonlinear springs at the base of each pier. Only translation in the transverse direction and rotation with respect to an axis parallel to the longitudinal axis of the bridge were accounted for. Other possible degrees of freedom were fixed because, under lateral loads, their effect was believed to be negligible.

HYSTERESIS MODEL

The loads are applied in small increments. The sign of the load may be positive or negative, thus allowing for reversal of the loads and cyclic loading. The cyclic characteristics of all nonlinear components are represented by a hysteresis model called "TQ-Hyst" (3). In the main-frame version of the program, two hysteresis models were incorporated. The TQ-Hyst model operates on a trilinear primary curve (force-deformation relationship for unidirectional loadings well into the nonlinear range). The rules to determine stiffness variations at different stages of loading, unloading, and reversed loading are sufficiently versatile to allow for simulation of the response for a variety of structural components. The model is described in detail in Ref. 3.

Pier Elements

Only single-column piers are allowed for in the program. In bridges with single-column piers, the maximum moment usually occurs at the bottom of the pier. In many bridges, the pier section near the base is smaller than other parts to avoid the transfer of a large moment in the longitudinal direction of the bridge. The nonlinear behavior, therefore, is assumed to be concentrated at the base of the pier over the height where the section is "weak". The shear resistance is assumed to be constant. The moment-curvature relationship for reinforced concrete elements consists of three distinct parts: precracked, cracked, and yielded, with each part having a smaller slope than the previous part (OCYU in Fig. 2). The curve is assumed to be symmetric with respect to the origin.

Deck Elements

The deck elements are assumed to remain elastic.

Because the section properties of reinforced concrete deck elements are generally controlled by vertical loads and because vertical loads on large spans (typically used in bridges) require relatively large sections, it is not expected that lateral forces will cause forces beyond cracking of the deck elements.

Foundation

It is known that most soil types exhibit inelastic behavior even at very small strains. In lateral loading of soil samples, typically, a curved relationship with a gradual but generally significant decrease in stiffness is obtained. Due to large variation in soil properties, construction of this curve without testing of the soil represents, at best, an approximation. Added to this is the effect of foundation structure. Studies on the cyclic behavior of foundations have generally revealed that the hysteresis relationships include deterioration of strength and stiffness with a trend similar to that assumed in the TQ-Hyst model. In the absence of extensive experimental data for lateral and rotational behavior of foundation systems, the TQ-Hyst model is assumed to represent the behavior of the foundation at pier bases.

Abutment Systems

The connection between the deck and abutment is represented by three springs (Fig. 1). By using appropriate values for the force-deformation relationships of these springs, it is possible to simulate the behavior of monolithic, hinged, or roller connections. For monolithic and hinged connections, it is reasonable to assume that the stiffness properties will not change as a result of loading, and the initial stiffness values may be used.

To achieve roller connections, neoprene elastomeric bearing pads are commonly used in the U.S. These pads, however, are known to transmit forces between the deck and the abutment structure. In addition, the force-deformation relationship for these pads is not linear. Cyclic testing of neoprene bearing pads in shear has shown that a nonlinear effect is present even at small load amplitudes (4). As loading continues, a reduction in stiffness is observed until slippage occurs. Upon unloading and reversing the loads, the stiffness changes. Cyclic loadings of bearing pads for vertical loads, on the other hand, have shown some stiffening effects as loading continues. This is, of course, due to compaction of neoprene layers as compressive load is applied. The TQ-Hyst model is used to simulate the cyclic response of the pads because it is found to be capable of producing the general characteristics of the hysteresis loops.

Total Bridge Structure

Based on the idealizations described, a computer model was developed for static nonlinear analysis of highway bridges subjected to lateral loads. The "P-Delta" effect is accounted for in the modeling. Structural nodes are assumed to be at the abutments, pier caps, and at the pier bases. Masses are assumed to be lumped at the nodes. Advantage is taken of the symmetry of the element stiffness matrices in storing the stiffnesses. Nodes and degrees-of-freedom are numbered in such a way as to minimize the bandwidth of the structural stiffness matrix. Stiffness submatrices corresponding to the lateral and rotational degrees-of-freedom are partitioned, and static condensation is used to minimize the size of the matrices to be inverted. Detailed formulation of the model is presented in Ref. 3.

Horizontal forces are applied at pier-deck intersections, abutments, and pier bases. For each load increment, the status of the nonlinear elements is checked, and stiffnesses are updated as necessary. To allow for close monitoring of force-deformation variations, the loads should be applied in small increments. For each load increment, lateral displacements, rotation, and all internal forces are computed.

