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IDARC: INELASTIC DAMAGE ANALYSIS OF REINFORCED CONCRETE FRAME — SHEAR-WALL STRUCTURES

by

Young J. Park, Andrei M. Reinhorn and Sashi K. Kunnath
Department of Civil Engineering
State University of New York at Buffalo
Buffalo, NY 14260

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16. Abstract (Limit: 200 words)

The needs for analytical tools to support experiments and design processes led the authors to develop a computer program for the Inelastic Damage Analysis of Reinforced Concrete Frame-Shear Wall Structures, IDARC. The program, based on original developments of constitutive models and structural modeling, performs an equivalent static and dynamic response analysis of R/C structures under earthquake excitations. Currently available programs for inelastic dynamic analysis of reinforced concrete structures possess various drawbacks. Program IDARC overcomes the above drawbacks as is evident from the following features: the equivalent static analysis determines the component properties including the identification of the inelastic behavior and failure mode under monotonic loads, as well as the determination of the natural period of the structure. The step-by-step inelastic dynamic response analysis is performed using a 'three-parameter' hysteretic model for reinforced concrete elements which permit modeling of shear and flexure differently. The formulation enables the subsequent damage analysis, both local and global, as well as the substructure analysis of individual components; strength levels are computed by the program and change progressively with the behavior of the component. The present developments are based on state-of-the-art in modeling of reinforced concrete behavior and structural analysis. This report presents a detailed description of new structural modelling techniques and the hysteretic models used in the analysis. Details of program organization, mathematical formulations and a user guide with a numerical example are presented herein.

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Young J. Park[1], Andrei M. Reinhorn[2] and Sashi K. Kunnath[3]

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1 Visiting Assistant Professor, Dept. of Civil Engineering, State University of New York at Buffalo
2 Associate Professor, Dept. of Civil Engineering, State University of New York at Buffalo
3 Graduate Student, Dept. of Civil Engineering, State University of New York at Buffalo

NATIONAL CENTER FOR EARTHQUAKE ENGINEERING RESEARCH
State University of New York at Buffalo
Red Jacket Quadrangle, Buffalo, NY 14261

ABSTRACT

The needs for analytical tools to support experiments and design processes led the authors to develop a computer program for the Inelastic Damage Analysis of Reinforced Concrete Frame-Shear Wall Structures, IDARC. The program, based on original developments of constitutive models and structural modeling, performs an equivalent static and a dynamic response analysis of R/C structures under earthquake excitations.

Currently available programs for inelastic dynamic analysis of reinforced concrete structures possess one or more of the following drawbacks: the analysis is carried out using equivalent properties of cracked or damaged sections using elastic models; the inelastic analysis is done using advanced hysteretic models that are general in nature but which do not always fit R/C component behavior (shear and flexure); strength limits have to be precomputed off-line and remain unchanged during the analysis.

Program IDARC overcomes the above drawbacks as is evident from the following features:

The equivalent static analysis determines the component properties including the identification of the inelastic behavior and failure mode under monotonic loads, as well as the determination of the natural period of the structure.

The step-by-step inelastic dynamic response analysis is performed using a 'three-parameter' hysteretic model for reinforced concrete elements which permit modeling of shear and flexure differently. The formulation enables the subsequent damage analysis, both local and global, as well as the substructure analysis of individual components.

Strength levels are computed by the program and change progressively with the behavior of the component.

The present developments are based on state-of-the-art in modeling of reinforced concrete behavior and structural analysis. This report presents a detailed description of new structural modelling techniques and the hysteretic models used in the analysis. Details of program organization, mathematical formulations and a user guide with a numerical example are presented herein.

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SECTION 1
INTRODUCTION

During the last three decades, a considerable amount of experimental research has been carried out in order to identify the inelastic behavior of reinforced concrete components and joints under earthquake-like loading reversals. Past experiments of columns and beams have shown that several structural parameters, such as concrete strength, longitudinal steel ratio, shear span ratio, stirrup ratio and axial stress level, affect the deformation and energy absorbing characteristics which may be observed as strength deterioration, stiffness degradation and pinching behavior in the load-deformation relation [1-8].

A comprehensive testing program on columns and shear walls revealed that loading history may also affect the deformation and damage characteristics considerably [9-10].

Based on the information of the hysteretic behavior of components, numerous studies have been carried out to obtain a realistic prediction of the inelastic dynamic response of reinforced concrete frames utilizing matrix analysis techniques [11-12].

Several computer programs are available in open publications including the one by the University of Illinois [13], the University of California, Berkeley [14], and the University of Tokyo [15]. Comprehensive literature surveys in this area are also available [16-17].

However, none of the available programs for inelastic dynamic analysis are capable of reproducing the complex hysteretic behavior of reinforced concrete under earthquake loadings.

Currently available programs for inelastic dynamic analysis of reinforced concrete possess one or more of the following drawbacks:

1. The analysis is carried out using equivalent properties of cracked or damaged sections with elastic models.

2. The inelastic analysis is done using advanced hysteretic models that are general in nature but which do not always fit R/C component behavior (shear and flexure).

3. Strength limits have to be precomputed off-line and remain unchanged during the analysis.

In addition to overcoming all of the above drawbacks, program IDARC was also conceived and developed as an analytical tool to support dynamic testing and aid design processes of reinforced concrete components and structures.

Program IDARC is developed based on current knowledge of structural properties of reinforced concrete components and structural modelling techniques, the details of which are presented in this report.

This report is also meant to serve as the user's manual of the computer program IDARC, which performs both the static and dynamic analysis of reinforced concrete structures under earthquake loadings, including a comprehensive damage analysis of the structure and its components.

The static analysis consists of the evaluation of strength and deformation parameters of each structural component, a failure analysis under monotonic loading and determination of the fundamental natural period of the structure.

The ensuing step-by-step dynamic response analysis yields the maximum response values and dissipated hysteretic energy which serve as input for the final damage analysis. The program has been designed to also determine the individual response of selected sub-structures.

Background information on component modelling, hysteretic modelling and structural modelling are provided in detail in Section 2. The mathematical modelling of the building components are specified in Section 3 including the development of the element stiffness matrices and the coordinate system that define the discretized building system. A numerical example of a realistic building analysis is also included.

A users guide to data input and output interpretation of program IDARC is presented in the Appendices.

SECTION 2
THEORY AND BACKGROUND

2.1 Structure Modelling

A reinforced concrete building is modelled using the following five element types:

1. Beam elements
2. Column elements
3. Shear wall elements
4. Edge column elements
5. Transverse beam elements

The modelling of the above components for a typical reinforced concrete frame - shear wall type building is illustrated in Fig. 2-1. Beams and columns are modelled as continuous flexural springs and shear walls are modelled by a combination of flexural and shear deformation springs. The edge columns of a shear wall can be modelled separately using one-dimensional springs. The main transverse beams which contribute to the stiffness of the building are assumed to have an effect on the rotational deformation of the shear walls or beams to which they are connected and are modelled using elastic linear and rotational springs (Fig. 2-1). Although axial deformation in columns and shear walls are considered in the analysis, the interaction between axial load and bending moment during earthquake motions is not included.[1] The combination of the above five element types allows for a wide variety of structural configurations.

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[1]Work is currently underway at the University of Buffalo to include this effect.

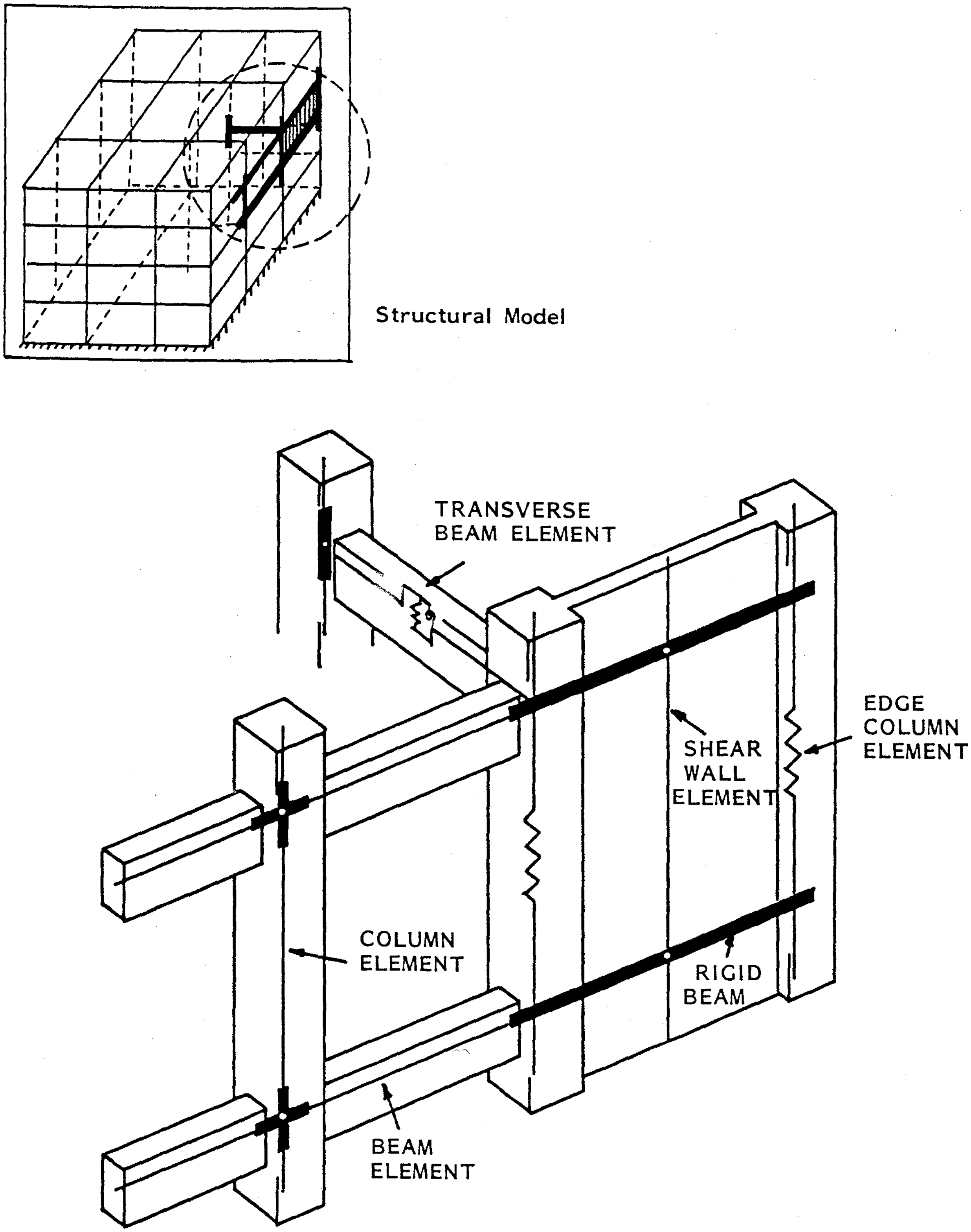


FIGURE 2-1 Component Modeling

Modelling of the inelastic deformation behavior and associated description of the constituent components is the fundamental basis for the structural idealization. The so-called 'hinge model' developed for steel frames may not be suitable for reinforced concrete structures since the inelastic deformation is distributed along the member length rather than being concentrated at critical sections.

2.2 New Distributed Model

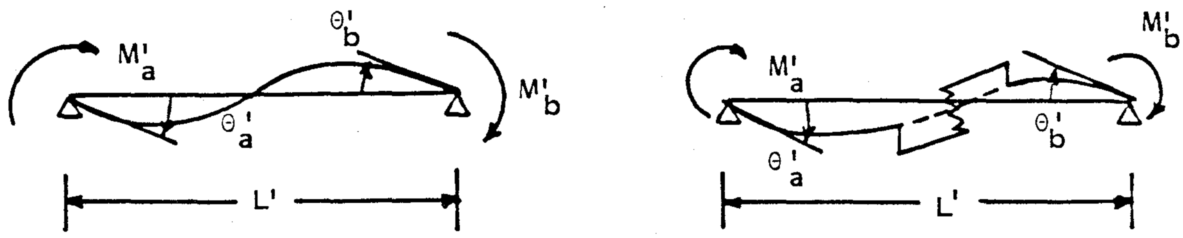
The inelastic beam model used in the analysis of beams, columns and shear walls is illustrated in Figs. 2-2 and Fig. 2-3. In the proposed model, the flexibility factor, 1/EI, is assumed to be linearly distributed along the member between the two critical sections and the point of contraflexure. The flexural factors at the critical sections are monitored throughout the analysis to keep updating the inelastic behavior of the components during earthquake action; an elastic property is given to the section at the contraflexure point as shown in Fig. 2-3. The flexibility matrix is expressed in the following incremental form (based on the notation in Figs. 2-2 and 2-3):

$$\begin{Bmatrix} \Delta\Theta'_a \\ \Delta\Theta'_b \end{Bmatrix} = L' \begin{bmatrix} f_{11} & f_{12} \\ f_{21} & f_{22} \end{bmatrix} \begin{Bmatrix} \Delta M'_a \\ \Delta M'_b \end{Bmatrix} \tag{2.1}$$

where, for case (a):

$$f_{11} = \frac{1}{12(EI)_a} (6\alpha - 4\alpha^2 + \alpha^3) +$$

$$\frac{1}{12(EI)_b} (1 - 3\alpha + 3\alpha^2 - \alpha^3) + \frac{1}{12(EI)_o} (3 - 3\alpha + \alpha^2) \quad \text{(a)}$$



(a) Flexural Spring (b) Shear-Flexure Spring

FIGURE 2-2 Inelastic Springs

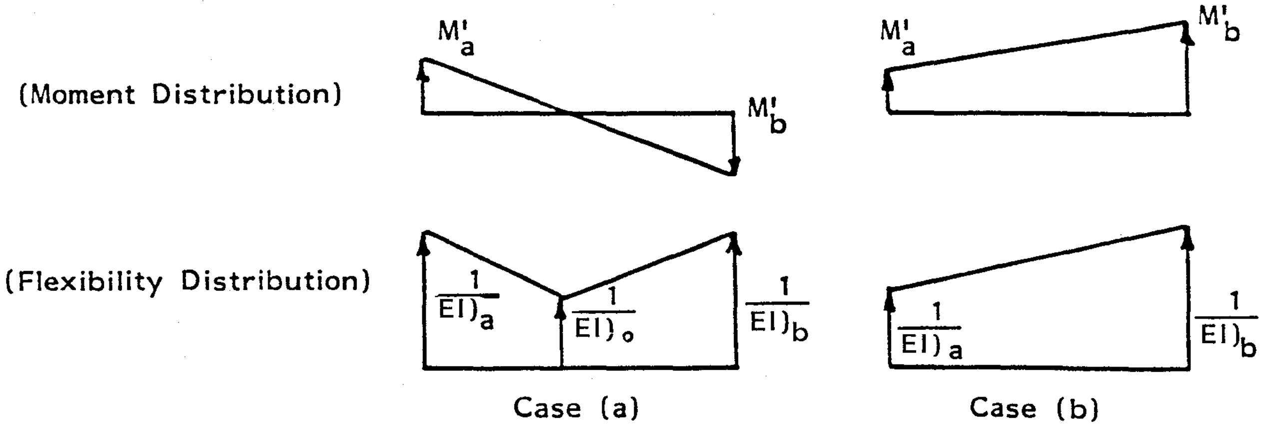


FIGURE 2-3 Distribution of Flexibility

$$f_{12} = f_{21} = \frac{1}{12(EI)_a} (-2\alpha^2 + \alpha^3) +$$

$$\frac{1}{12(EI)_b} (-1 + \alpha + \alpha^2 - \alpha^3) + \frac{1}{12(EI)_o} (-1 - \alpha + \alpha^2) \quad \text{(b)}$$

$$f_{22} = \frac{1}{12(EI)_a} \alpha^3 + \frac{1}{12(EI)_b} (3 - \alpha - \alpha^2 - \alpha^3)$$

$$+ \frac{1}{12(EI)_o} (1 + \alpha + \alpha^2) \quad \text{(c)}$$

and, for case (b):

$$f_{11} = \frac{1}{4(EI)_a} + \frac{1}{12(EI)_b}$$

$$f_{21} = f_{12} = -\frac{1}{12(EI)_a} - \frac{1}{12(EI)_b}$$

$$f_{22} = \frac{1}{12(EI)_a} + \frac{1}{4(EI)_b}$$

where:

$$\alpha = \frac{M'_a}{M'_a + M'_b}$$

In evaluating the flexural stiffness, $(EI)_a$ and $(EI)_b$, the increase in deformation due to shear cracking and bond slippage from the anchorage should be carefully considered. Detailed quantification of the inelastic deformation characteristics is presented in the next section.

For shear wall elements, the shear spring and flexural spring are connected in series such that shear and flexural failure can be considered independently (see Fig. 2-2b). Accordingly, the flexibility matrix is modified as follows:

$$\begin{bmatrix} \text{flexibility} \\ \text{matrix} \end{bmatrix} = L' \begin{bmatrix} f_{11} & f_{12} \\ f_{21} & f_{22} \end{bmatrix} + \frac{1}{GAL'} \begin{bmatrix} 1 & 1 \\ 1 & 1 \end{bmatrix} \tag{2.2}$$

where:

G = Shear rigidity

A = Area of cross-section of the shear wall.

2.3 Strength - Deformation Models

2.3.1 Beams and Columns

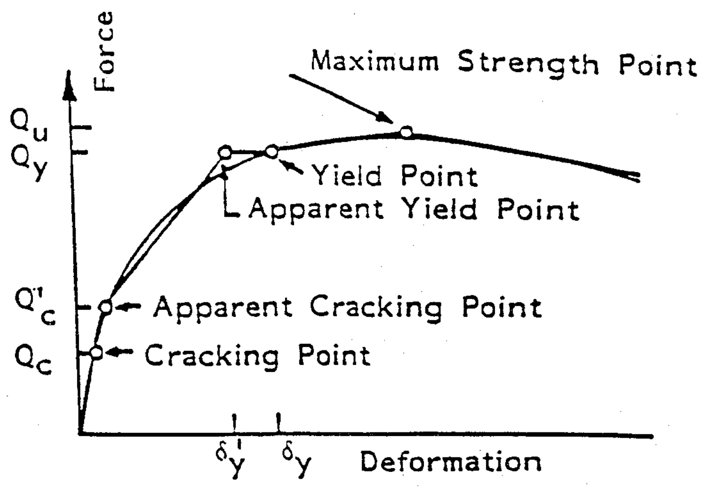
It is common practice to describe the envelope curve of the restoring force-deformation relation of reinforced concrete components by a multi-linear function with three turning points; viz., the cracking point, the yield point and the ultimate strength point as shown in Fig. 2-4.

For beams and columns, the strength - deformation relation is expressed as moment vs. curvature. The cracking, yield and ultimate moments (M_c, M_y and M_u respectively) may be expressed empirically as follows [18]:

$$M_c = 11.\sqrt{f'_c}\ Z_e + Nd/6 \tag{2.3}$$

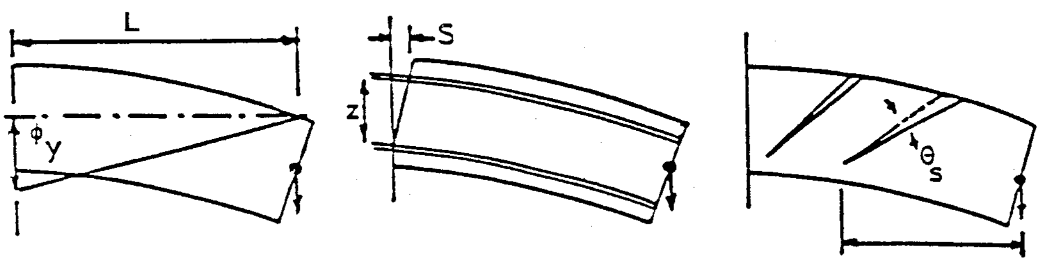
$$M_y = 0.5\ f'_c\ bd^2\ \{(1 + \beta_c - \eta)\ n_o + (2 - \eta)p_t + (\eta - 2\beta_c)\ \alpha_c\ p'_t\} \tag{2.4}$$

$$M_u = (1.24 - 0.15p_t - 0.5\eta_o)M_y \tag{2.5}$$



(Envelop Curve)

FIGURE 2-4 Multilinear Envelop Curve



$\delta_f = \varphi_y \cdot L^2/3$

$\delta_b = S \cdot L/z$

$\delta_s = \Sigma\ L_i \times \Theta_s$

flexure

bond

shear

FIGURE 2-5 Components of Inelastic Deformation at Yield

where:

$$p_t = \frac{A_t f_y}{bd\ f'_c} \quad ; \quad p'_t = \frac{A_c f_y}{bd\ f'_c} \quad ; \quad n_\circ = \frac{N}{bd\ f'_c} \quad ; \quad \alpha_y = \frac{\varepsilon_y}{\varepsilon_\circ} \quad ;$$

$$\beta_c = \frac{d_c}{d} \quad ; \quad \alpha_c = (1 - \beta_c)\ \frac{\varepsilon_c}{\varepsilon_y} - \beta_c \leq 1.0; \ \eta = \frac{0.75}{1-\alpha_y} \left(\frac{\varepsilon_c}{\varepsilon_\circ}\right)^{0.7}$$

in which:

b = Width of components' cross-section
d = Computational depth of components' cross-section
d_c = Cover depth for compression bars
A_t = Areas of tensile reinforcing bars
A_c = Areas of compressive reinforcing bars
f'_c = Material strength of concrete in ksi
f_y = Material strength of steel in ksi
N = Axial load
Z_e = Section modulus
ε_0 = Strains at maximum strength of concrete
ε_y = Strains at yield stress of steel
ε_c = Extreme compression fiber strain

The yield curvature of reinforced concrete can be estimated as the sum of the flexural deformation, φ_f, the deformation due to bond-slippage, φ_b, the inelastic shear deformation , φ_s, and the elastic shear deformation ,φ_e (see Fig. 2-5):

$$\varphi_y = \varphi_f + \varphi_b + \varphi_s + \varphi_e \tag{2.6}$$

'φ_e' may be evaluated by the conventional elastic beam theory. However, a more accurate approximation is required for the remaining parameters. Empirical formulations for estimating these deformations are described below.