IMPLEMENTATION ON COMMODORE 64

The analytical model described above was implemented in a program named SIBA-C64-1. In addition, two relatively short programs, named SIBA-C64-2 and 3, were developed for output preparation and graphics purposes, respectively. Links between the programs are shown in Fig. 3. All the programs were written in BASIC V2 on a Commodore 64, with approximately 39K-bytes of user-available memory.

The first program (SIBA-C64-1) reads the input information, either interactively or from a sequential data file, and analyzes the bridge. The data file is automatically generated upon running the program for the first time. The flow chart for SIBA-C64-1 is shown in Fig. 4. Nodal displacements, nodal rotations, and element internal forces are determined for each load increment. These data are used to update the stiffness matrices for the nonlinear components. The program is capable of storing the data in a sequential file to be printed as output.

Bridges of up to six spans may be analyzed using the program. No limit exists on the number of load increments, but the user may choose to obtain the output only for a selected number of load increments, thus reducing the size of the output and shortening printing time.

Programs SIBA-C64-2 and 3 were not incorporated in the first program because of the limitation on computer memory space. To include these programs in SIBA-C64-1, it would be necessary to limit the number of spans to four or five. Program SIB-C64-2 reads the input data and output from the sequential file formed by SIBA-C64-1, and prints all the input values and the output for the loads specified by the user.

Program SIBA-C64-3 uses screen graphics to plot general information about the geometry, node numbering, and element numbering of the bridge. In addition, it plots the individual bents and illustrates the applied loads. This program reads its input from the sequential data file (Fig. 3). Program SIBA-C64-3 is used only to review the information described; therefore, it does not affect the computations.

NUMERICAL EXAMPLES

Two highway bridges were used to demonstrate the SIBA group. One was the Meloland Bridge which is a two-span bridge located near El Centro in Southern California, and the other was the Rose Creek Bridge which has five spans and is located near Winnemucca in Northern Nevada. Detailed information about these bridges is presented in Ref. 5. Only, the response quantities are presented and discussed herein.

The Meloland Bridge

The Meloland Road overpass is a two-span, multicell box girder bridge located near El Centro, California. The bridge has monolithic abutments and is symmetric. A single-column prismatic pier rigidly connected to the deck supports the deck (Fig. 5). The bridge was subjected to earthquake loads in the study presented in Ref. 5. The element properties used in the study presented herein were obtained from that reference and will not be repeated.

The Meloland Bridge was analyzed using SIBA-C64-1 for 10 load increments applied at the deck center. The magnitudes of the load increments were chosen such that (1) large nonlinear displacements are developed and (2) the bridge behavior during the unloading and load reversal stages can be studied. The load-displacement response for the top of the pier (deck center) is shown in Fig. 7. The maximum displacement was 7.82 in. which corresponded to the total load of 4,259 k. This load was approximately equal to 1.6 times the gravity load and may be assumed to be equal to the maximum credible earthquake load in a zone with severe seismicity. The ratio of the maximum displacement to the pier height is 2.75% which is considered indicative of a large degree of nonlinearity. It can be seen in Fig. 7 that, using SIBA-C64-1, it was possible to determine the residual displacements corresponding to zero load and the softening effects produced by load reversal.

The plan view deflection of the bridge for different load amplitudes is shown in Fig. 8. The solid lines present the deflection during loading (cases a to c (see also Fig. 7)), and the broken lines show the deflection during unloading and load reversal (cases d and e). Comparison of cases a through c with cases d and e shows that the deflected shape of the deck changed as the bridge developed nonlinear deformations. The abutment displacement increased relative to the center indicating that the stiffness loss at the abutments was more pronounced than that of the pier.

The execution time to run the uncompiled version of SIBA-C64-1 for the Meloland bridge was approximately 50 seconds per load increment. A major part of the running time is for matrix operations. For each load increment, two banded matrices are inverted, one with a size of 4 and band width of 4 and the other with a size of 8 and band width of 3. Based on experience with other Commodore 64 programs, the execution time for the compiled version is expected to be about 20 seconds per load.

The Rose Creek Bridge

The Rose Creek bridge is a five-span, reinforced concrete, multicell box girder bridge with a total length of 400 feet, located on highway I-80 near Winnemucca, Nevada. The substructure consists of four single piers (Fig. 6) and the abutments, which are all supported by pile foundations. The deck is continuous with no intermediate expansion joints and is supported by five elastomeric bearing pads at each abutment. The superstructure and the substructure are symmetric (Fig. 6). The foundation, however, is slightly unsymmetric due to small differences between the soil profiles at the southern and northern piers. These differences were considered negligible, and the complete structure was assumed to be symmetric. With the initial properties of the components obtained from Ref. 3, the SIBA-C64 group was used to analyze the bridge.