The flexural yield curvature is determined with reasonable accuracy by the 'plane-section' assumption with linear curvature distribution along the member. The yield curvature is accordingly expressed as [19]:

$$\varphi_f' = \frac{\varepsilon_y}{(1-k)d} \tag{2.7}$$

where:

$$k = \left\{(p_t + p_t')^2 \frac{1}{4\alpha_y^2} + (p_t + \beta_c\, p_t') \frac{1}{\alpha_y}\right\}^{\frac{1}{2}} - (p_t + p_t') \frac{1}{2\alpha_y}$$

Since the relation in Eq.(2.7) underestimates the yield curvature, the following modification is suggested to include the effect of the inelasticity of concrete and the axial stress in columns [18]:

$$\varphi_f = \left(1 + \frac{1.5n_\circ}{0.84 + 2p_t' - p_t}\right) \varphi_f' \tag{2.8}$$

The curvature due to bond-slippage has been determined based on available pullout data [18]. At yielding, the slippage of tension bars, 'S', is expressed as follows:

$$S/D = 0.0003\, f_y^{1.5}\, \tau_m^{-0.75} \tag{2.9}$$

where:

D = Bar diameter
f_y = Yield strength of the steel
τ_m = Maximum bond strength of concrete

The value of 'τ_m' ranges from 0.9 to 1.5 ksi, and is a function of the degree of compactness of concrete. A mean value of τ_m =

1.2 ksi may be assumed if the degree of compactness is not specified. The equivalent curvature for bond slippage assuming linear curvature distribution along the member is given by the following relation (Fig. 2-5b):

$$\varphi_b = \frac{3S}{zL} \tag{2.10}$$

The determination of the inelastic shear deformation 'Φ_b' is more difficult due to the unpredictable shear cracking mechanism. The shear cracking model developed in Ref. [18] is used to evaluate the shear deformation in the present analysis. Details of the model may be found in Ref. [18]. The equivalent curvature due to shear cracking is (Fig. 2-5c):

$$\varphi_s = 3\left\{\frac{1}{L} + \frac{1-(L_s'/L)^2}{2z}\right\}\Theta_s \tag{2.11}$$

where:

L = Shear span
z = Arm between the tension and compression reinforcement
L_s = Length of a "no shear crack zone"
Θ_s = Shear rotation.

The length 'L_s' can be obtained as:

$$L_s' = \frac{M_c}{\{(M_y L - \sqrt{f_c'}\,bd) + z\}} \tag{2.12}$$

The shear rotation 'Θ_s' is a function of the shear span ratio 'L/d' (replaced by 1.5 if $L/d < 1.5$), stirrup ratio in percent 'p_w'(replaced by 0.2% if $p_w < 0.2\%$) and the normalized average bond stress, $u = \tau_b/\sqrt{f_c'}$, as follows:

$$A_s = \frac{0.002}{L/d - 0.5} \quad ; \qquad u < 5 \text{ or } \frac{L}{d} > 4$$

$$= \frac{0.002}{L/d - 0.5} \left\{1 + 0.27(u-5)\right\} \; ; \qquad u > 5 \text{ and } 2.5 < \frac{L}{d} < 4$$

$$= \frac{0.002}{L/d - 0.5} \left\{1 + 0.185 \frac{(u-5)}{\sqrt{p_w} - 0.4}\right\} ; \qquad u > 5 \text{ and } \frac{L}{d} < 2.5 \qquad (2.13)$$

The strength model described above for beam and column type elements has been used successfully in Ref. [18] and was consequently adopted for the development of program IDARC.

2.3.2 Shear Walls

The strength - deformation parameters for shear wall elements arise from the following:

1. Flexural behavior
2. Shear behavior

The flexural deformation characteristics of shear walls having different cross-sections may be estimated using the traditional fiber-model analysis [19], the details of which are described in Section 3.

The inelastic shear behavior of shear walls is evaluated based on regression analysis of a large number of test data presented in Ref [9]. The cracking and yield shear strengths 'V_c' and 'V_y' are determined from the following empirical relations:

$$V_c = \frac{0.6\ (f'_c + 7.11)}{M/(VL_w) + 1.7}\ b_e\ L_w \qquad (2.14)$$

$$V_Y = \left\{ \frac{0.08\ \rho_t^{0.23}(f'_c + 2.56)}{M/(VL_w) + 0.12} + 0.32\sqrt{f_Y \rho_w} + 0.1\ f_a \right\} b_e\ L_w \tag{2.15}$$

where:

$M/(VL_w)$ = Shear span ratio
ρ_t = Tension steel ratio in percent
ρ_w = Wall reinforcement ratio
f_a = Axial stress
b_e = Equivalent web thickness
L_w = Distance between edge columns.

The yield shear deformation may be determined from the secant stiffness 'k_Y' as follows:

$$k_Y = \beta_s k_e \quad ; \quad \beta_s = \frac{0.5M}{(VL_w)} \tag{2.16}$$

where:

k_e = Elastic shear stiffness.

The above relations which resulted from the parametric analysis of test data [9] was found to be the most suitable for defining the shear properties of walls and was, therefore, used in the development of program IDARC.

2.4 Inelastic Model

For the inelastic analysis, a proper selection of hysteretic models for the constituent components is one of the critical factors in successfully predicting the dynamic response under strong earthquake motions. Several models have been proposed in the past for reproducing various aspects of reinforced concrete behavior under inelastic loading reversals. In order to closely reproduce the hysteretic behavior of various components, a highly versatile model is required in which several significant aspects of hysteretic loops can be included, i.e., stiffness degradation, strength deterioration, pinching behavior and the variability of hysteresis loop areas at different deformation levels under repeated loading reversals. However, the model should also be as simple as possible since a large number of inelastic springs are necessary in modelling the entire structure, and additional parameters to describe a complicated hysteresis loop shape may sometimes require excessive amount of information.

Some of the existing popular models: Clough [21], Fukada [22], Aoyama [20], Kustu [5], Tani [23], Takeda [24], Park [18], Iwan [25], Takayanagi [12], Muto [26], Atalay [4] and Nakata [27] are shown in Fig. 2-6. A critical evaluation of these models relating to their versatility and complexity is presented in Table 2-I. It appears that most of the available models are aimed at a particular type of component, such as for the use of beams, columns or shear walls only, and therefore, fall short of the versatility required for modelling practical buildings having a large number of different components. A different model which fit most of the typical building components is suggested herein and comprises the major inelastic model used in the development of the program.

2.4.1 Three Parameter Model

The hysteretic model (the three parameter model) that has been developed for use in program IDARC is illustrated in Fig. 2-7. A variety of hysteretic properties are obtained through the combination of the trilinear skeleton curve and the three parameters 'α', 'β' and 'γ'. The values of these parameters determine the properties of stiffness degradation, strength deterioration and pinching behavior, respectively. When the parameters assume program default values, i.e. $\alpha => \infty$, $\beta = 0$

Table 2.I Comparison of Hysteretic Models

		Controlled Parameters				Comparative Remarks		
Model	Type	Stiffness Degradation	Pinching	Strength Deterioration	Hysteresis Loop Area	Additional* Parameters	Overall Versatility	Overall Complexity
Clough	S	N	N	N	N	0	L	L
Fukuda	S	Y	N	N	N	0	L	L
Aoyama	S	N	Y	Y	Y	4	M	H
Kustu	S	N	Y	N	N	4	M	H
Tani	S	Y	N	N	Y	2	H	M
Takeda	S	Y	N	N	N	1	L	M
Park	C	Y	N	N	Y	2	H	H
Iwan	S	N	Y	N	Y	1	L	M
Takayanagi	S	Y	Y	Y	N	3	M	M
Muto	S	Y	N	N	N	0	L	L
Atalay	C	Y	Y	N	N	4	L	H
Nakata	C	Y	Y	Y	Y	6	H	H

* Bending envelope characteristics

Notation:

Y: Yes
N: No
S: Straight Line
C: Curved Line (continuous)

L: Low
M: Medium
H: High

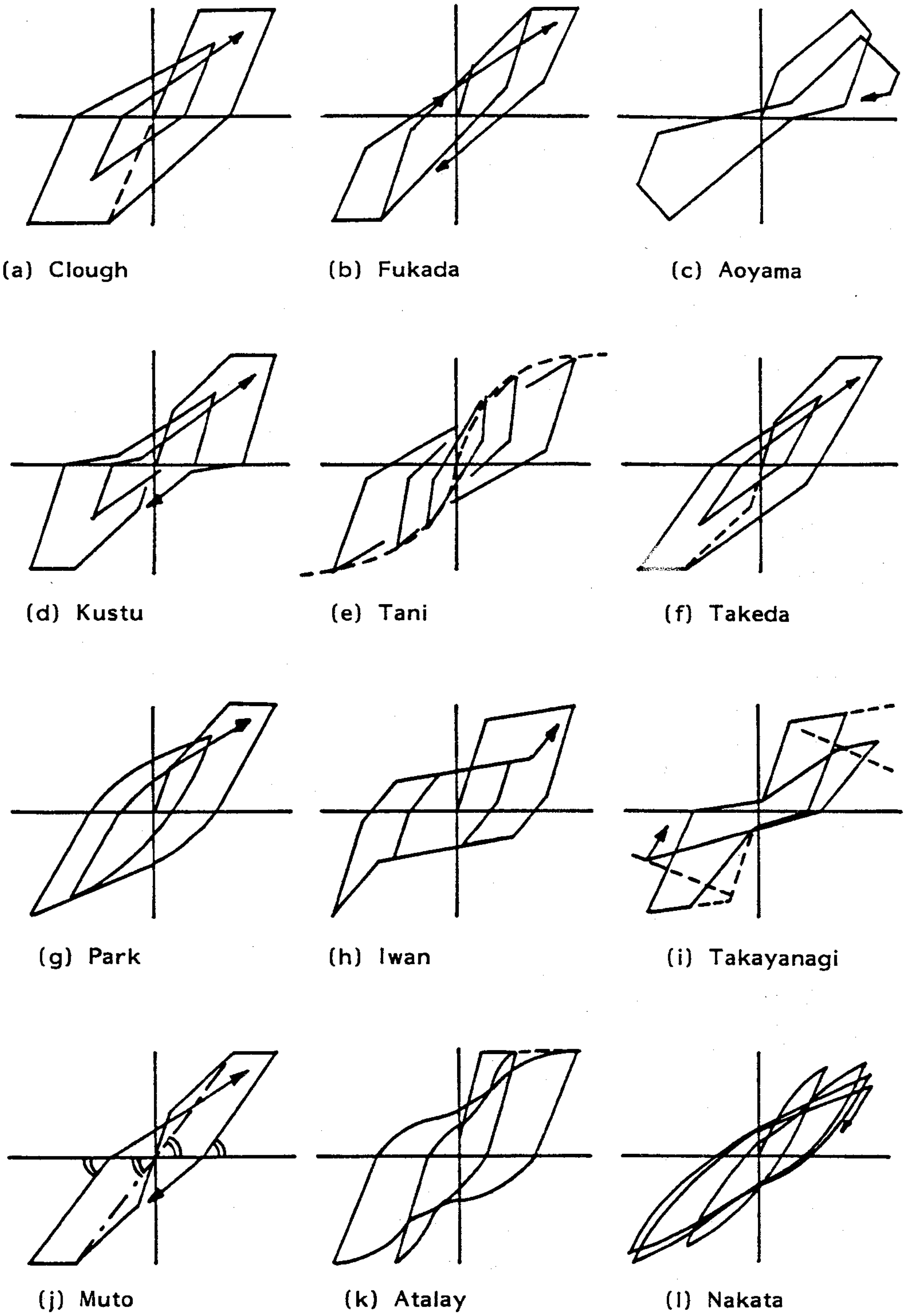
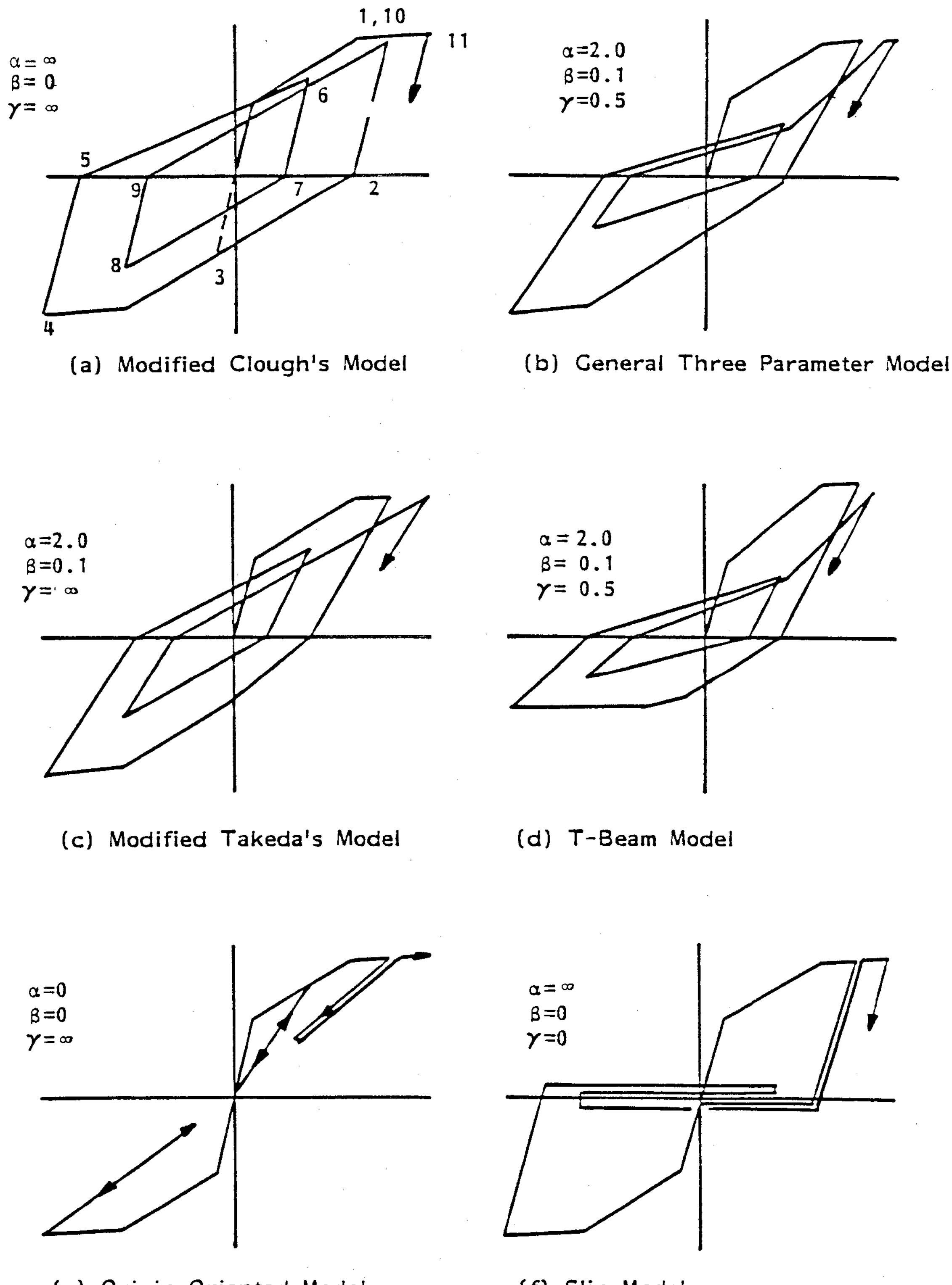


FIGURE 2-6 Hysteretic Models



(a) Modified Clough's Model

(b) General Three Parameter Model

(c) Modified Takeda's Model

(d) T-Beam Model

(e) Origin-Oriented Model

(f) Slip Model

FIGURE 2-7 Versatility of Three Parameter Model and $\gamma \Rightarrow \infty$, a hysteretic property similar to the Clough model [21] is obtained as shown in Fig. 2-7a.

The hysteretic model shown in Fig. 2-7c is quite similar to the Takeda model [24], except for strength deterioration, and may be exclusively used for the flexural springs of various components.

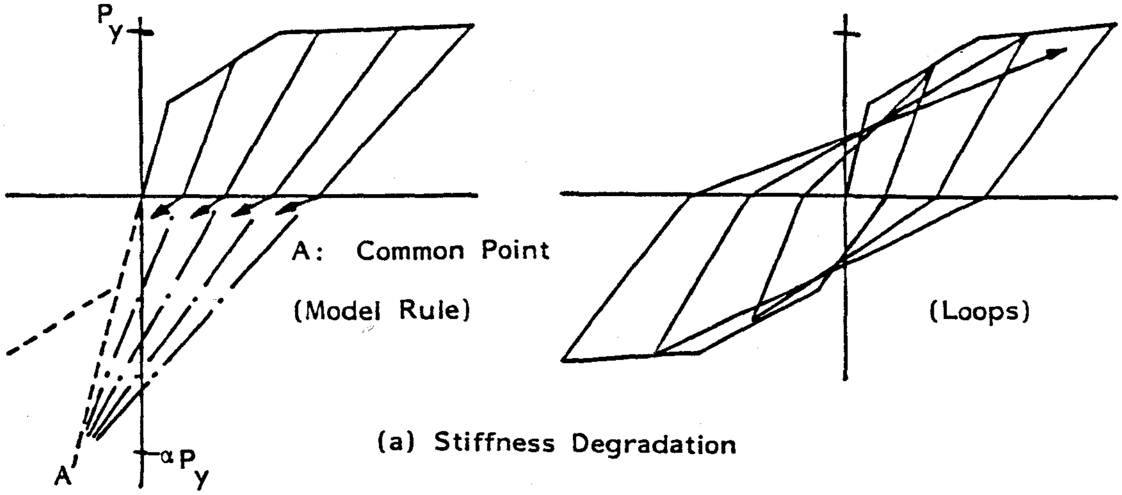
T-Beams, however, due to a large difference in the longitudinal steel ratios between the top and bottom bars, generally show a biased pinching behavior in the region of negative moment. Such a model is shown in Fig. 2-7d.

The inelastic shear spring, which is connected to the flexural spring of shear walls in series, is modelled using the origin-oriented model of Fig. 2-7e (for concrete) and the slip model of Fig. 2-7f (for masonry walls).

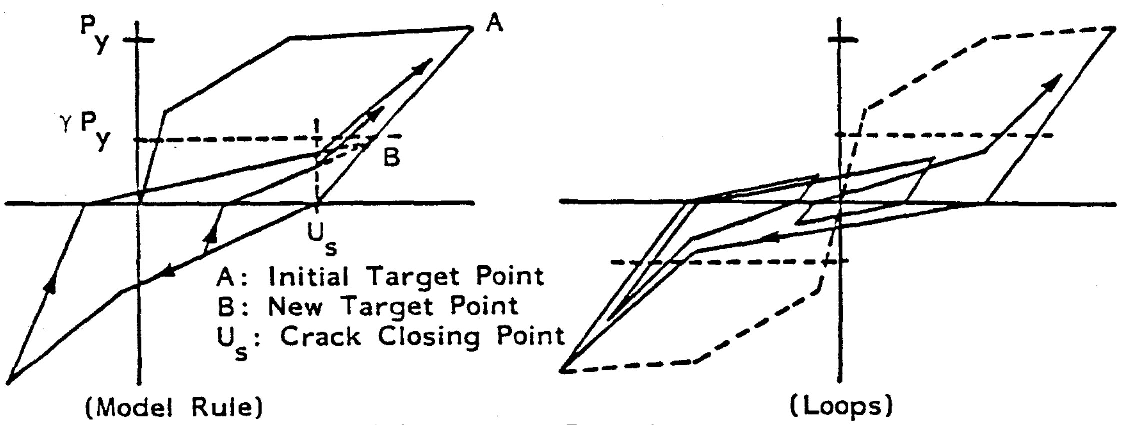
Fig. 2-8 illustrates the manner in which the three parameters 'α', 'β' and 'γ', transform the original hysteretic model of Fig. 2-7a:

1. The stiffness degradation is introduced by setting a common point on the extrapolated initial skeleton curve line, and assumes that the unloading lines aim at this point until they reach the x-axis (Fig. 2-8a). The parameter 'α' specifies the degree of stiffness degradation, and, more importantly, the area enclosed by the hysteresis loops; a comparison of Figs. 2-8a,c,e clarifies how the parameter 'α' changes the hysteresis loops.

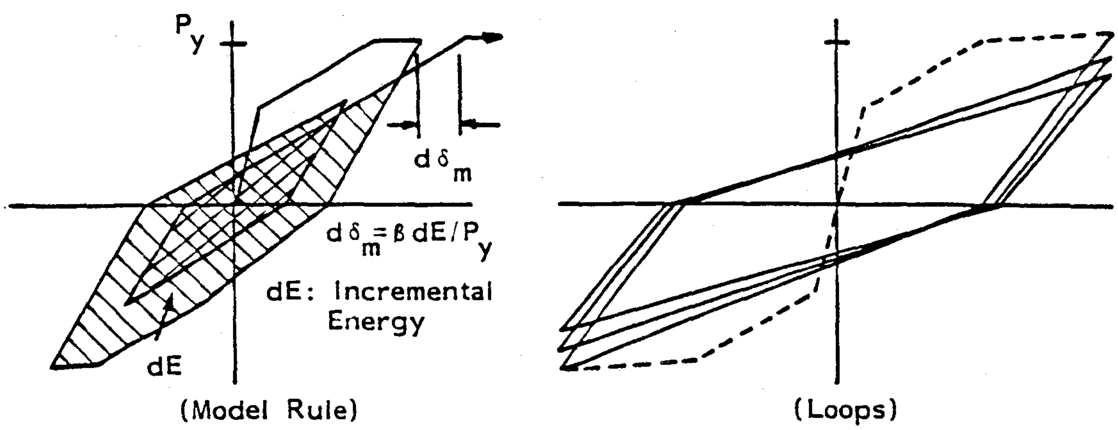
2. The pinching behavior is introduced by lowering the target maximum point (point A in Fig. 2-8b) to a straight level of 'γP_y' (point B in Fig. 2-8b) along the previous unloading line. Reloading points aim this new target point 'B' until they reach the crack closing deformation ('u_s' of Fig. 2-8b). The stiffness of reloading paths is changed at this



(a) Stiffness Degradation



(b) Pinching Behavior



(c) Strength Deterioration

FIGURE 2-8 Effects of Three Parameters

point to aim the previous target maximum point 'A'. The introduction of such a pinching behavior also leads to a reduction of hysteresis loop areas and indirectly, the amount of dissipated energy.

3. The parameter 'β' specifies the rate of strength degradation as illustrated in Fig. 2-8c. The same parameter 'β' may be found in the definition of the damage index ,D, which defines the earthquake structural damage as a linear combination of the maximum deformation 'δ_m' and the absorbed hysteretic energy $\int dE$ as follows [18]:

$$D = \frac{\delta_m}{\delta_u} + \frac{\beta}{\delta_u P_y} \int dE \tag{2.17}$$

where:

D = Damage index scaling the structural damage from zero to one
δ_u = Ultimate deformation under monotonic loading
P_y = Yield strength

The parameter β gives the ratio of the incremental damages caused by the increase of the maximum response, $d\delta_m/\delta_u$, to the normalized incremental hysteretic energy, $dE/(\delta_u P_y)$, as follows:

$$\beta = \frac{d\delta_m / \delta_u}{dE/(\delta_u P_y)} = \frac{d\delta_m}{dE/P_y} \tag{2.18}$$

As illustrated in Fig. 2-8c, the incremental increase of the maximum deformation due to the dissipated hysteretic energy is expressed as follows:

$$d\delta_m = \beta \; dE/P_y \tag{2.19}$$

The value of 'β' can be determined as a function of several parameters (described in the next section).

The other two parameters, 'α' and 'γ' are difficult to quantify. The use of available or preliminary quasi-static testing results of similar components, i.e., having similar structural parameters such as shear span ratio, steel ratio and axial stress, may be a practical way to determine such values.

The details of the computational algorithm for the three-parameter model are described in the next section.

2.4.2 Hysteretic Rule

The properties of the hysteretic rule which govern the inelastic behavior of the building components is presented in this section.

The skeleton curve is shown in Fig. 2-9. Nine constants are necessary to determine a non-symmetric trilinear curve. The unloading and reloading curves are illustrated in Fig. 2-10. As mentioned previously, the unloading lines b-c and f-g aim the common points 'm' and 'n' until they reach the x-axis. Therefore, the first unloading line in both the positive and negative regions, E_1^+ and E_1^- are:

$$E_1^+ = (P_e^+ + \alpha \; P_y^+) \; / \; (u_e^+ + \alpha \; P_y^+/E_o)$$

$$E_1^- = (P_e^- + \alpha \; P_y^-) \; / \; (u_e^- + \alpha \; P_y^-/E_o) \tag{2.20}$$

(The variables for this relation and those for subsequent equations are shown in Figs. 2-9 - 2-12.)

The second unloading lines, i.e., lines c-d and g-h will ai- the minimum and maximum points 'f' and 'g', respectively. When the

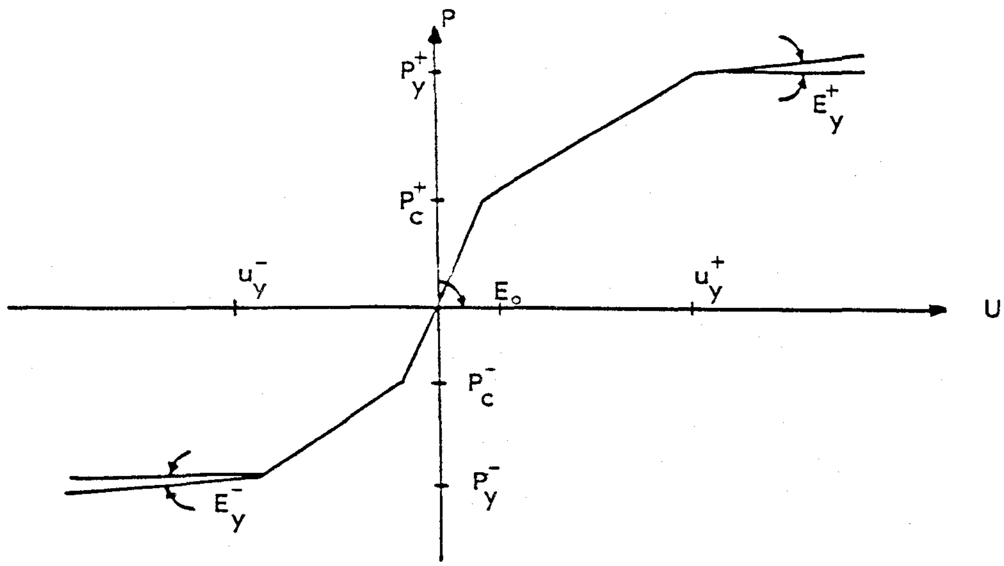


FIGURE 2-9 Nonsymmetric Trilinear Skeleton Curve

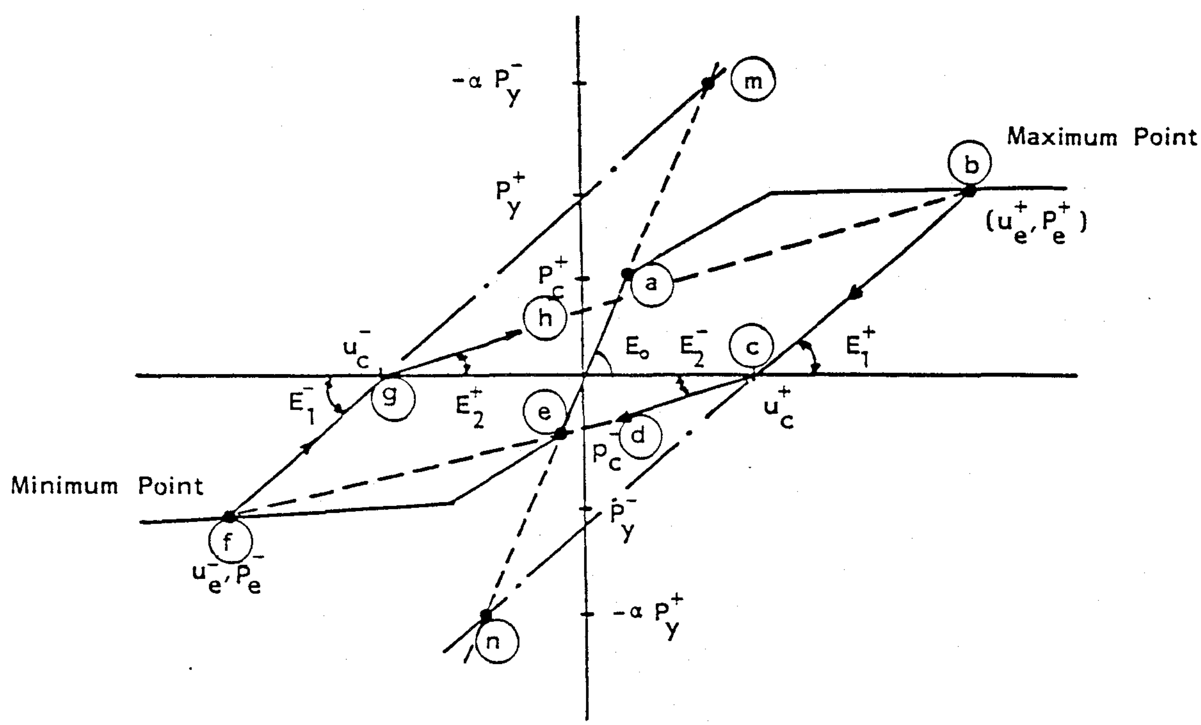


FIGURE 2-10 Unloading Stiffness

maximum or minimum point is in the elastic range, the second unloading line will aim the cracking point, i.e., the line c-d will aim point 'e' if the minimum point is still in the elastic range. Therefore, the second unloading stiffness is:

$$
\begin{aligned}
E_2^+ &= P_e^+/(u_e^+ - u_c^-) && \text{if } P_e^+ > P_c^+ \\
&= P_c^+/(P_c^+/E_\circ - u_c^-) && \text{if } P_e^+ < P_c^+ \\
E_2^- &= P_e^-/(u_e^- - u_c^+) && \text{if } P_e^- < P_c^- \\
&= P_e^-/(P_c^-/E_\circ - u_c^+) && \text{if } P_e^- > P_c^-
\end{aligned}
\tag{2.21}
$$

Fig. 2-11 illustrates up to nine loading paths. Loading paths from 1 to 5 define the envelop curve, whereas loading paths from 6 to 9 are used to identify the unloading curves in both positive and negative directions.

When pinching is considered, six more branches are necessary as shown in Fig. 2-12. At the crack-closing deformation, U_s^+ and U_s^-, the second unloading lines change their stiffness. The branches 10 and 11 may be called the third unloading and reloading lines, whereas branches 12 to 15 are assigned to the unloading lines within a hysteresis loop. Due to pinching, the stiffness 'E_2' of the second unloading and reloading lines may be calculated as follows (instead of Eq. 2.21):

$$
\begin{aligned}
E_2^+ &= P_s^+/(P_s^+/E_1^+ + u_s^+ - u_s^-) \\
E_2^- &= P_s^-/(P_s^-/E_1^- + u_s^- - u_s^+)
\end{aligned}
\tag{2.22}
$$

The third unloading and reloading lines are:

$$
\begin{aligned}
E_3^+ &= (P_e^+ - E_2^+(u_s^+ - u_s^-))/(u_e^+ - u_s^+) \\
E_3^- &= (P_e^- - E_2^-(u_s^- - u_s^+))/(u_e^- - u_s^-)
\end{aligned}
\tag{2.23}
$$

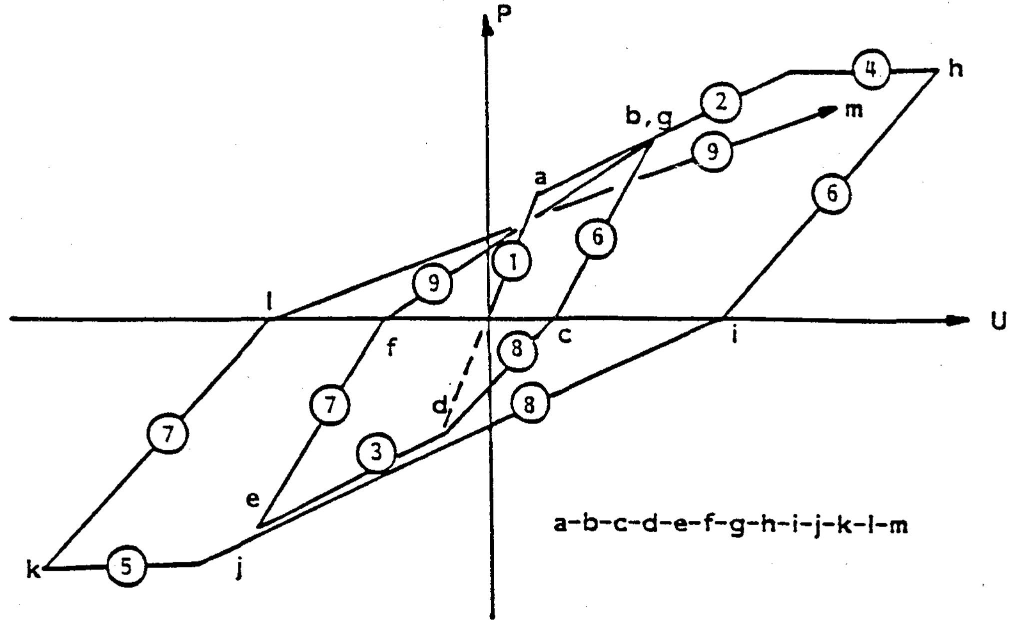


FIGURE 2-11 Branch Number and Loading Path

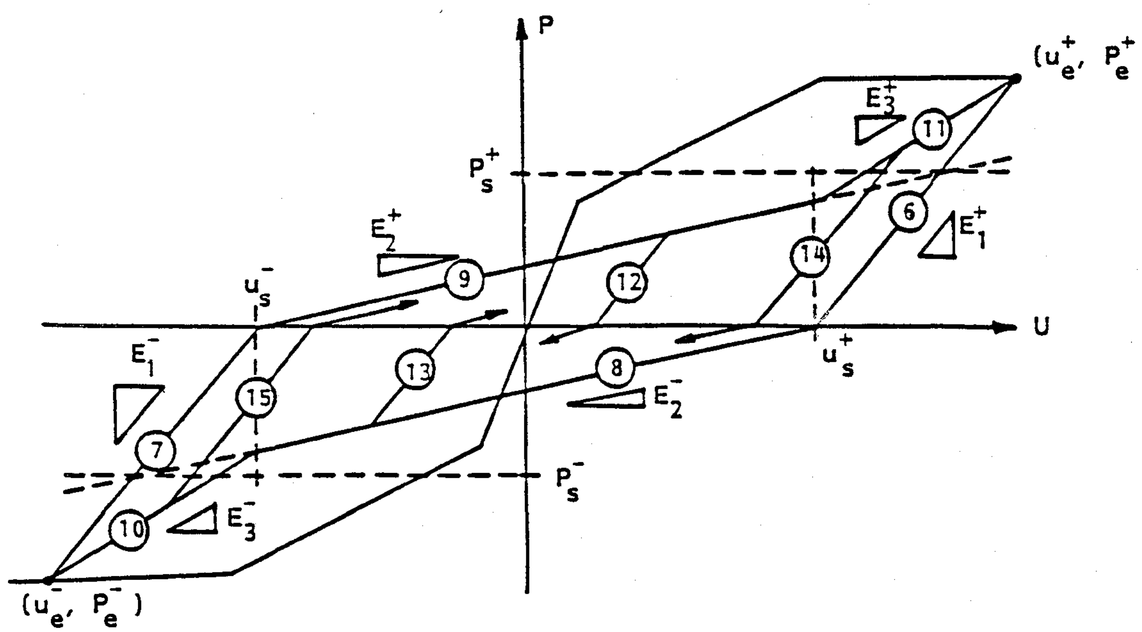


FIGURE 2-12 Modeling of Pinching Behavior

Fig. 2-13 illustrates the determination of the increased maximum deformation point (u_t^+ , P_t^+) due to energy absorption. This point is determined using Eq. (2.19) at the prediction point, i.e., when the reloading line passes the x-axis. When an unloading occurs between the prediction point and the point u_t^+ or P_t^+ , the point u_t^+ or P_t^+ becomes the new maximum point if the unloading point is outside the previous hysteresis loop (case b in Fig. 2-13), i.e.,

$$
\begin{aligned}
u_e^+ &= u_t^+ \\
P_e^+ &= P_t^+
\end{aligned}
\tag{2.24}
$$

The three-parameter model offers a wide range of options in modeling the inelastic behavior of reinforced concrete components. By setting the values of these parameters to either zero or an infinitely large value, it is possible to reproduce a range of existing inelastic models. Also, the user need input only two of the three parameters (unless otherwise required) since the program computes the strength deterioration coefficient during the equivalent static analysis.

2.5 Damage Index Model

The damage model developed by Park [18] is suggested as a measure of the accumulated damage sustained by the constituent components, each story level and the entire building.

The structural damage is expressed in terms of the damage index given by Eq. (2.17). The parameters 'δ_u' and 'β' were determined based on regression analysis of about 400 reinforced concrete columns and beams as follows:

$$R_u = 0.543(L/d)^{0.93} k_p(-0.27)_{p_w}(0.48)_{n_\circ}(-0.48)_{f'_c}(-0.15) \tag{2.25}$$

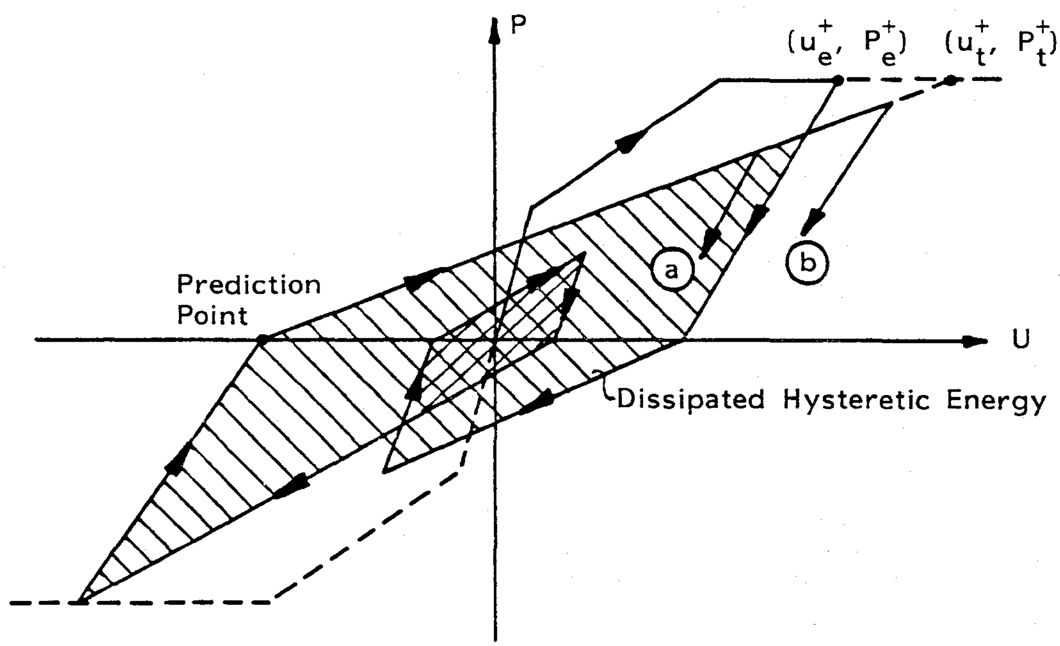


FIGURE 2-13 Deteriorating Rule

where:

R_u = δ_u/L Ultimate rotational capacity (percent)

L/d = Shear span ratio

k_p = $\frac{\rho_t f_y}{0.85 f'_c}$ Normalized steel ratio

p_w = Confinement ratio (replaced by 0.4 % if p_w < 0.4 %)

n_o = $\frac{N}{bdf'_c}$ Normalized axial stress (replaced by 0.05 if $n_o < 0.05$)

$$\beta = \left[0.37 n_o + 0.36 (k_p - 0.2)^2\right] 0.9^{\,p_w} \tag{2.26}$$

The story level damage index and the damage index for the total building is determined using the component damage indices 'D_i' as:

$$D = \Sigma\, \lambda_i D_i \quad ; \quad \lambda_i = \frac{E_i}{\Sigma\, E_i} \tag{2.27}$$

where:

λ_i = Energy weighting factor

E_i = Total energy absorbed by each component.

The energy term appearing in Eq. (2.27) is the total absorbed energy, while the energy referred to in Eq. (2.17) is the dissipated hysteretic energy which excludes the potential energy stored (resulting from the maximum deformation of the component).

SECTION 3
DESCRIPTION OF PROGRAM

3.1 Program Organization

The program package consists of three parts:

1. SYSTEM IDENTIFICATION- The main program performs the static analysis to determine component properties (such as yield strength, cracking moment, corresponding curvature, etc.) and the ultimate failure mode of the building.

2. DYNAMIC RESPONSE ANALYSIS- The secondary program includes subroutine RCDYNA, which performs a step-by-step inelastic dynamic analysis.

3. APPLICATIONS: SUBSTRUCTURE ANALYSIS & DAMAGE ANALYSIS- The final part consists of the analysis of selected substructures and a comprehensive damage analysis which includes a damage index for each structural component, the story level damage index and an overall index for the total building.

The system identification based on the equivalent static analysis is an essential prerequisite in performing the dynamic analysis.

The program sequence for the system identification is as follows:

1. Determination of component properties
2. Determination of fundamental period of structure
3. Determination of failure mode of structure, including the variation of base shear coefficient vs. overall top deformation

Results from the static analysis are carried forward to subroutine RCDYNA.

The dynamic response analysis under both horizontal and vertical base excitations is then performed. The hysteretic behavior of the constituent components is included in establishing the overall response of the structure. A major part of the dynamic analysis includes the determination of independent responses of selected substructures.

Finally, the strength parameters from the equivalent static analysis and the response parameters from the dynamic response analysis are recovered by the final segment of the program to carry out the damage analysis.

A brief summary of the way in which program IDARC is organized is shown in Table 3-I.

The program flow with a view to related applications is shown in Table 3-II. Two major applications can be performed with the program as indicated in Table 3-II:

1. Laboratory experiment of sub-assemblages
2. Post-earthquake damage assessment

Details of modelling of the various building components are described in the following sections.

TABLE 3-I PROGRAM ORGANIZATION

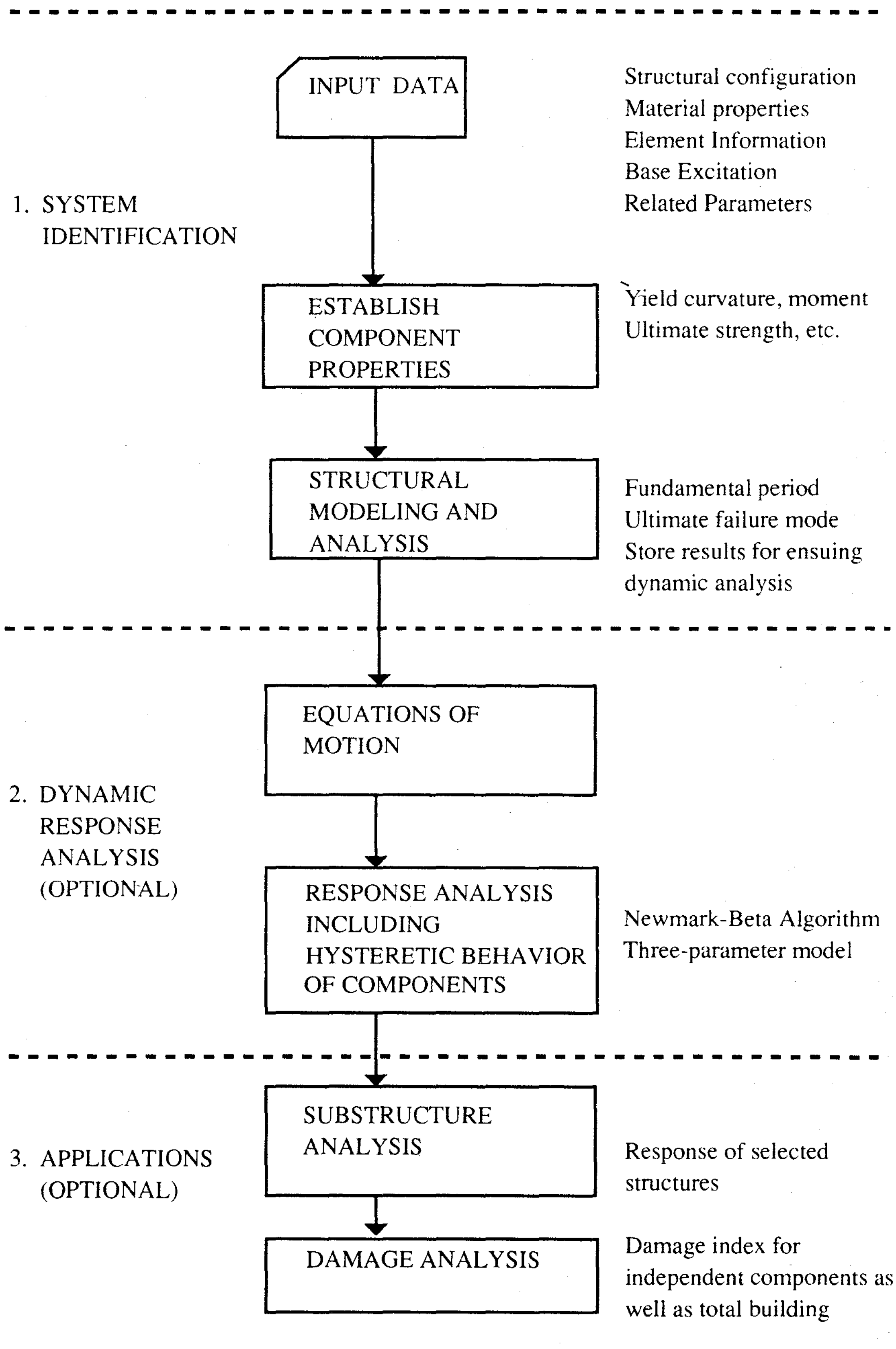
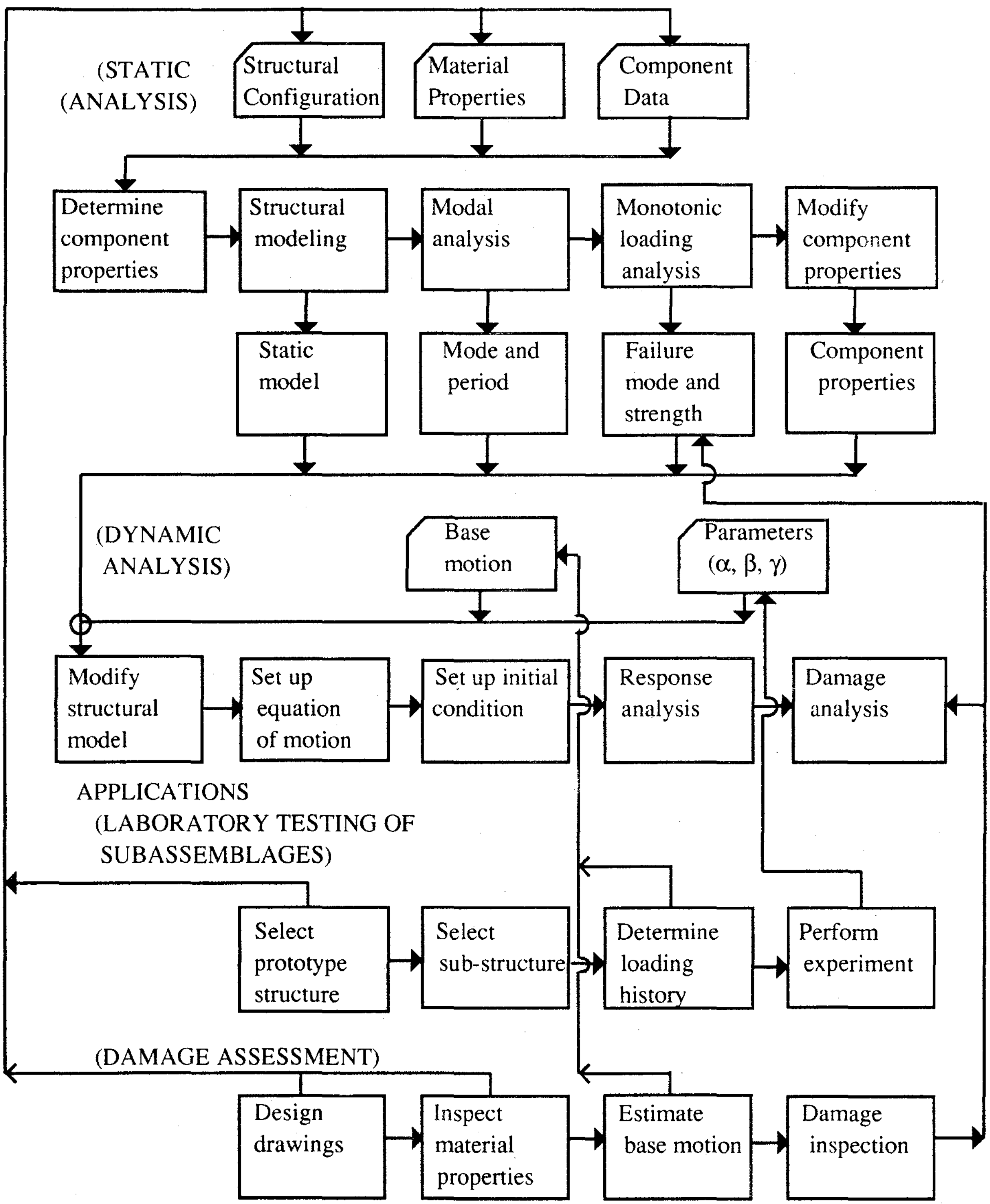


TABLE 3-II PROGRAM FLOW AND RELATED APPLICATIONS



3.2 Structure Idealization

Basic Assumption: A common technique in the three-dimensional analysis of tall buildings is to treat floor diaphragms as rigid links thus requiring only one horizontal floor degree-of-freedom. Such an approach greatly reduces the total computational effort, in addition to taking advantage of this special feature in typical building frames. The program IDARC uses the above simplified assumption, thereby neglecting effects of slab flexibility [2].