The Rose Creek bridge was analyzed for loads applied at the intersection of piers and the deck. Four load increments were used. The magnitude of each increment was 60 kips per pier. The relationship between the center displacement and the loads is shown in Fig. 9.

The applied forces corresponded to approximately 20 percent of gravity which are considered to be forces due to a moderate earthquake. The drift caused by the load was 1.5 percent. For reinforced concrete structures, this value of drift is believed to correspond to a damage level beyond which restoration becomes difficult.

Figure 9 also shows the measured data obtained in experimental testing of the Rose Creek bridge by applying relatively small loads (6). The figure shows that the correlation between the measured and calculated data was very close indicating that the modeling scheme is appropriate, at least, for small loads.

The computer time to analyze the Rose Creek bridge was approximately 9 minutes per load increment for the uncompiled version of SIBA-C64-1. For each increment two banded matrices are inverted, one with a size of 10 and band width of 10, and the other with a size of 16 and band width of 3. The execution time for the compiled version is estimated at about 3.5 minutes.

CONCLUSIONS

The model presented can be used for two purposes in analysis of regular, symmetric highway bridges subjected to transverse loads. One is to perform the elastic analyses required in the ATC-6 seismic design guidelines for highway bridges, and the other is to check the response of the bridge for extreme cyclic loads.

The successful implementation of an advanced analytical method on a low-cost microcomputer demonstrates the potential that microcomputer applications may have in improving the current structural analysis and design methods. Too many simplifying assumptions have been used in routine analysis and design raising doubts about whether the idealized system represents the real structure. The primary reasons often mentioned for not utilizing more realistic techniques have been (1) lack of adequate computing facilities, and (2) inadequate background of typical designers to interpret more realistic methods.

This paper showed that it was possible to use a low-cost microcomputer (less than $1000) to determine the nonlinear response of highway bridges of up to six spans subjected to lateral loads. The fact that the model allows for the flexibility of foundations and abutments is a significant departure from the more common assumption of fixed boundary elements. Through experimental tests (6), the contribution of foundations and abutments to structural flexibility has been found to be significant.

The model is relatively simple in that it utilizes many of the concepts familiar to a typical designer. Admittedly, a structural designer would need to spend some time and effort to learn about the model. Learning new methods should not be considered a burden to the designer, because today's rapidly improving technology demands a commitment from engineers to continually update their knowledge.

ACKNOWLEDGMENTS

The study presented in this report was part of a continuing study at the University of Nevada, Reno (UNR) on the seismic response of highway bridges. Funding for this study was provided by the National Science Foundation grants CEE-81-08124 and CEE-84-12576.

Dr. Bruce Douglas, a professor of Civil Engineering at UNR, is thanked for his valuable comments.

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3. Saiidi, M., J. D. Hart, and B. M. Douglas, "Inelastic Static and Dynamic Analysis of Short R/C Bridges Subjected to Lateral Loads," Report No. CCEER-84-3, Civil Engineering Department, University of Nevada, Reno, July 1984.

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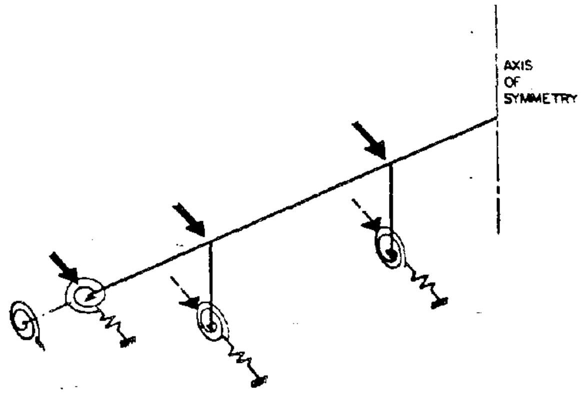