The building is considered as a series of plane frames linked by rigid horizontal diaphragms. Each frame must lie in the same vertical plane. Since the floors are assumed to be infinitely rigid in their plane, identical frames are simply lumped together and the stiffness factored by the number of duplicate frames.

Fig. 3-1 shows a typical structure composed of columns, beams and floors. The convention adopted in numbering the nodes is also shown.

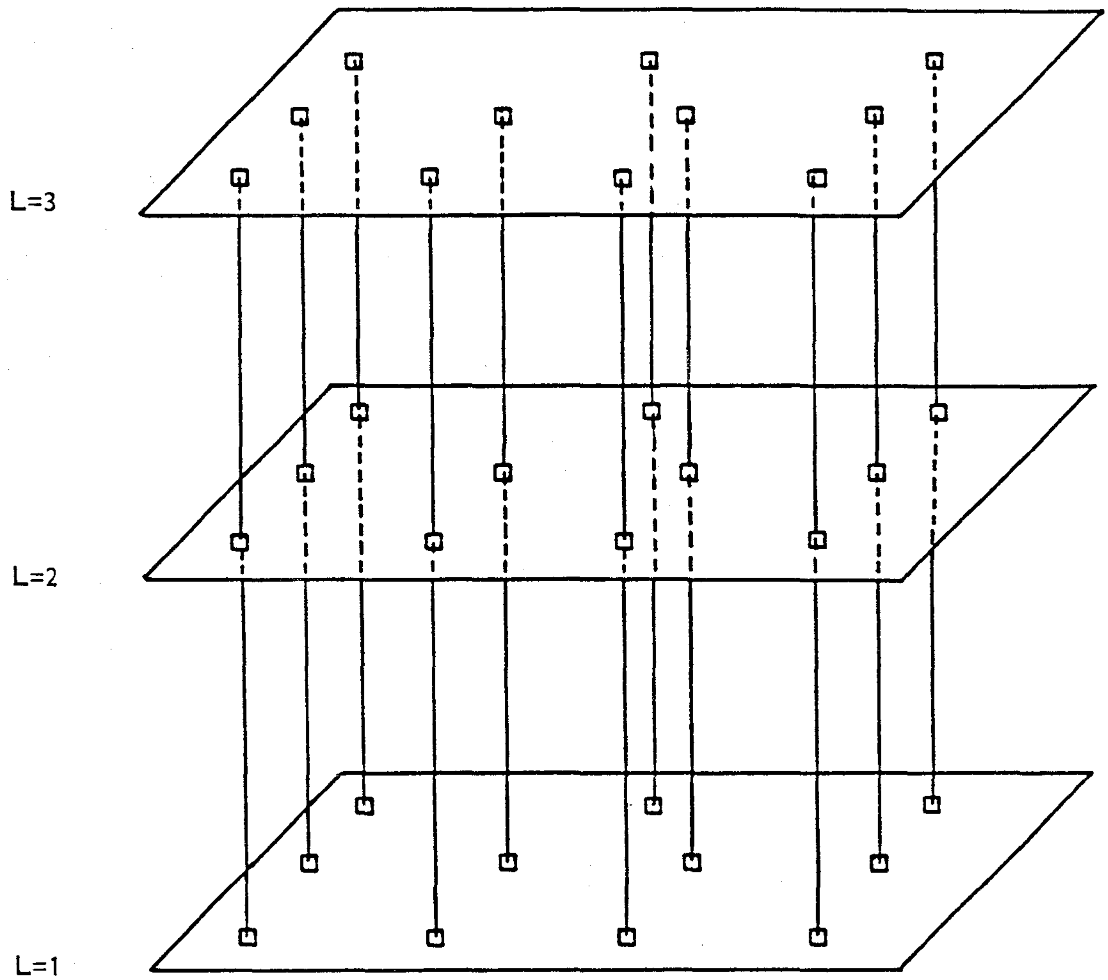
3.3 Modelling Structural Components

The analysis can be performed using five types of structural elements. The following element types are currently available:

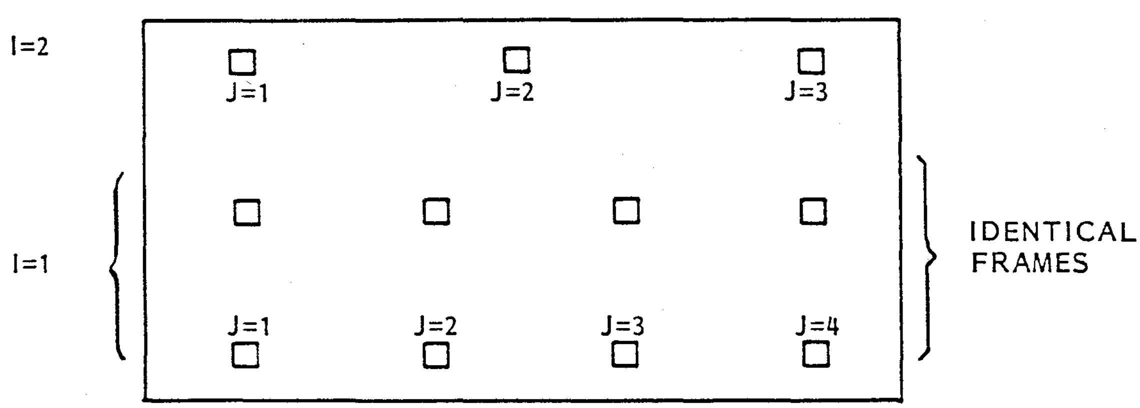
1. Beam elements
2. Column elements
3. Shear wall elements
4. Edge column elements
5. Transverse beam elements

-----

[2] Work is currently underway to modify program IDARC to include effects of slab flexibility.



(ISOMETRIC VIEW)



(PLAN)

FIGURE 3-1 Idealized Structural Model

Beams are modelled as continuous flexural springs. Shear deformation is coupled with flexural effects by means of an 'equivalent' spring which is assumed to act in series with the flexural spring.

Columns are modelled in an identical way as beam elements. Axial deformation in the columns is included but its interaction with bending moment is ignored, thus allowing axial effects to be uncoupled.

Shear walls are modelled as a series combination of flexural and shear-deformation springs.

Edge columns of a shear wall are modelled separately as one-dimensional springs.

Transverse beams are modelled as elastic springs with one vertical and one rotational (torsion) degree of freedom.

The detailed modelling of each of the above elements and the empirical equations used to determine the component properties are described in the following sections.

3.3.1 Beam Elements

The basic beam element is one that is parallel to the axis of loading. Beam elements are modelled as simple flexural springs in which shear-deformation effects have been coupled. A typical beam element and its degrees-of-freedom are shown in Fig. 3-2.

In deriving the basic flexibility matrix, it is assumed that the flexibility factor (1/EI) has a linear variation as described in Section 2. Consequently, two possibilities arise, depending upon the location of the point of contraflexure, as shown in Fig. 3-3. Hence:

$$\begin{Bmatrix} \Theta'_a \\ \Theta'_b \end{Bmatrix} = L' \begin{bmatrix} f_{11} & f_{12} \\ f_{21} & f_{22} \end{bmatrix} \begin{Bmatrix} M'_a \\ M'_b \end{Bmatrix} \tag{3.1}$$

(repeat Eq.2.1)

in which the coefficients of the flexibility matrix have been previously defined in Eq. (2.1). From geometry, the relationship between these quantities and the bending moments 'M_a', 'M_b' and rotational deformations 'Θ_a', 'Θ_b' at the nodal points (or joint centers) across the rigid zones at both ends is expressed by the following transformation matrices (Fig. 3-2 and Fig. 3-3):

$$\begin{Bmatrix} M_a \\ M_b \end{Bmatrix} = [\ \tilde{L}\ ] \begin{Bmatrix} M'_a \\ M'_b \end{Bmatrix} \tag{3.2}$$

$$\begin{Bmatrix} \Theta'_a \\ \Theta'_b \end{Bmatrix} = [\ \tilde{L}\ ]^T \begin{Bmatrix} \Theta_a \\ \Theta_b \end{Bmatrix} \tag{3.3}$$

where:

$$[\ \tilde{L}\ ] = \frac{1}{1-\lambda_a-\lambda_b} \begin{bmatrix} 1-\lambda_b & \lambda_a \\ \lambda_b & 1-\lambda_a \end{bmatrix} \tag{3.4}$$

Therefore, from Eqs. (3.1-3.4), the basic stiffness equation relating moments and rotations is:

$$\begin{Bmatrix} M_a \\ M_b \end{Bmatrix} = \begin{bmatrix} K_s \end{bmatrix} \begin{Bmatrix} \Theta_a \\ \Theta_b \end{Bmatrix} \tag{3.5}$$

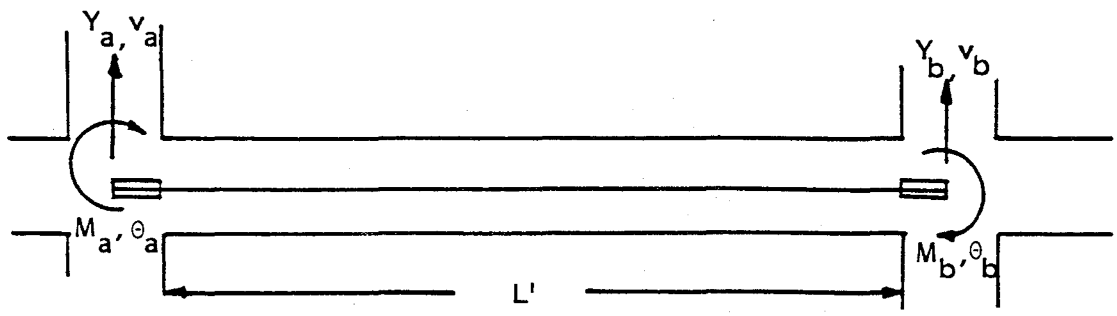


FIGURE 3-2 Typical Beam with Degrees of Freedom

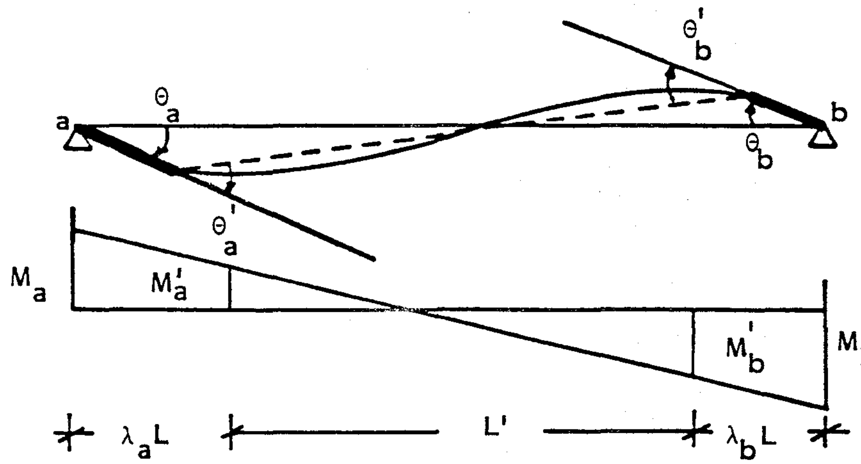


FIGURE 3-3 Beam Model with Rigid Zone

where:

$$\left[K_s\right] = \left[\tilde{L}\right] \left[k'\right] \left[\tilde{L}\right]^T \tag{3.6}$$

and [k'] is the inverted flexibility matrix.

From force-equilibrium, we have:

$$\begin{Bmatrix} Y_a \\ M_a \\ Y_b \\ M_b \end{Bmatrix} = \left[R_B\right] \begin{Bmatrix} M_a \\ \\ M_b \end{Bmatrix} \tag{3.7}$$

where:

$$\left[R_B\right] = \begin{bmatrix} -1/L & -1/L \\ 1 & 0 \\ & \\ 1/L & 1/L \\ 0 & 1 \end{bmatrix} \tag{3.8}$$

Hence, the stiffness equation for beam elements is:

$$\begin{Bmatrix} Y_a \\ M_a \\ Y_b \\ M_b \end{Bmatrix} = \left[K_b\right] \begin{Bmatrix} v_a \\ \Theta_a \\ v_b \\ \Theta_b \end{Bmatrix} \tag{3.9}$$

where:

$$\left[K_b\right] = \left[R_B\right] \left[K_s\right] \left[R_B\right]^T \tag{3.10}$$

is the element stiffness matrix.

Determination of Properties of Beam Elements: A multilinear function is used to describe the envelop curve of the moment-curvature relationship (Fig. 3-4). General expressions for

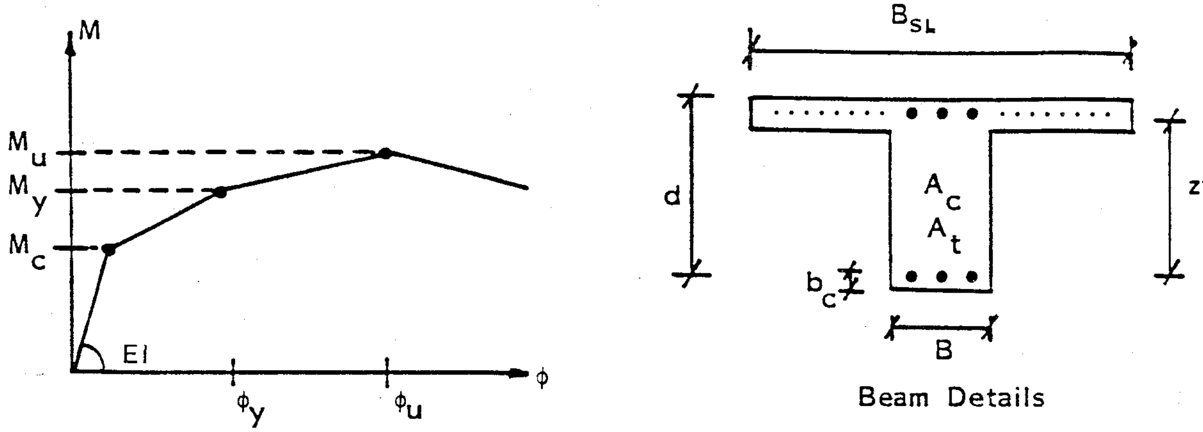


FIGURE 3-4   Deformation Parameters

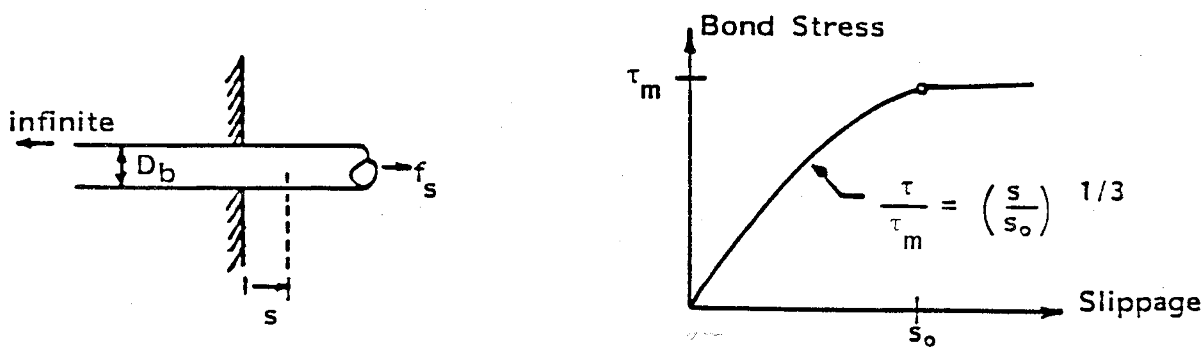


FIGURE 3-5   Bond Slippage at Anchorage

strength parameters have been outlined in Section 2. The precise form of the same equations for beam elements is discussed below.

Idealized Cracking Moment: This parameter is obtained as a linearization of the skeleton curve in preparation of the trilinear model [18]:

$$M^{+}_{cr} = 11.0 \sqrt{f'_c}\ (I_g/\bar{x}) \tag{3.11}$$

$$M^{-}_{cr} = 11.0 \sqrt{f'_c}\ (I_g/(h-\bar{x})) \tag{3.12}$$

where:

M^{+}_{cr} = Positive cracking moment
M^{-}_{cr} = Negative cracking moment
I_g = Gross moment of inertia of section including steel
$\bar{x}$ = Distance from base to centroid of section
h = Height of section

Yield Curvature and Moment: Assuming the concrete in compression remains elastic up to yielding of the tension reinforcement, the yield curvature is obtained from Eq. (2.7) with linear curvature distribution imposed along the member. As before, the effect of including the inelasticity of concrete is to amplify φ'_y with a constant 'c':

$$\varphi^{+}_{yf} = c\ \frac{E_y}{(1-k)d} \tag{3.13}$$

$$\varphi^{-}_{yf} = c\ \frac{E_y}{(1-k')d'} \tag{3.14}$$

where all quantities have been previously defined in Section 2.2.1; and k' is the neutral axis parameter (similar to 'k') for the negative moment and $d' = d - t_s/2$, 't_s' being the slab thickness.

Consequently, the yield moments are given by [18]:

$$M_y^+ = 0.5 f_c' B_{sL} d^2 \left[(2-\eta)p_t + (\eta - 2\beta_c)\alpha_c p_t'\right] \tag{3.15}$$

$$M_y^- = 0.5 f_c' B (d')^2 \left[(2-\eta)p_t + (\eta' - 2\beta_c)\alpha_c p_t'\right] \tag{3.16}$$

where:

$$\eta = \frac{0.75}{1+\alpha_y}\left(\frac{\varepsilon_c}{\varepsilon_o}\right)^{0.7} ; \quad \eta' = \frac{0.75}{1+\alpha_y}\left(\frac{\varepsilon_c'}{\varepsilon_o}\right)^{0.7} \tag{3.17}$$

$$\varepsilon_c = \varphi_y d - \varepsilon_y \quad ; \quad \varepsilon_c' = \varphi_y' d' - \varepsilon_y \tag{3.18}$$

$$\left.\begin{aligned} \alpha_c &= (1-\beta_c)\frac{\varepsilon_c}{\varepsilon_y} - \beta_c \leq 1.0 \\ \alpha_c' &= (1-\beta_c')\frac{\varepsilon_c'}{\varepsilon_y} - \beta_c' \leq 1.0 \end{aligned}\right\} \tag{3.19}$$

in which:

M_y^+ = Positive yield moment
M_y^- = Negative yield moment
ε_c = Maximum strain in concrete in compression
ε_c' = Maximum strain in concrete in tension

NOTE: All additional parameters are defined in Fig. 3-4.

Ultimate Moment: The following expression was proposed in Ref [18] based on the analysis of experimental data and is used in the program:

$$M_u^+ = (1.24 - 0.15\rho)\, M_y^+ \tag{3.20}$$

$$M_u^- = (1.24 - 0.15\rho')\, M_y^- \tag{3.21}$$

where:

M_u^+ = Positive ultimate moment

M_u^- = Negative ultimate moment

Coupling of Flexural and Shear Deformation: Shear effects are included by means of an 'equivalent' spring that is assumed to act in series with the inelastic flexural spring. To determine the stiffness of the equivalent spring, consider the variation of 'φ' across the length of the section (Fig. 2-5):

$$\delta_s = \int_0^L \varphi \frac{x}{L} \; x \, ds \tag{3.22}$$

$$\delta_s = \varphi \frac{L^2}{3} \tag{3.23}$$

The relationship between shear deformation 'δ_s' and shear stiffness 'k_s' can be expressed as:

$$P = k_s \delta_s \tag{3.24}$$

Substituting Eq. (3.23) into Eq. (3.24), premultiplying both sides by 'L' and comparing with the analogous $M = E\,I\,\varphi$ gives:

$$(EI)_s = k_s \frac{L^3}{3} \tag{3.25}$$

and

$$K_s = \frac{GA^*}{1.2L} \tag{3.26}$$

where:

G = Shear modulus
A^* = Effective shear area.

The equivalent stiffness due to shear given by Eq. (3.25) is then coupled in series to a flexural spring. The combined equivalent stiffness is, therefore, given by:

$$(EI)_{eq} = \frac{(EI)_s \; (EI)_f}{(EI)_s + (EI)_f} \tag{3.27}$$

where:

$(E\,I)_f$ = Flexural spring stiffness.

Bond Slippage: The idealized bond-slippage relation shown in Fig. 3-5 is used. The empirical relationship given below has been validated by examining data of available pull-out tests [18]. The equivalent curvature due to bond-slippage is (Fig. 3-5b):

$$\varphi^{+}_{yb} = \frac{3S}{L_s(1-\beta_c)d} \tag{3.28}$$

$$\varphi^{-}_{yb} = \frac{3S'}{L_s(1-\beta_c)d'} \tag{3.29}$$

where:

$$S = 0.0003\ f_y^{1.5}\ \tau_m^{-0.75}\ \ D_b \tag{3.30}$$

$$S' = 0.0003\ f_y^{1.5}\ \tau_m^{-0.75}\ \ D_b' \tag{3.31}$$

in which:

S, S'	=	Bond-Slippage, in inches
τ_m	=	Bond stress
D_b, D_b'	=	Mean diameter of bottom and top bars, respectively
L_s	=	Shear span length

Inelastic Shear Deformation: The idealized shear crack model used in the analysis has been presented in Section 2. Eqs. (2.11-2.13) define completely the equivalent curvature due to shear and were used in the equivalent static analysis.

3.3.2 Columns

Column elements are modelled similar to beam elements, i.e., as flexural springs in which shear deformation effects are coupled by means of an equivalent spring. However, an additional one-dimensional spring is included to account for the effect of axial deformation.

A typical column element that forms part of a reinforced concrete building structure is shown in Fig. 3-6.

From force-equilibrium, we have:

$$\begin{Bmatrix} X_a \\ M_a \\ X_b \\ M_b \end{Bmatrix} = \begin{bmatrix} R_c \end{bmatrix} \begin{Bmatrix} M_a \\ M_b \end{Bmatrix} \tag{3.32}$$

where:

$$\begin{bmatrix} R_c \end{bmatrix} = \begin{bmatrix} 1/L & 1/L \\ 1 & 0 \\ -1/L & -1/L \\ 0 & 1 \end{bmatrix} \tag{3.33}$$

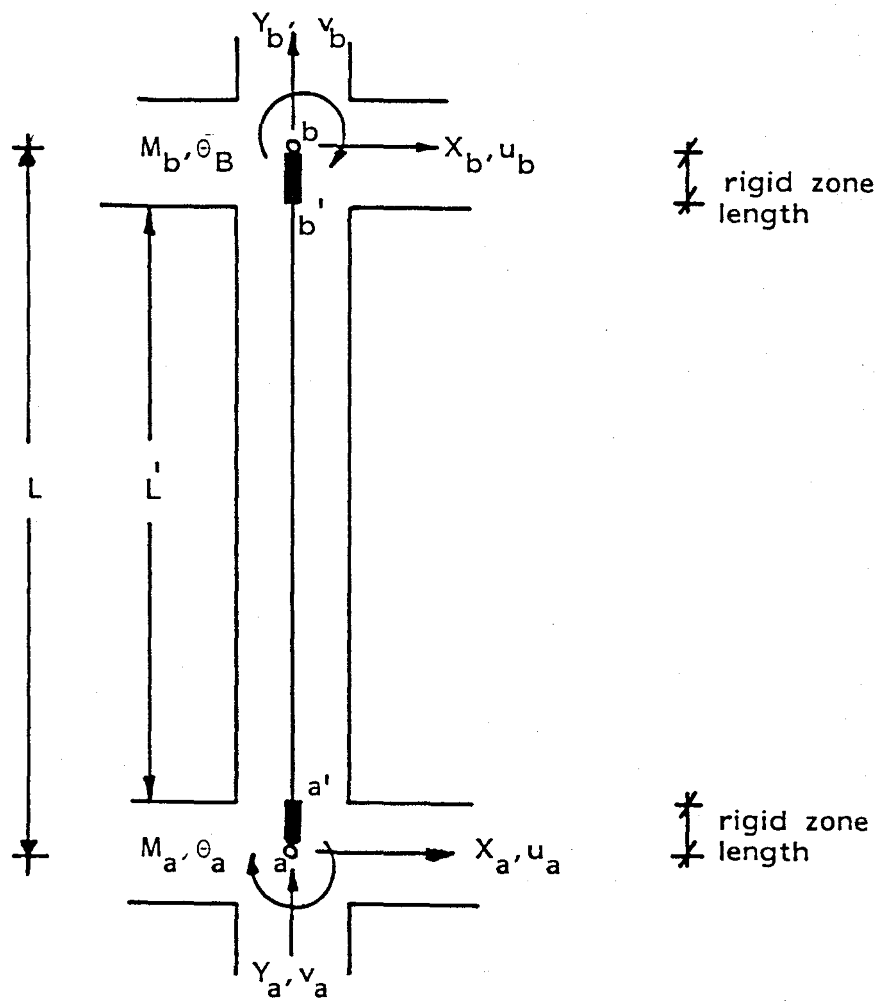


FIGURE 3-6 Typical Column Element With Degrees of Freedom

The flexibility distribution shown in Fig. 2-3 and the corresponding flexibility matrix (Eq. 3.1) that were used for the beam element are appropriately utilized in deriving the column element stiffness equation:

$$\begin{Bmatrix} X_a \\ M_a \\ X_b \\ M_b \end{Bmatrix} = \begin{bmatrix} K_c \end{bmatrix} \begin{Bmatrix} u_a \\ \Theta_a \\ u_b \\ \Theta_b \end{Bmatrix} \tag{3.34}$$

where:

$$\begin{bmatrix} K_c \end{bmatrix} = \begin{bmatrix} R_c \end{bmatrix} \begin{bmatrix} K_s \end{bmatrix} \begin{bmatrix} R_c \end{bmatrix}^T$$

is the element stiffness matrix, and $[K_s]$ is given by Eq. (3.6).

The interaction between bending moment and axial load is not considered, hence the axial degree-of-freedom is easily uncoupled and the force-deformation relation for the resulting elastic spring is as follows:

$$\begin{Bmatrix} Y_a \\ Y_b \end{Bmatrix} = \frac{EA}{L} \begin{bmatrix} 1 & -1 \\ -1 & 1 \end{bmatrix} \begin{Bmatrix} v_a \\ v_b \end{Bmatrix} \tag{3.35}$$

Component Properties for Columns: The strength parameters for column elements are essentially the same as those derived for beam elements, except for the following modifications:

1. The effect of axial load is included
2. No distinction is made between positive and negative moments and curvatures, since
3. The area of steel reinforcement in compression and tension is assumed to be identical.

Consequently, we have the following expressions:

Cracking Moment: The effect of axial load is included:

$$M_{cr} = 11.\varphi\sqrt{f'_c}\;Z_e^* + Nd/6 \tag{3.36}$$

(repeat Eq. 2.3)

Yield Curvature and Moment: Using the plane section assumption and linear curvature distribution as before:

$$\varphi_y^* = \frac{\varepsilon_y}{(1-k)d} \tag{3.37}$$

(repeat Eq.2.7)

Eq. (3.37) tends to underestimate the actual curvature since the inelasticity of concrete and the effect of axial load is not taken into account. Based on results of an iterative analysis [20] the following modification is introduced:

$$\varphi_y = \left[1.05 + (C_2 - 0.05)\frac{n_o}{0.03}\right] \varphi_y^* \tag{3.38}$$

where:

$$C_2 = 0.45/(0.84 + p_t) \tag{3.39}$$

$$n_o = N/(f'_c\,Bd) \tag{3.40}$$

The yield moment is given by:

$$M_y = 0.5\, f'_c\, Bd^2 \Big\{(1 + \beta_c - \eta)\, n_o + (2 - \eta)p_t \tag{3.41}$$

$$+ (\eta - 2\beta_c)\, \alpha_c\, p'_t\Big\}$$

(repeat Eq.2.4)

where:

$$\eta = \frac{0.75}{1+\alpha_y} \left(\frac{\varepsilon_c}{\varepsilon_o}\right)^{0.7} \tag{3.42}$$

$$\alpha_c = (1-\beta_c)\frac{\varepsilon_c}{\varepsilon_y} - \beta_c \quad < 1.0 \tag{3.43}$$

Ultimate Moment: This expression corresponds to Eq. (3.20-3.21) with the effect of axial load being included:

$$M_u = (1.24 - 0.15p_t - 0.5n_o)\, M_y \tag{3.44}$$

(repeat Eq. 2.5)

Bond Slippage: Again, the idealized bond-slippage relation of Fig. 3-5 is used. The expression for curvature due to bond-slip is given by:

$$\varphi_{yb} = \frac{3S}{Z}\left(\frac{1}{L_s}\right) \tag{3.45}$$

where:

S = Bond slippage, inches, given by Eq. (3.30)
Z = Distance between top and bottom bars
L_s = Shear span length

3.3.3 Shear Walls

The modelling of shear wall elements is achieved by means of a shear spring and a flexural spring connected in series.

The flexibility matrices used for beams and columns are valid for modelling flexural deformation. The addition of the spring results in the following form of the modified flexibility matrix:

$$\left[K_f\right] = L'\begin{bmatrix} f_{11} & f_{12} \\ f_{21} & f_{22} \end{bmatrix} + \frac{1}{GAL'}\begin{bmatrix} 1 & 1 \\ 1 & 1 \end{bmatrix} \tag{3.46}$$

A typical shear wall element is shown in Fig. 3-7. From force-equilibrium we have:

$$\begin{Bmatrix} X_a \\ M_a \\ X_b \\ M_b \end{Bmatrix} = \begin{bmatrix} R_w \end{bmatrix} \begin{Bmatrix} M_a \\ M_b \end{Bmatrix} \tag{3.47}$$

where:

$$\begin{bmatrix} R_w \end{bmatrix} = \begin{bmatrix} 1/L & 1/L \\ 1 & 0 \\ -1/L & -1/L \\ 0 & 1 \end{bmatrix} \tag{3.48}$$

For axial deformation, we have:

$$\begin{Bmatrix} Y_a \\ Y_b \end{Bmatrix} = \frac{EA}{L} \begin{bmatrix} 1 & -1 \\ -1 & 1 \end{bmatrix} \begin{Bmatrix} v_a \\ v_b \end{Bmatrix} \tag{3.49}$$

The location of the point of contraflexure determines the flexibility matrix to be used. The resulting stiffness matrix has the usual form:

$$\begin{Bmatrix} X_a \\ M_a \\ X_b \\ M_b \end{Bmatrix} = \begin{bmatrix} K_w \end{bmatrix} \begin{Bmatrix} u_a \\ \Theta_a \\ u_b \\ \Theta_b \end{Bmatrix} \tag{3.50}$$

where:

$$\begin{bmatrix} K_w \end{bmatrix} = \begin{bmatrix} R_w \end{bmatrix} \begin{bmatrix} K_s \end{bmatrix} \begin{bmatrix} R_w \end{bmatrix}^T \tag{3.51}$$

is the stiffness matrix for shear wall elements.

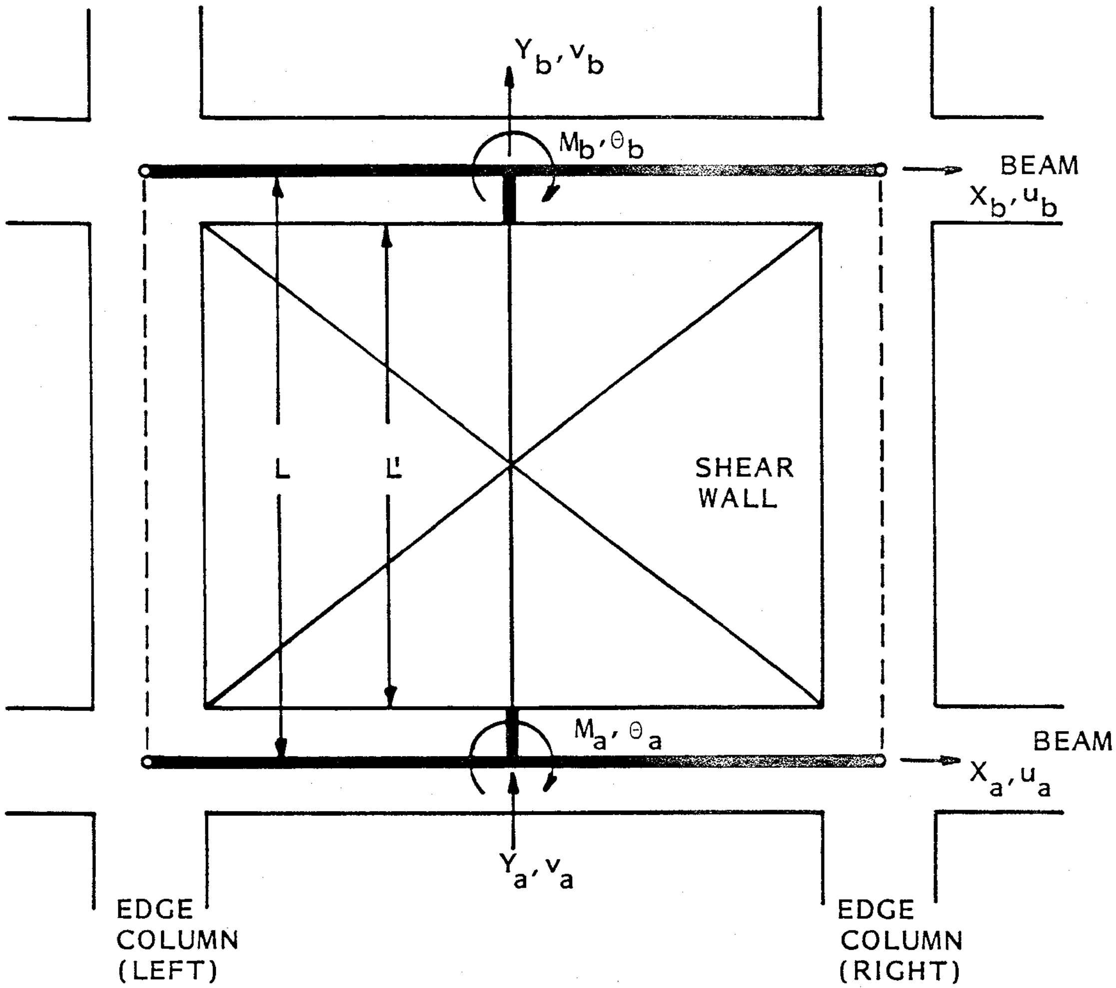


FIGURE 3-7 Typical Shear Wall Element Showing Degrees of Freedom

Component Properties for Shear Walls: Flexural deformation characteristics are determined using the fiber model, the details of which are described below.

Shear strength parameters are established from empirical relations that have already been outlined in Section 2.2. Eqs. (2.13-2.15) are used to compute the cracking shear strength, yield shear strength and yield shear deformation, respectively.

Fiber Model: Fig. 3-8 shows the cross-section of a shear wall and the edge columns to which it is connected (if there are no edge columns, the half-length d/2 is replaced by c/2). In establishing the flexural behavior using the fiber model, the entire wall cross-section is divided into a number of smaller sections. The fibers at the ends of the wall are chosen at closer intervals than the rest of the length where inelastic strains are expected to be significant.

In Fig. 3-8, '$\bar{X}_i$' corresponds to the distance from the center of the shear wall to the center of section 'i', whose area of cross-section is given by 'A_i'.

At the start of the analysis, the axial load is applied in full while the applied moment is divided into small increments. At the end of each cycle, the total axial force on the wall is determined from the stresses in the divided sections. The difference in value between this computed axial force and the total applied load is then applied as a "corrective" load in the next cycle in order to avoid accumulation of numerical errors.

The incremental deformations in each cycle are determined as follows:

The expressions for incremental load and moment are:

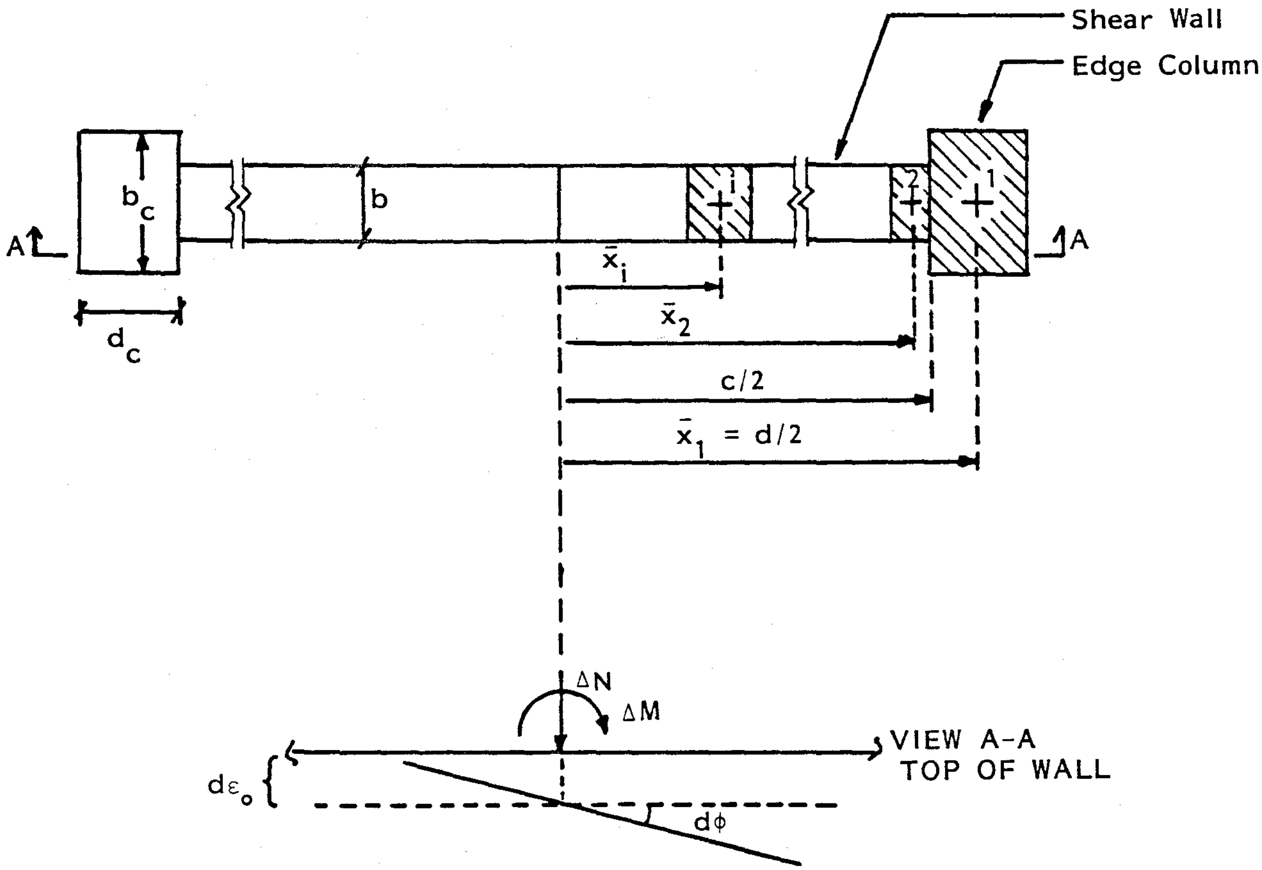


FIGURE 3-8 Fiber Model Analysis of Shear Wall

$$dN = \int E \, d\varepsilon \;\; dA \tag{3.52}$$

$$dM = \int E \, d\varepsilon \; x \; dA \tag{3.53}$$

The strain at any section along the wall is given by:

$$d\varepsilon = d\varepsilon_\circ + x \, d\varphi \tag{3.54}$$

where:

$d\varepsilon_\circ$ = Central axial strain
$d\varphi$ = Curvature to be determined.

Substituting into Eqs. (3.52-3.53):

$$\begin{Bmatrix} dN \\ dM \end{Bmatrix} = \begin{bmatrix} \int EdA & \int ExdA \\ \int ExdA & \int Ex^2dA \end{bmatrix} \begin{Bmatrix} d\varepsilon_\circ \\ d\varphi \end{Bmatrix} \tag{3.55}$$

Integrating numerically and solving for strain and curvature:

$$\begin{Bmatrix} d\varepsilon_\circ \\ d\varphi \end{Bmatrix} = \frac{1}{C_x} \begin{bmatrix} \Sigma \; E_i x_i^{\,2} & - \Sigma \; E_i x_i \\ - \Sigma \; E_i x_i & \Sigma \; E_i A_i \end{bmatrix} \begin{Bmatrix} dN \\ dM \end{Bmatrix} \tag{3.56}$$

where:

$$C_x = \left(\Sigma \; E_i A_i\right)\left(\Sigma \; E_i X_i^{\,2}\right) - \left(\Sigma \; E_i X_i\right)^2$$

The incremental strain in each fiber is then evaluated from Eq. (3.54).

The computed strains in each fiber are analyzed against the stress-strain curves for concrete and steel, respectively. Any change in the value of 'E', the modulus of elasticity, is updated and stresses are evaluated accordingly. The stress-strain curves used in the analysis are shown in Figs. A-5 and A-6.

The numerical algorithm used in this routine checks for the nonlinearity of the flexural rigidity 'EI' and introduces a load-step reduction as the instantaneous stiffness drops to 1/3 of its initial stiffness. The incremental curvatures computed at each step and the corresponding moment values are stored to enable a final regression analysis that yields the envelop curve using a trilinear model. The two turning points identify the cracking moment, yield moment and corresponding curvatures, respectively.

3.3.4 Edge Columns

Edge column elements constitute the columns that are connected to shear wall elements. Their behavior is primarily dependent on the deformation of the shear wall and is, therefore, modelled separately as a one-dimensional axial spring (Fig. 3-9).

However, the user may use these elements to model other transverse elements such as secondary shear walls that can be lumped with the corresponding column element. Equivalent properties may be used. The numerical example presented in the Appendix demonstrates this technique.

The stiffness matrix for the pair of elements is as follows:

$$\begin{Bmatrix} Y_a \\ M_a \\ Y_b \\ M_b \end{Bmatrix} = \frac{EA_L}{h} \begin{bmatrix} 1 & \lambda & -1 & -\lambda \\ \lambda & \lambda^2 & -\lambda & -\lambda^2 \\ -1 & -\lambda & 1 & \lambda \\ -\lambda & -\lambda^2 & \lambda & \lambda^2 \end{bmatrix} + \frac{EA_r}{h} \begin{bmatrix} 1 & -\lambda & -1 & \lambda \\ -\lambda & \lambda^2 & \lambda & -\lambda^2 \\ -1 & \lambda & 1 & -\lambda \\ \lambda & -\lambda^2 & -\lambda & \lambda^2 \end{bmatrix} \tag{3.57}$$

where:

A_L = cross-sectional areas of the left edge-column elements
A_r = cross-sectional areas of the right edge-column elements.