Fig. 1 The Idealized Bridge Model and the Possible Loads

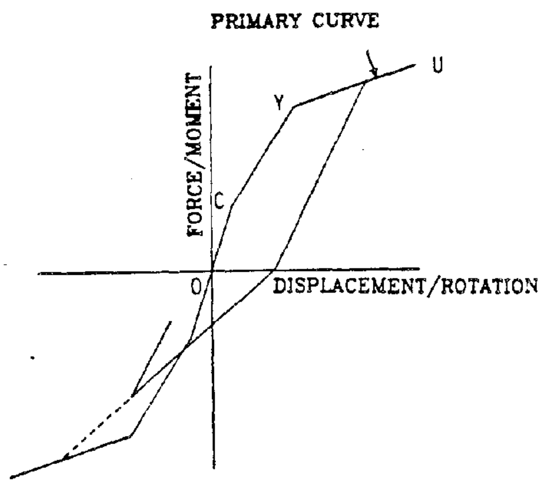

Fig. 2 The TQ-Hyst Model

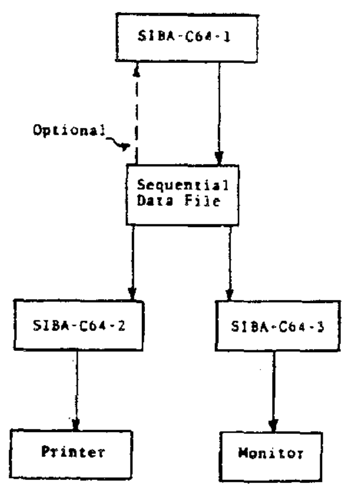

Fig. 3 Links Between Programs

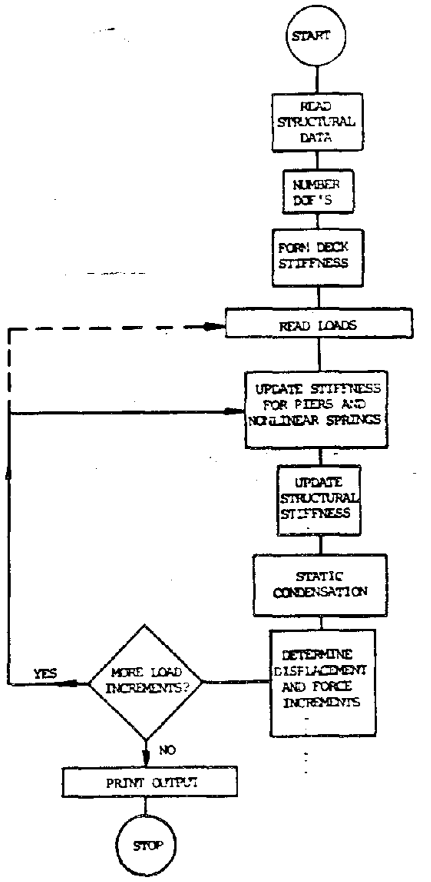

Fig. 4 Flow Chart for SIBA-C64-1

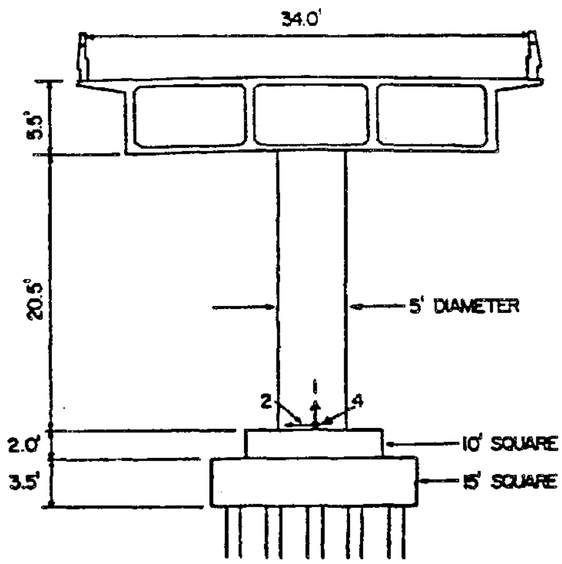

Fig. 5 Meloland Bridge Cross Section

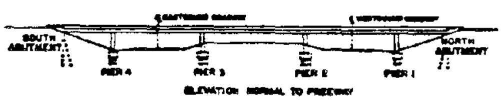

Fig. 6 The Rose Creek Bridge

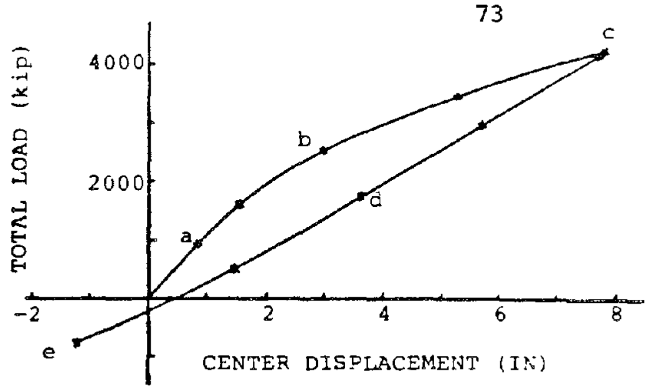

Fig. 7 Load-Displacement Response for the Meloland Bridge

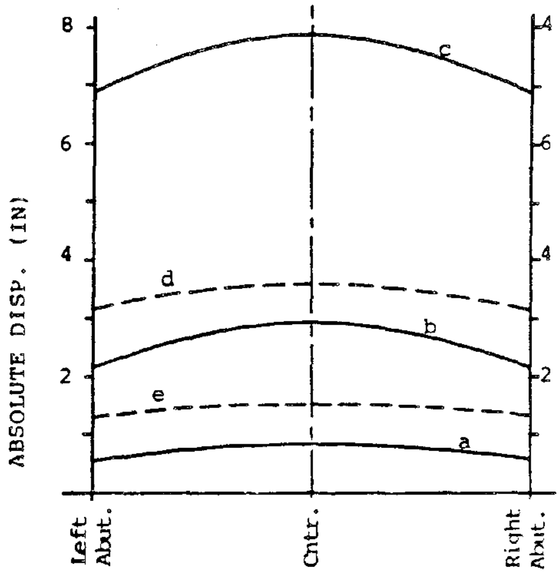

Fig. 8 Displaced Shape of the Deck for Different Loads

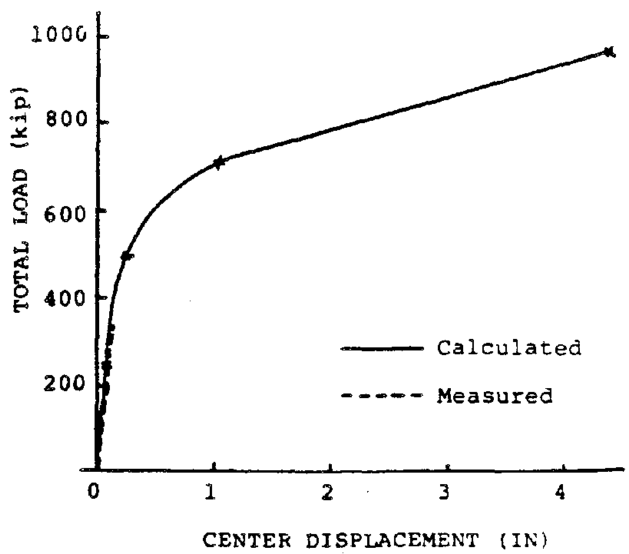

Fig. 9 Load-Displacement Response for the Rose Creek Bridge

APPENDIX B

LIST OF CCEER PUBLICATIONS

Report No.	Publication
CCEER-84-1	Saiidi, Mehdi and Renee A. Lawver, "User's Manual for LZAK-C64, A Computer Program to Implement the Q-Model on Commodore 64," Civil Engineering Department, Report No. CCEER-84-1, University of Nevada, Reno, January 1984.