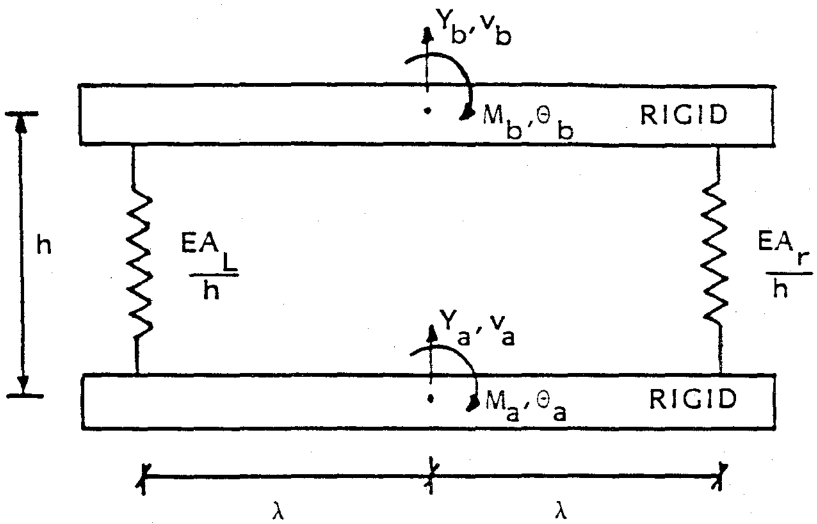


FIGURE 3-9 Edge Column Elements

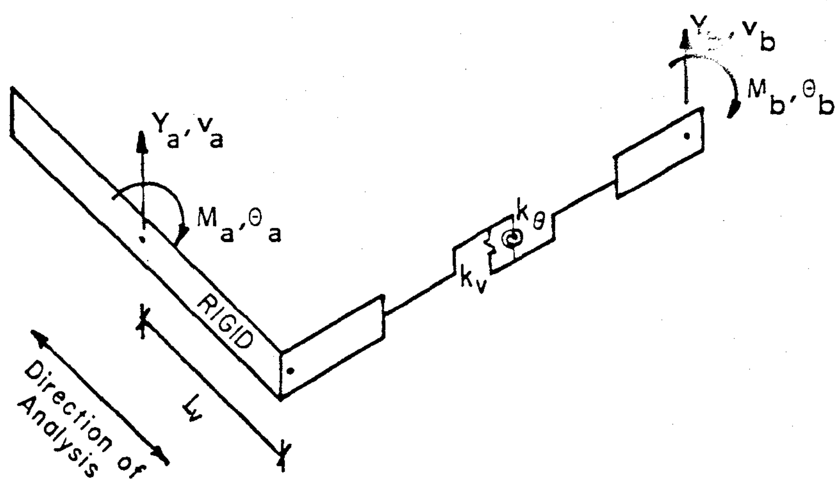


FIGURE 3-10 Transverse Beam Element

3.3.5 Transverse Beams

Fig. 3-10 shows the modelling of a transverse beam connected to a shear wall element. Two types of transverse beam elements exist: beams that are connected to shear walls; and beams connected to the main beams in the direction of loading.

Two springs, 'k_v' and 'k_Θ', are used to include the additional resistance of the beam against rotational deformation of the shear wall to which it is connected. In the case of beam-to-beam connections, only a torsional spring may be adequate. The following stiffness matrix is obtained:

$$\begin{Bmatrix} Y_a \\ M_a \\ Y_b \\ M_b \end{Bmatrix} = k_v \begin{bmatrix} 1 & -L_v & -1 & 0 \\ -L_v & L_v^2 & L_v & 0 \\ -1 & L_v & 1 & 0 \\ 0 & 0 & 0 & 0 \end{bmatrix} + k_\Theta \begin{bmatrix} 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & -1 \\ 0 & 0 & 0 & 0 \\ 0 & -1 & 0 & 1 \end{bmatrix} \qquad (3.58)$$

For beam-to-beam connections, only those transverse elements whose torsional stiffness is expected to contribute significantly in restraining the rotation of the main beams need be considered. It must also be stated that these restraining springs are important in restoring numerical stability to the computational algorithm especially when the rotations of the main beams become excessive.

3.4 Computational Procedure

The complete analysis is carried out in a series of sequential steps:

1. The strength and deformation parameters of all components are first established.
2. The above information is then used to determine the failure mode of the structure under monotonic loading.

3. A step-by-step dynamic response analysis is then performed. Optionally, the response of selected substructures is also determined.
4. The final state of the structure is then analyzed to compute relevant damage indices.

3.4.1 Static Analysis (for equivalent loads)

The static analysis routine, as performed by IDARC, involves the solution of the following equilibrium equation:

$$[K] \ \{\Delta u\} = \{\Delta F\} \tag{3.59}$$

where:

[K] = Assembled global stiffness matrix (stored in banded form)
{Δu} = Required solution vector of incremental nodal displacements
{ΔF} = Incremental load vector

The lateral load applied to the structure at each floor level is computed from the estimated base shear coefficient. The total weight of the structure is factored by the estimated base shear coefficient and applied in small increments. The contribution at each floor level is computed from the following equation:

$$f_j = \frac{W_j \ h_j}{\sum_{i=1}^{n} W_i \ h_i} \ W_t^* \tag{3.60}$$

where:

Subscript j = Story level under consideration
w = Floor weight

h = Height of corresponding floor from the base of the structure

W_t^* = Factored total weight of the building

n = Total number of stories.

A stress analysis follows each computational step to establish the stress-state of each component. Stresses are computed at critical sections defined as the end sections for beams and columns. In addition, for shear wall elements only, the shear stress at mid-section is examined. Edge columns are modelled using one vertical degree-of-freedom, consequently, only axial stress is computed.

A qualitative plot of stress states at each critical section is printed by the program. Also printed is the variation of the base shear coefficient as a function of the top lateral deflection as a result of the monotonic loading analysis.

3.4.2 Dynamic Analysis

The step-by-step dynamic response analysis involves the solution of the following equation of motion:

$$\left[M\right]\left\{\ddot{u}_r\right\} + \left[C\right]\left\{\dot{u}_r\right\} + \left\{R(u_r)\right\} = \left\{F(t)\right\} \qquad (3.61)$$

where:

$\{F(t)\}$ = Vector of effective loads resulting from earthquake ground motions

u_r = Relative displacement of the structure with respect to the ground.

In constructing the diagonal mass matrix [M], the horizontal inertia effects are lumped at the floor levels while vertical inertia effects are lumped uniformly at each joint. Rotational inertia effects are ignored in the present analysis.

The Newmark-Beta algorithm [30] is used to determine the step-by-step solution of the dynamic equation of motion.

The element stiffness matrix in each time step is updated only if there is a change of stiffness. Hence, only a portion of the overall stiffness matrix is changed depending on the elements that change stiffness during a particular time step.

The following information is also updated during each time step to aid in the damage index computations:

1. The total energy absorbed by each component of the structure;

2. The dissipated hysteretic energy of each component (excluding the contribution due to potential energy);

3. The maximum deformation experienced by each element during the step-by-step response analysis.

Finally, the stress states of each member is analyzed against the strength parameters carried forward from the static analysis.

Output information from the dynamic analysis include:

1. Maximum response values of displacement, story drift and interstory shear at each floor level;

2. Time-history response of any or all the above parameters for any set of floor levels;

3. Qualitative plot of the final state of stress for each frame.

3.5 Substructure Analysis

An important feature of program IDARC is its capability to analyze selected sub-assemblages that can be extracted from the total building.

A substructure may consist of either the entire length of a frame or a part of a frame that includes only one vertical line. Examples of such sub-assemblages are shown in Figs. A-13 and B-5. The program requires the following input:

1. Frame number
2. Column (or j-coordinate location, else the entire frame length is used)
3. Upper and lower boundaries of the substructure

In the case that the substructure consists of only a single vertical line, the program uses half-lengths of the connecting beams.

Using the node numbering scheme illustrated earlier in Fig. 3-1, the following information is necessary to identify the substructure:

1. The frame number

2. The j-coordinate location of the column; a zero input will force the entire frame length to be considered as part of the sub-assemblage (case (c) in Figs. A-13 and B-5.)

3. The ratio, h_1^*/h_1

4. The ratio, h_2^*/h_2

where h_1, h_1^*, h_2, and h_2^* are defined in Fig. A-13.

Three components of the response, i.e., the horizontal, vertical and/or rotational deformation, can be computed. The basic components of the response are established by linear interpolation between the floor levels from which the substructure is extracted.

The output of the substructure analysis includes:

1. The time history of the displacement (or rotation) and shear forces at the upper and lower boundaries of the subassemblage for any or all of the following:

   a. horizontal component of response
   b. vertical component of response
   c. rotational component of response

2. The time history of the shear forces at the ends of the boundary beams (see Fig. A-13 for boundary beam notation).

3.6 Damage Index Computations

Three physically relevant damage indices are computed:

1. A damage index for each of the main building components, i.e., beams, columns and shear walls;

2. The story level damage index classified further into vertical and horizontal components at each floor level;

3. The overall damage index for the building.

The equations set forth in Section 2 form the basis of the damage index computations. The damage index 'D' as defined by Eq. (2.17) is repeated here for convenience:

$$D = \frac{\delta_m}{\delta_u} + \frac{\beta}{\delta_u P_y} \int dE \qquad (3.62)$$

repeat (Eq. 2.17)

Three parameters, viz., the ultimate deformation 'δ_u', the constant 'β' and the yield strength 'P_y' can be obtained from the static analysis. The maximum deformation due to the earthquake loading 'δ_m' and the absorbed hysteretic energy 'dE' are computed during the step-by-step dynamic response analysis.

The story level damage indices are computed from the damage index values of the components comprising that story level. The vertical components (columns, shear walls) are separated from the horizontal components (beams) before applying Eq. (2.26).

The energy values used in establishing the weighting factor 'λ_i' constitute the total absorbed energy while the energy term appearing in Eq. (3.62) is exclusive of the accumulated potential energy. Program IDARC accounts for this distinction by neglecting the energy accumulated as a consequence of increasing the previous maximum deformation point.

The damage index used in this report was calibrated with respect to observed damage of nine reinforced concrete buildings [29]. Table 3-III corresponds to the calibrated index [29] and can be used to interpret the overall damage index of the building.

TABLE 3-III INTERPRETATION OF OVERALL DAMAGE INDEX

Degree of Damage	Physical Appearance	Damage Index	State of Building
COLLAPSE	Partial or total collapse of building	> 1.0	Loss of building
SEVERE	Extensive crashing of concrete; disclosure of buckled reinforcements	0.4-1.0	Beyond repair
MODERATE	Extensive large cracks spalling of concrete in weaker elements	< 0.4	Repairable
MINOR	Minor cracks throughout building; partial crushing of concrete in columns		
SLIGHT	Sporadic occurrence of cracking		

SECTION 4
EXAMPLE OF BUILDING ANALYSIS

The numerical example presented here is meant to illustrate the applicability of the proposed program to a building having realistic size and complexity.

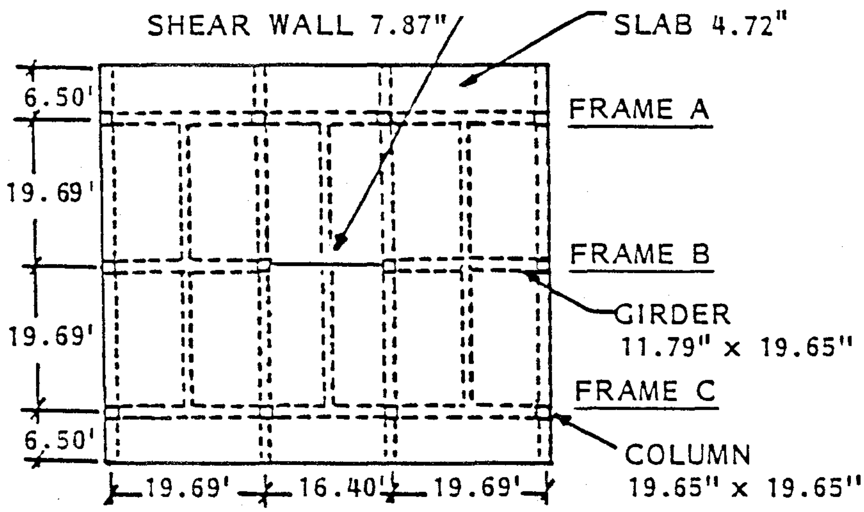
A seven-story building tested using the full-scale psuedo-dynamic testing facility at Tsukuba, Japan under the U.S.-Japan Cooperative Research Program [15] is analyzed.

In the actual testing, the fundamental mode shape was imposed throughout the loading so as to eliminate erroneous domination of higher modes caused by experimental errors that are normally associated with the pseudo-dynamic testing. Therefore, the test results do not represent the general MDOF dynamic response of the building.

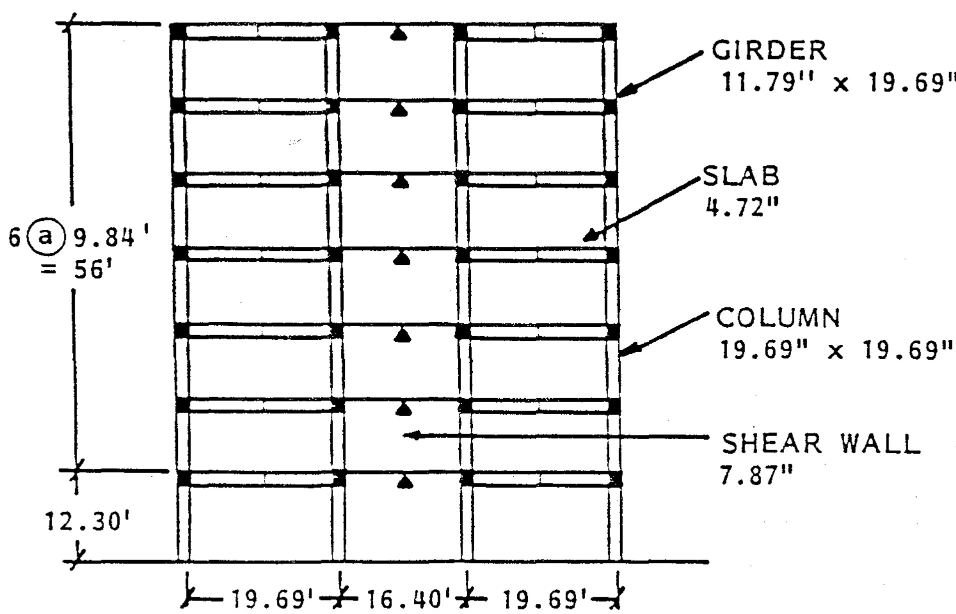
The 7-story structure consists primarily of three frames, two of which are identical (Fig. 4-1). Owing to the rigid-diaphragm assumption described in Section 3.2, input information is required of the two unique frames only. Program IDARC accounts for the stiffness of the duplicate frames by merely lumping together such identical frames.

Eight different concrete types and five different reinforcing bars were used in the actual construction of the structure. The pertinent details of this and the rest of the input information are more clearly listed in the output.

The building is composed of all 5 element types. In addition, there are several secondary transverse shear walls. To account for the stiffness contribution of these walls, 'effective' edge columns were added to the regular columns. It is hence possible, in an indirect sense, to incorporate such secondary elements as the complexity of the structure dictates.



(a) Plan



(b) Elevation of Frame 'B'

FIGURE 4 -1 Details of 7-Story Structure

It is advisable to make detailed sketches of the structural model showing the different elements with their element numbers and 'element type' information. The numbering of all elements for the seven-story structure analyzed here is shown in Figs. 4-2 through 4-4. Such a scheme along with the program output will enable easier interpretation of results.

It is necessary to use the static analysis option for the first run. A base shear coefficient of 1.0 can be used for this preliminary run and then corrected (based on the results of the static analysis) for subsequent dynamic and damage analysis.

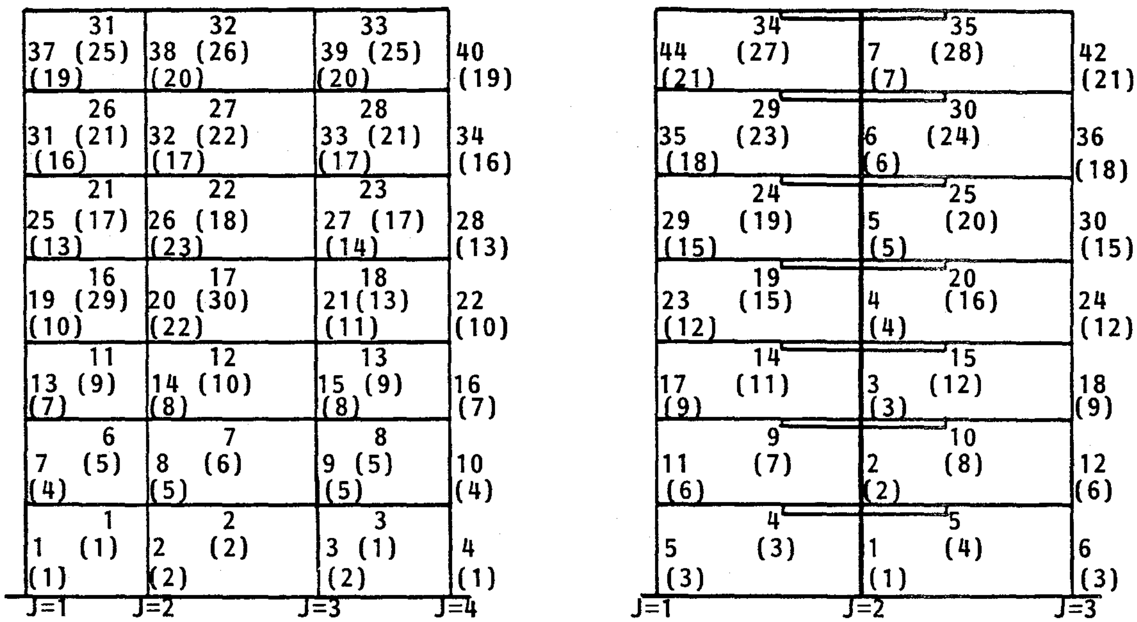
For the present analysis, the recorded accelerogram of the 1968 Tockachi-Oki earthquake, as shown in Fig. 4-5, was used as the input base motion with a scaled horizontal maximum acceleration of 0.357g.

The resultant time-history of the top story displacement as well as the variation of the top displacement vs. story shear are shown in Figs. 4-6 and 4-7. The computed response is in good agreement with test results [15]; the small variations can be attributed to the effect of higher modes that were eliminated in the pseudo-dynamic testing.

For the substructure analysis, two sub-assemblages were extracted from the total structure. Fig. 4-8 shows the respective substructures including relevant input information. Fig. 4-9 and 4-10 show the load-deformation relation of the respective sub-assemblages.

For the second subassemblage, the analysis was carried out for a maximum horizontal acceleration of 0.25g and a time duration of 20 secs. The time interval of the analysis was 0.005 secs.

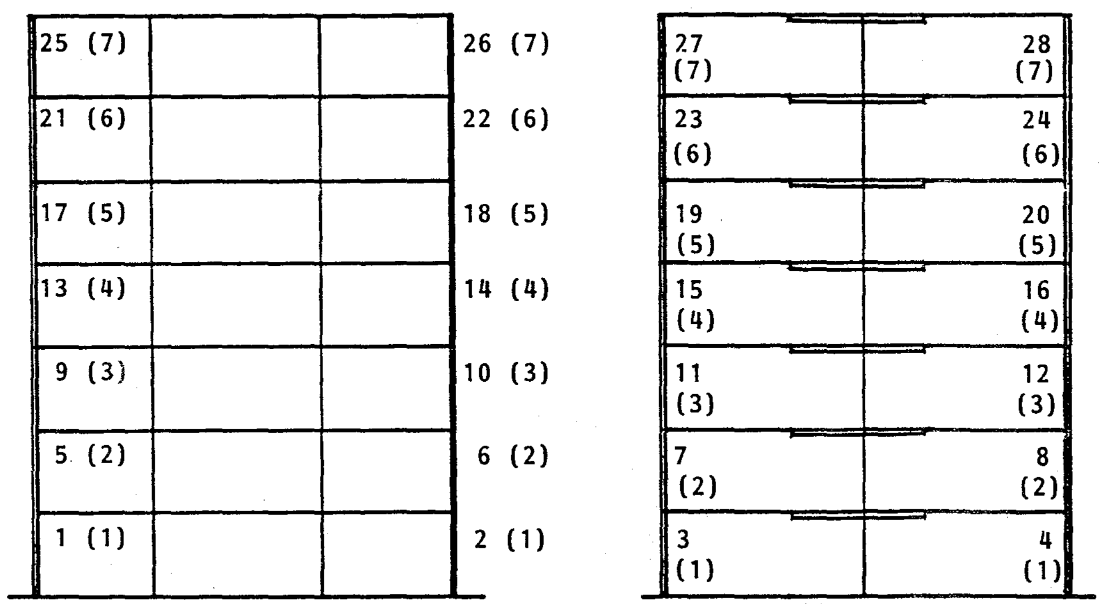
The results from such a substructure analysis is extremely useful in the determination of loading histories for the experimental testing of actual sub-assemblages on shaking tables.