CCEER-84-2	Douglas, Bruce M. and Toshio Iwasaki, "Proceedings of the First USA-Japan Bridge Engineering Workshop," held at the Public Works Research Institute, Tsukuba, Japan, Civil Engineering Department, Report No. CCEER-84-2, University of Nevada, Reno, April 1984.
CCEER-84-3	Saiidi, Mehdi, James D. Hart, and Bruce M. Douglas, "Inelastic Static and Dynamic Analysis of Short R/C Bridges Subjected to Lateral Loads," Civil Engineering Department, Report No. CCEER-84-3, University of Nevada, Reno, July 1984.
CCEER-85-1	Norris, Gary M. and Pirouze Abdollaholiaee, "Laterally Loaded Pile Response: Studies with the Strain Wedge Model," Civil Engineering Department, Report No. CCEER-85-1, University of Nevada, Reno, April 1985.
CCEER-86-1	Ghusn, George E. and Mehdi Saiidi, "A Simple Hysteretic Element for Biaxial Bending of R/C Columns and Implementation in NEABS-86," Civil Engineering Department, Report No. CCEER-86-1, University of Nevada, Reno, July 1986.
CCEER-86-2	Saiidi, Mehdi, Renee A. Lawver, and James D. Hart, "User's Manual for ISADAB and SIBA, Computer Programs for Nonlinear Transverse Analysis of Highway Bridges Subjected to Static and Dynamic Lateral Loads," Civil Engineering Department, Report No. CCEER-86-2, University of Nevada, Reno, September 1986.