() = Type Numbers (WALL)

Frame No. 1 Frame No. 2

FIGURE 4-2 Numbering of Column, Beam and Wall Elements



() = Type Number

Frame No. 1 Frame No. 2

FIGURE 4-3 Numbering of Edge Column Elements

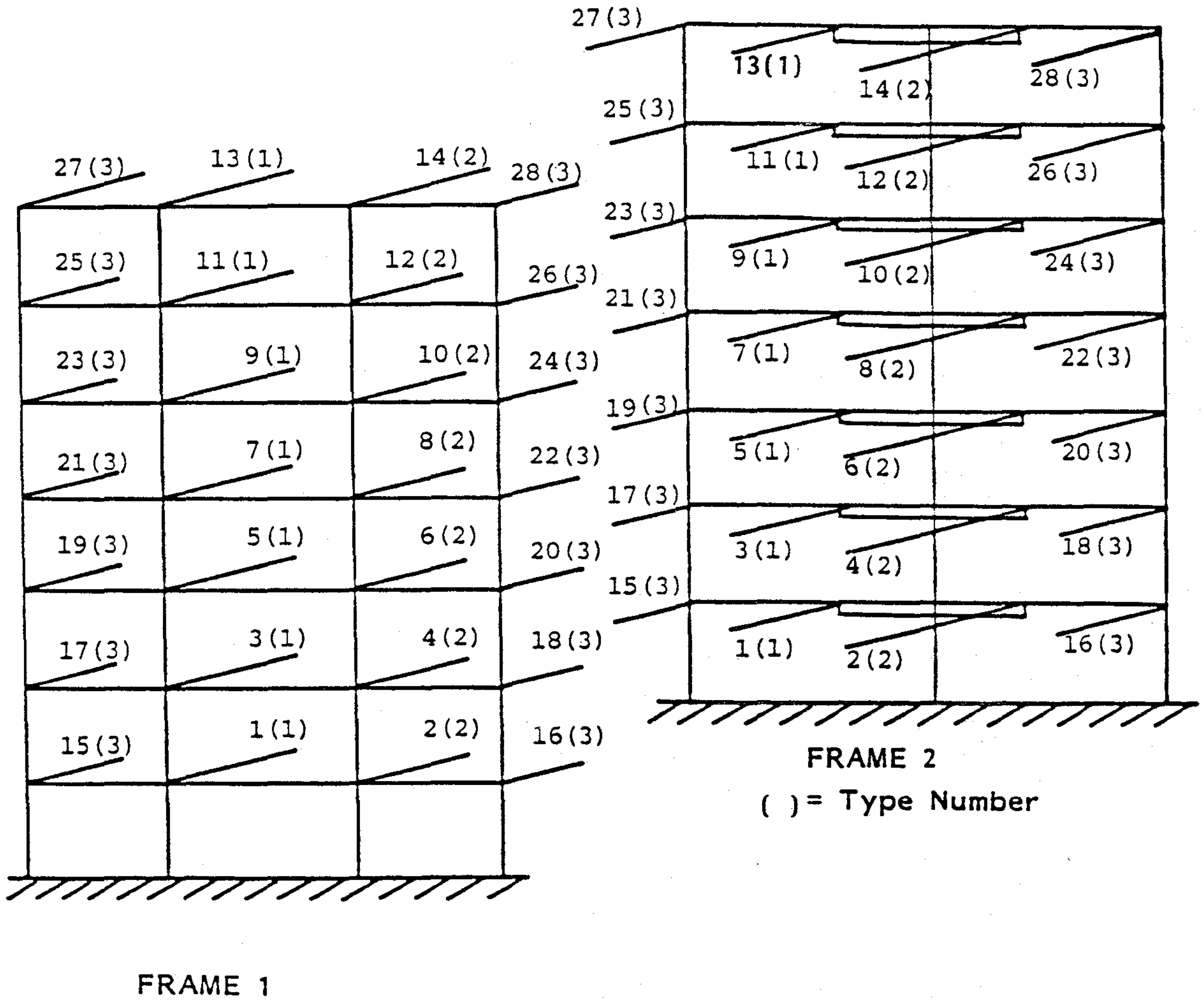


FIGURE 4-4 Numbering of Transverse Beams

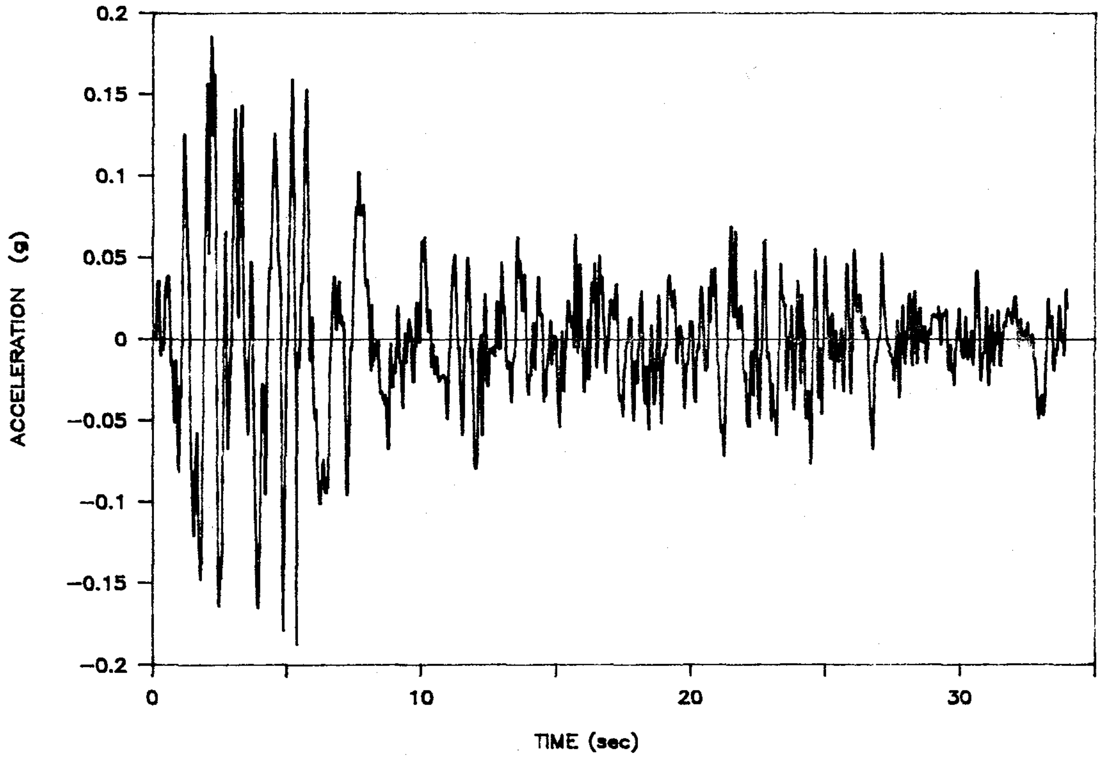


FIGURE 4-5 Tockachi Oki Accelerogram

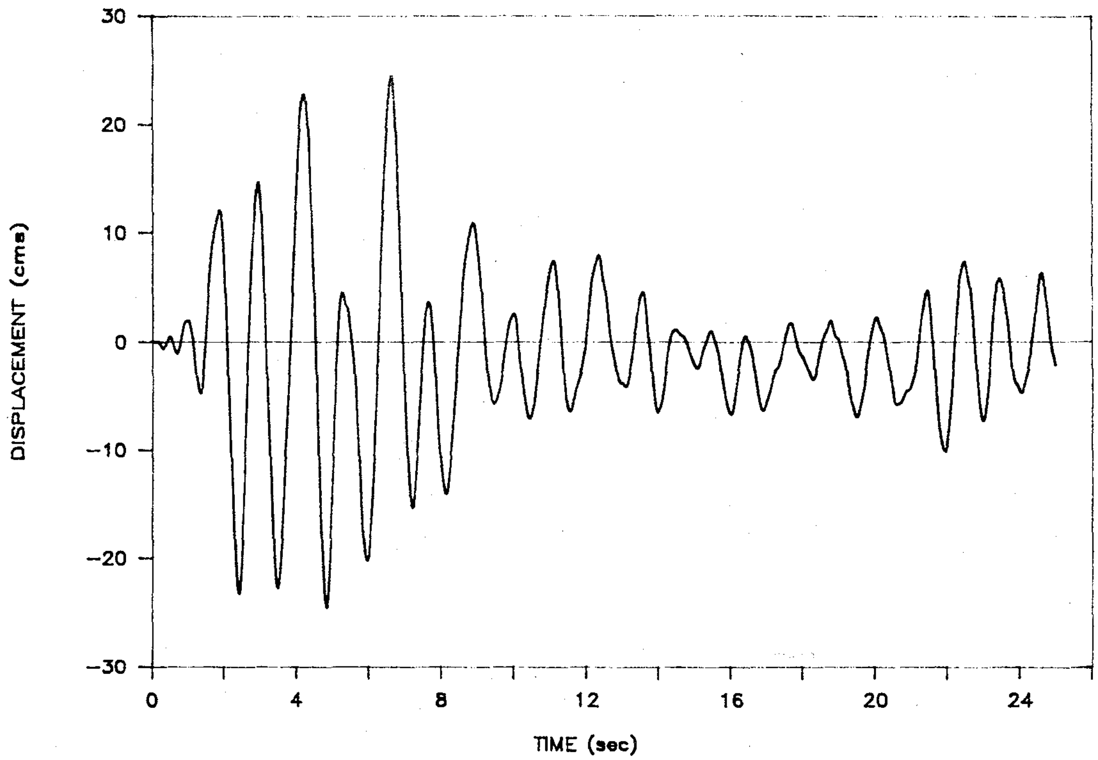


FIGURE 4-6 Displacement Time History

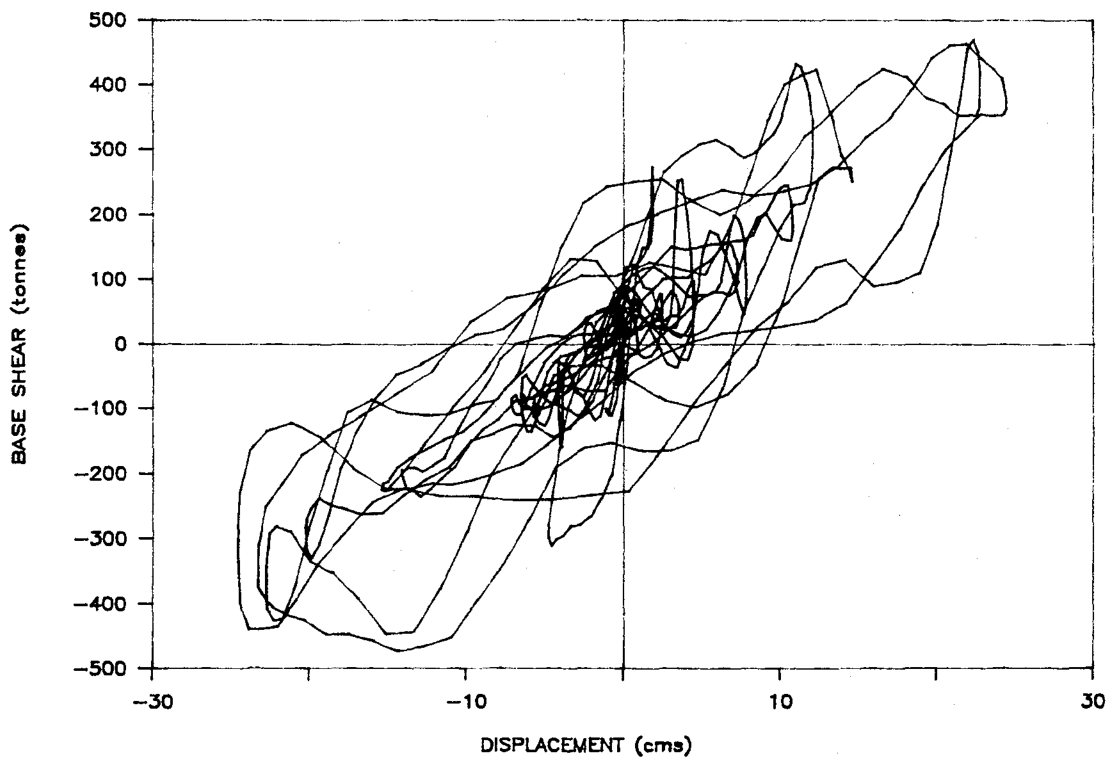
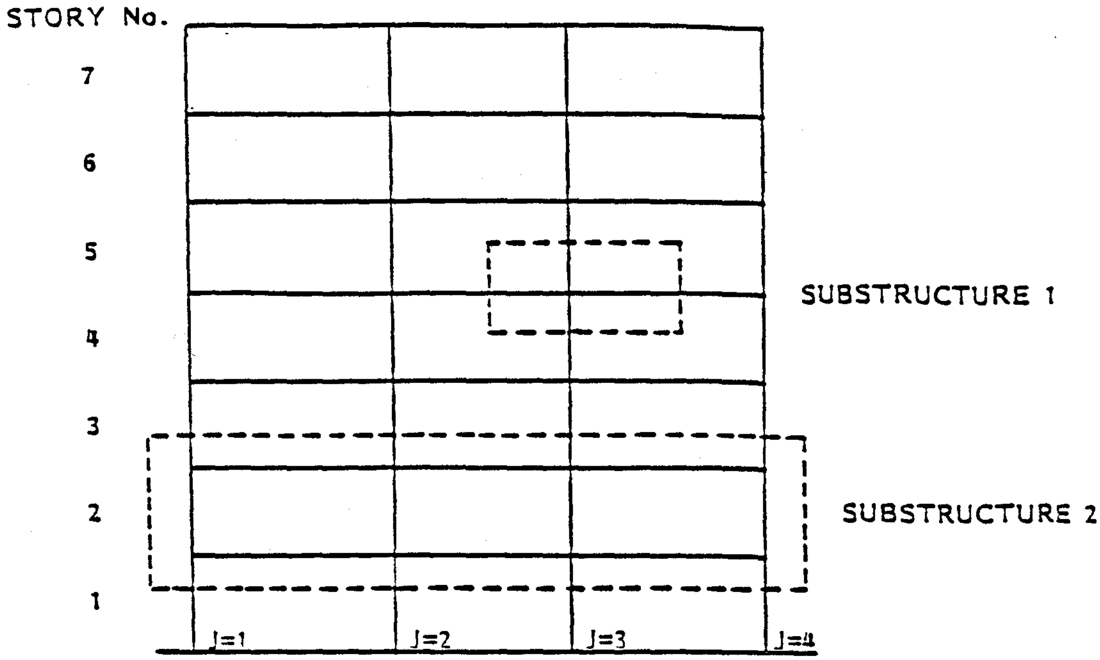
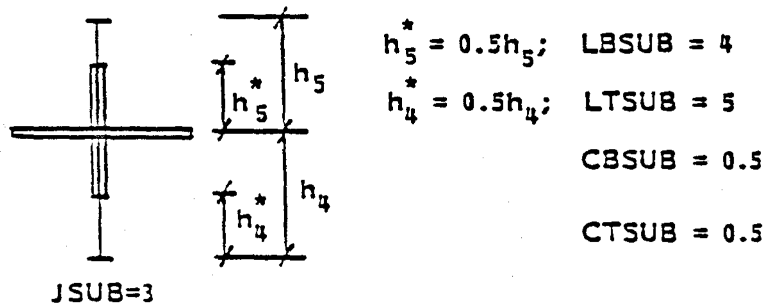


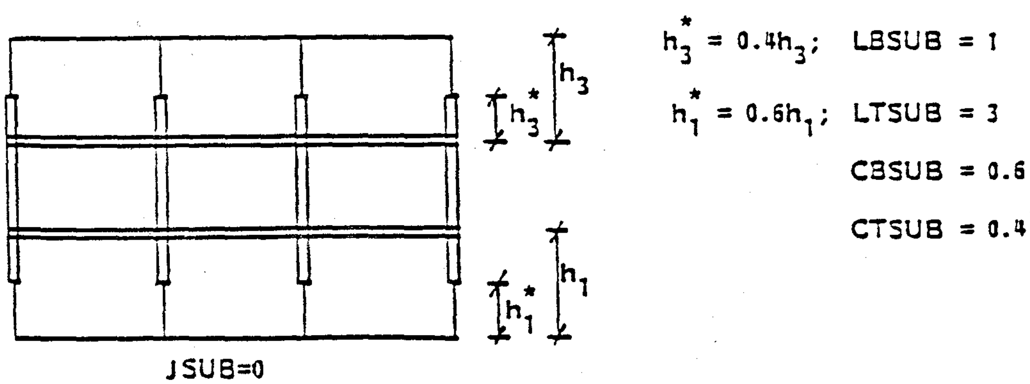
FIGURE 4-7 Base Shear vs. Top Displacement



a) FRAME #1 ; ISUB=1



b) Subassemblage 1



c) Subassemblage 2

FIGURE 4-8 Subassemblages

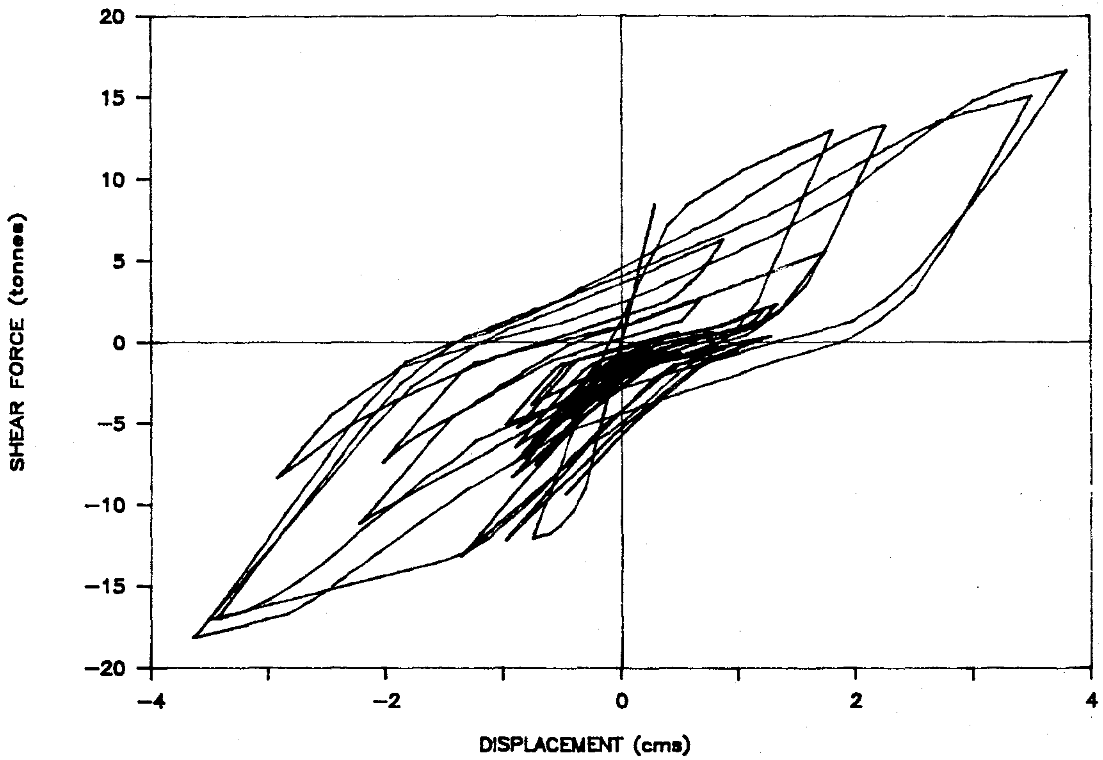


FIGURE 4-9 Force Displacement Relation for Substructure 1

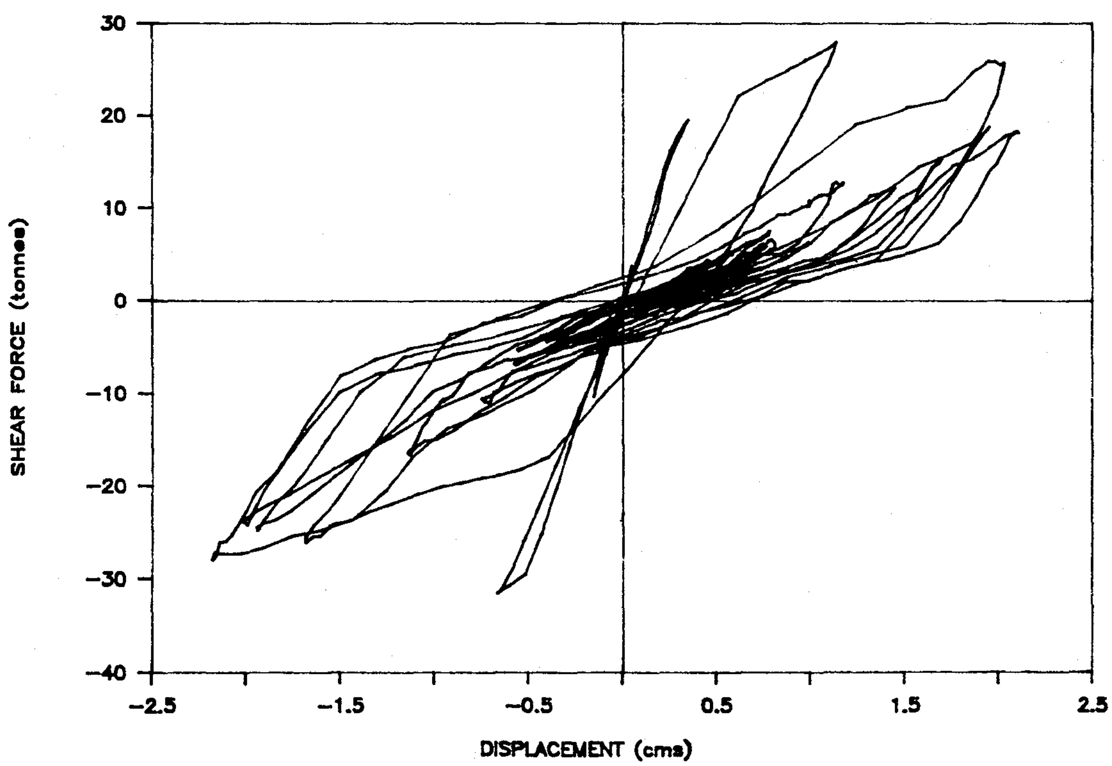


FIGURE 4-10 Force Displacement Relation For Substructure 2

SECTION 5
CONCLUSION

This report summarizes the development and details of the computer program IDARC which performs an equivalent static analysis, a step-by-step dynamic response analysis and a comprehensive damage analysis of reinforced concrete frame-shear wall type structures. Also discussed are the hysteretic model used for the inelastic dynamic response analysis, the modeling of the building components and the nature of the substructure analysis.

The program in its present form is highly versatile and can model buildings with reasonably complex configurations. However, this current version of IDARC is meant to comprise the basic structure of a more comprehensive dynamic analysis package for reinforced concrete buildings with emphasis on substructure and damage analysis. Proposed modifications of the program include:

1. Inclusion of a new hysteretic model for shear wall elements;

2. Inclusion of slab elements to model inplane flexibility of floor diaphragms;

3. Static analysis under user-specified loads and boundary conditions;

4. A powerful graphics preprocessor and postprocessor for analysis and design.

The overall program package is expected to contribute significantly in the experimental testing of R/C subassemblages, damageability assessment of existing buildings and a host of related applications.

The program is available for use either on DEC/VAX computers or IBM mainframe systems and the IBM-3090-400 Vector Computer at Cornell University's Supercomputing Facility.

SECTION 6

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APPENDIX A
USER GUIDE

A.1. Input Format

A free format is used to read all input data. Hence, conventional delimiters (comma, blank) may be used to separate data items. Standard FORTRAN variable format is used. Input data must, therefore, conform to the specified variable type.

NOTE: NO BLANK CARDS ARE TO BE INPUT

VARIABLES	DESCRIPTION
SET A:	
CARD #1: Title	
TITLE	Alpha-numeric title, up to 80 characters.
CARD #2: Control Information	
NSO,NFR,MCON,MSTL	NSO = No. of stories
	NFR = No. of different frames (not including identical frames) see Fig. 3-1.
	MCON = No. of different concrete material properties.
	MSTL = No. of types of steel reinforcement properties.

NOTES:

1. The number of stories refers to the total number of floor levels excluding the base level.
2. A typical structure may be composed of a number of frames, of which some may be identical to each other. Input information is required only of the

unique frames. Two examples are shown in Fig. A-1 to demonstrate this distinction. In Fig. A-1a, there is only one unique frame since the second and third are identical to the first. In Fig. A-1b, two of the four frames are identical to each other, thereby giving an NFR value of 3.

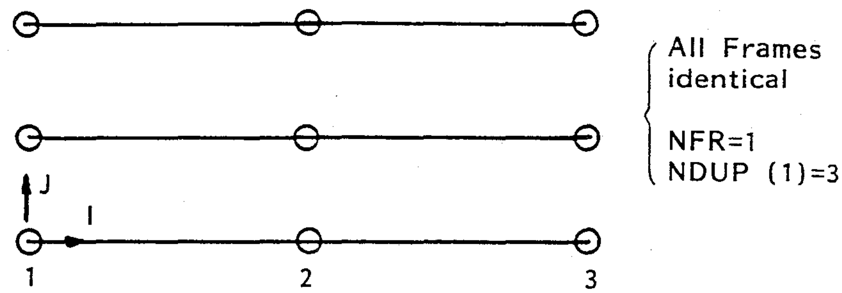
3. The different concrete properties refer to the different types of concrete used in the construction of the various elements. A concrete belongs to the same 'type' if it has the same stress-strain curve (to be input in SET C)

4. The number of types of steel reinforcement refers to strength parameters and not the size of bars used. All steel bars with the same stress-strain curve (input in SET D) belong to the same steel type.

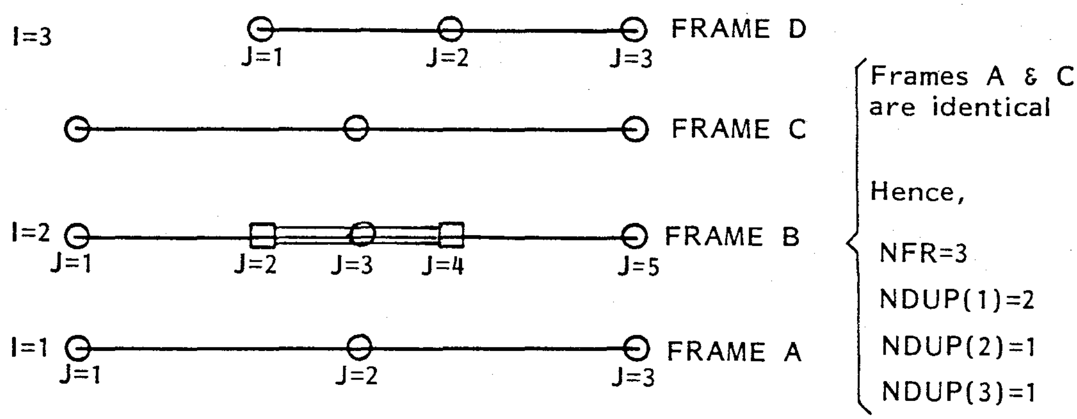
CARD #3: ELEMENT TYPES

MCOL,MBEM,MWAL,MEDG,MTRN	MCOL = No. of types of columns
	MBEM = No. of types of beams
	MWAL = No. of types of shear walls
	MEDG = No. of types of edge columns
	MTRN = No. of types of transverse beams

NOTES: The number of types of a particular element is meant to group together a set of similar elements with identical properties. As an example, consider the frame shown in Fig. A-2. The frame consists of 12 column elements and 9 beam elements. However, in this example, we assume that the columns and beams at each floor level are composed of elements with similar properties



a) Plan with Identical Frames



b) Plan with Different Frames

FIGURE A-1 Coordinate Configuration in Plan (dimensions, reinforcement, material properties). Hence, we have 3 beam types and 3 column types.

CARD #4: ELEMENT DATA

NCOL,NBEM,NWAL,NEDG,NTRN	NCOL = No. of columns NBEM = No. of beams NWAL = No. of shear walls NEDG = No. of edge columns NTRN = No. of transverse beams

NOTES: This input refers to the total number of elements in the building. Using the frame of Fig. A-2, NCOL=12, NBEM=9, and NWAL = NEDG = NTRN = 0.

CARD #5: BASE SHEAR ESTIMATE

PMAX	Estimate of base shear strength coefficient (as ratio of shear strength to total weight)

NOTES: The program uses this information only to determine the load steps for the static analysis under monotonic loading. An initial value of 1.0 may be input for the first run using the static analysis option (to be input later). The true base shear coefficient is computed by program IDARC based on this initial estimate. Use this value for subsequent dynamic and damage analysis.

CARD #6: Units

IU	System of units =1, inch, kips =2, cms, metric tonnes

NOTES: Use '1' if all data is input in inches, kips. Use '2' if all data is input in cms and tonnes. In both cases, output information will also be in the same units.

CARD #7: FLOOR ELEVATIONS

HIGT(I),I=1,NSO	Elevation of each story from the base, beginning with the first floor level. (see Fig. A-3)

CARD #8: FLOOR WEIGHTS

WIGT(I),I=1,NSO	Weight of each floor beginning with the first floor (Fig. A-3).

CARD #9: IDENTICAL FRAMES

NDUP(I),I=1,NFR	No. of duplicate (or identical) frames for each of 'NFR' frames (listed in data card #2). See Fig. A-1 for details.

CARD #10: CONFIGURATION OF PLAN

NVLN(I),I=1,NFR	Number of j-coordinate points in each frame. (See Fig. A-4)

NOTES: A set of NVLN points for each frame should define completely the j-coordinates necessary to specify every element in that frame.

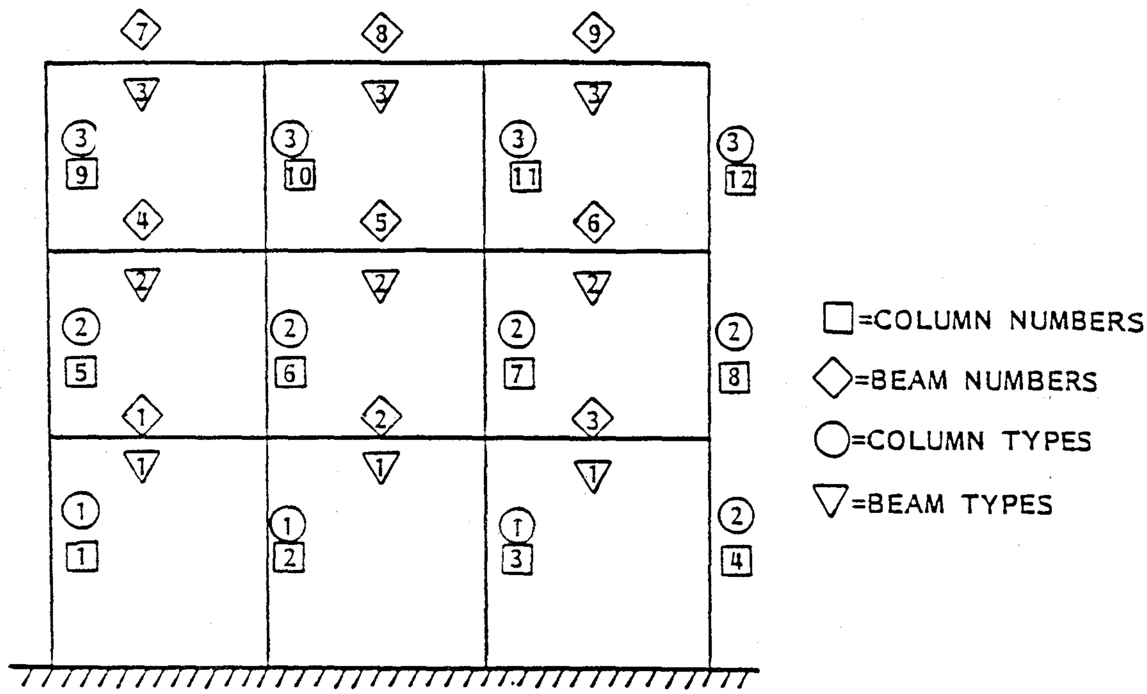


FIGURE A-2 Element Types and Numbers

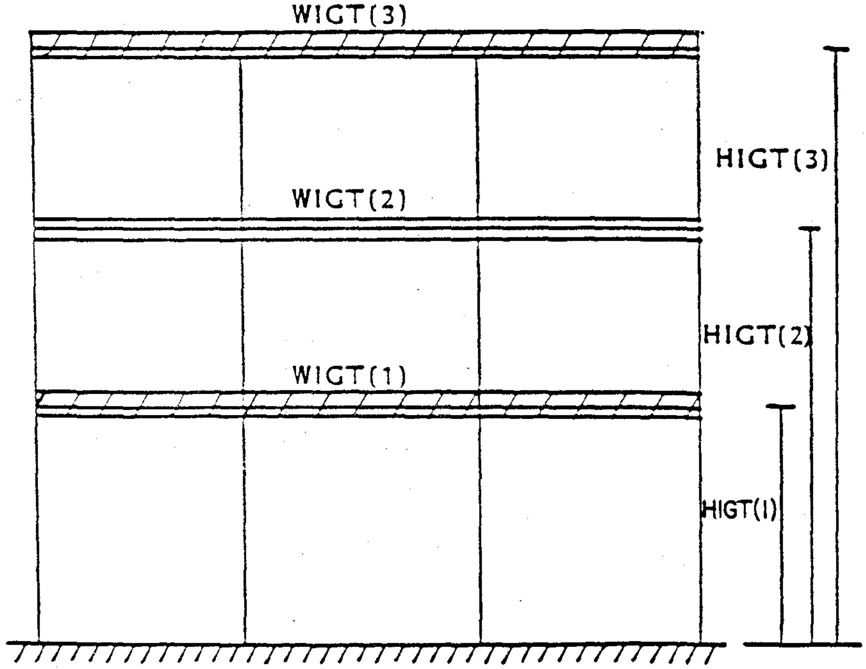


FIGURE A-3 Floor Elevation and Weights

SET B: J-COORDINATE LOCATIONS

SPANX(1,1) .. SPANX(1,NVLN(1))	For each frame:
.	input the 'distance' of
SPANX(NFR,1)....SPANX(NFR,NVLN(NFR))	each of the NVLN points from any reference line (left to right)

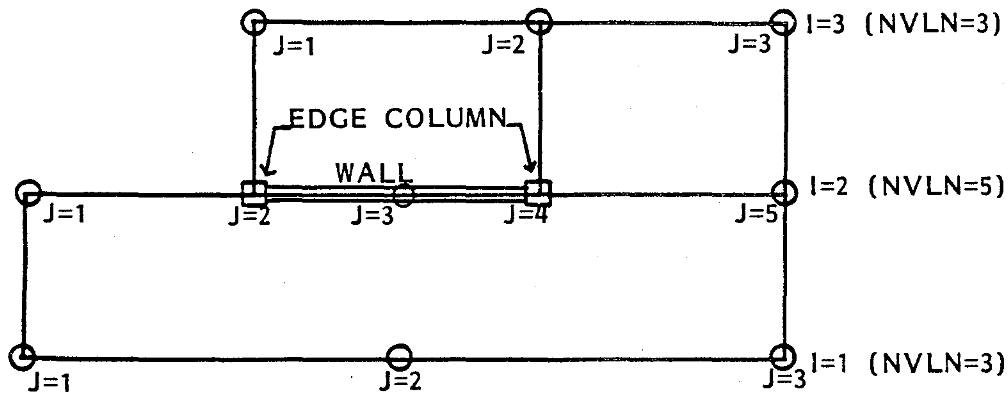
NOTES: Choose a reference line, preferably to the left of the leftmost j-coordinate point (as shown in Fig. A-4). Another convenient location for the reference line would be along the leftmost j-coordinate location itself. However, there is no restriction as to where this line is located as long as it is perpendicular to the loading axis.

The x-coordinate refers to the distance of each j-coordinate location from this reference line. A typical example is shown in Fig. A-4.

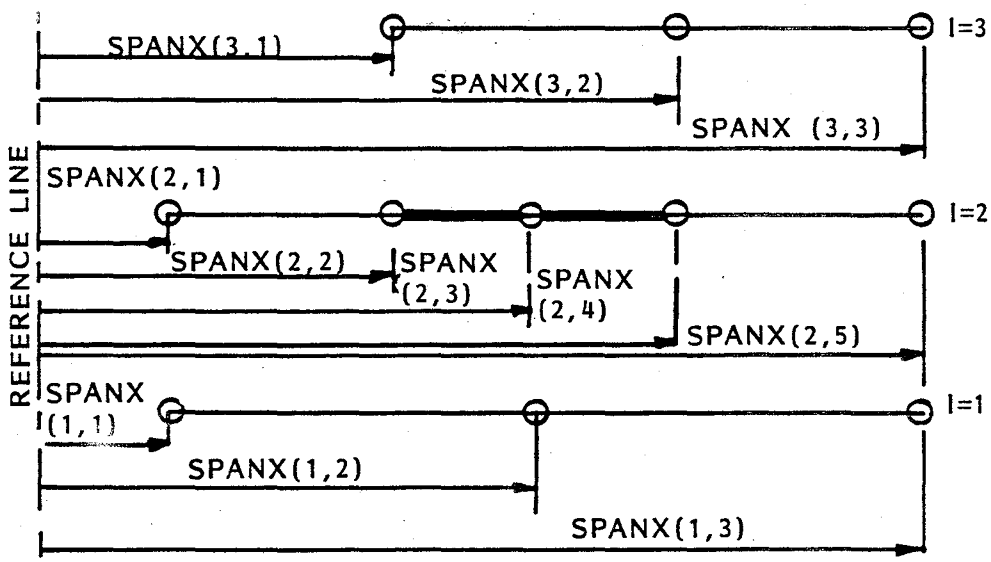
SET C: CONCRETE PROPERTIES

I,FC(I),EC(I),EPSO(I),TAUM(I)	Characteristics of concrete stress -strain curve (see Fig. A-5):
.	I = Concrete type number
.	
MCON,FC(MCON).... TAUM(MCON)	FC = f'_c, concrete strength
	EC = Young's modulus (default: $57 \sqrt{f'_c}$)
	EPSO= Comp. strain of concrete at max stress (%)
	TAUM= Bond strength, τ_m (default: 1.2 ksi)

NOTES: For each of the 'MCON' types of concrete input in card #2, relevant parameters describing the stress-strain curve (as listed above) are necessary. Fig. A-5 shows



(a) Plan Showing J-Coordinate Locations



(b) X-Coordinate Locations

FIGURE A-4 Nodal Location Input

the stress-strain curve along with the parameters needed to fully define the curve. The equation of the non-linear function is used primarily in the fiber model analysis of shear walls.

The bond strength of concrete is obtained typically from experimental testing, however, the program uses a default value of 1.2 ksi if such data is unavailable. It is assumed that the concrete can resist tension up to 1/10 of its strength in compression.

SET D: PROPERTIES OF REINFORCEMENT

I,FS(I),FSU(I),ES(I),ESH(I), EPSH(I) . . . MSTL,FS(MSTL) ..... EPSH(MSTL)	Characteristics of steel stress-strain curve for each steel type. (See Fig. A-6): I = Steel type number FS = Yield strength FSU = Fracture strength ES = Youngs Modulus (default: 29000 ksi) ESH = Modulus of strain hardening (default: 500 ksi) EPSH= Strain at initiation of hardening in % (default: 3%)

NOTES: A trilinear curve (as shown in Fig. A-6) is used to define the stress-strain characteristics of the steel reinforcement. The properties are assumed to be identical in both tension and compression.

A set of MSTL cards is required in this input section as specified in card #2 of set A.

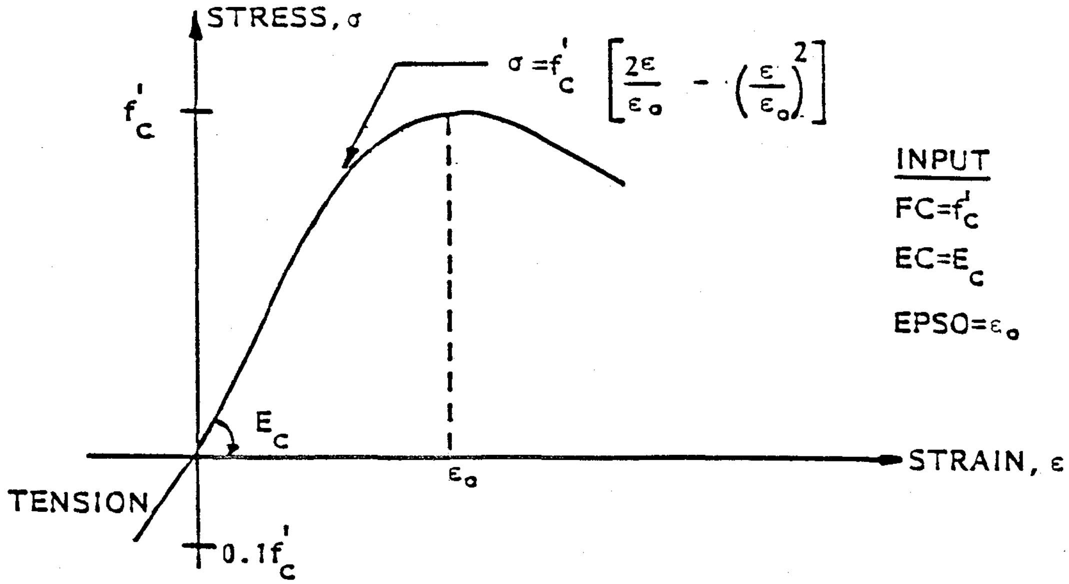


FIGURE A-5 Stress-Strain Curve for Concrete

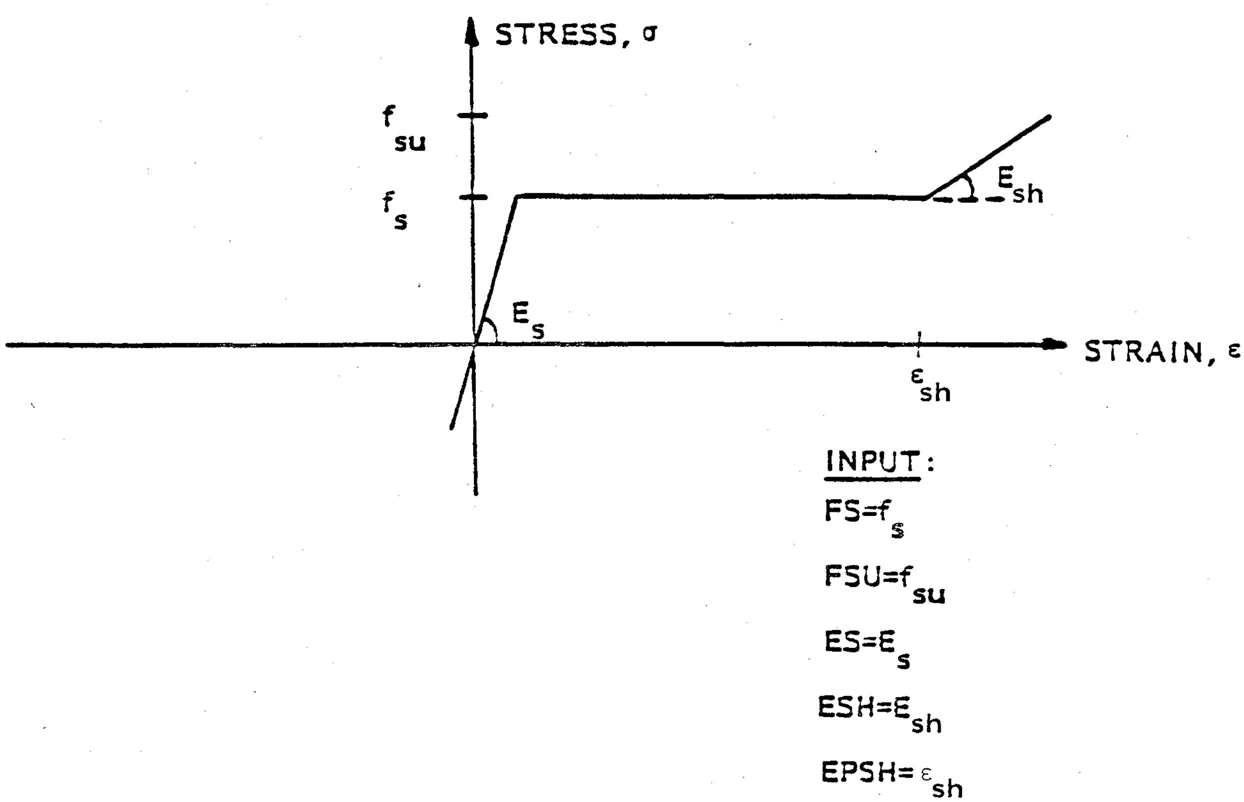


FIGURE A-6 Stress-Strain Curve for Steel

SET E: COLUMN PROPERTIES

NOTE: SKIP THIS INPUT IF THE STRUCTURE HAS NO COLUMNS

M,IMC,IMS,AN,D,B,BC,AT,PE, PW,RW,AMLC(M),RAMC1(M), RAMC2(M)	Properties of each column type (see Fig. A-7):
	M = Column type number
.	IMC = Concrete material type number
.	IMS = Steel material type number
.	AN = Axial load
MCOL,IMC,IMS......	D = Depth of column
PW,RW........	B = Width of column
RAMC2(MCOL)	BC = Distance from centroid of reinforcement to face of column
	AT = Area of tension reinforcement.
	PE = Total perimeter of all tension reinforcement
	PW = Web reinforcement ratio (%)
	RW = Confinement ratio
	AMLC = Center-to-center column height
	RAMC1 = Rigid zone length at bottom
	RAMC2 = Rigid zone length at top

NOTES: The basic properties of each of the MCOL columns (input in card #3) is required in this input section.

IMC and IMS refer to the concrete and steel stress-strain curves respectively, that are to be used in establishing the strength parameters of the column.

The axial load is determined from the effective vertical load acting on the column (and any other axial load that may act on the column under consideration).

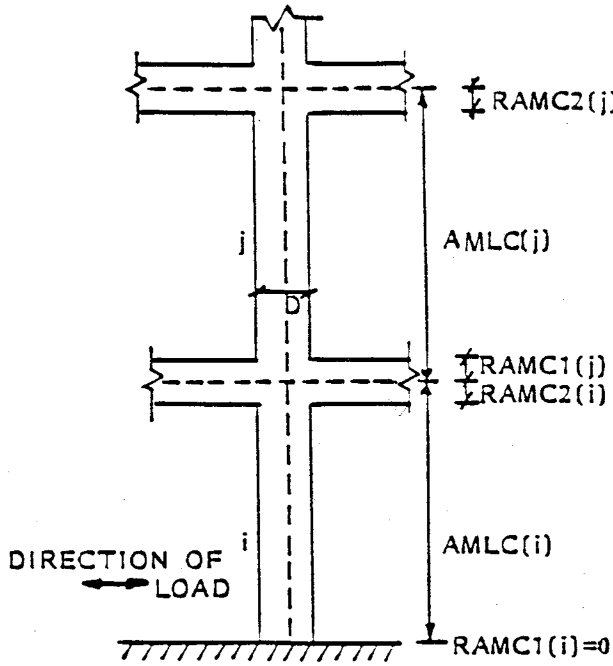
Fig. A-7 shows the details of two typical columns. Column 'i' is fixed at the base and hence has no rigid arm at the bottom. The length AMLC of a column is basically the center-to-center length (except in the absence of a rigid arm, as in the case of column 'i').

The parameter 'AT' is the total area of the tension reinforcement. The analysis, however, assumes that the area of the tension and compression reinforcement are equal. If the actual areas are in fact different, then it is advisable to use the average of the two areas. The web reinforcement ratio and confinement ratio are computed in the usual manner. (the confinement ratio 'PW' is the volumetric ratio of the hoops to the core concrete.)

SET F: BEAM PROPERTIES

NOTE: SKIP THIS INPUT IF THE STRUCTURE HAS NO BEAMS

M,IMC,IMS,SIGBL(M),SIGBR(M), D,B,BSL,TSL,BC1,AT1,AT2, PE1,PE2,PW,RW,AMLB(M), RAMB1(M),RAMB2(M)	Properties of each beam type: (Fig. A-8)
.	M = Beam type number
.	IMC = Concrete type number
.	IMS = Steel type number
MBEM,IMC,IMS................ D,B,BSL............. RAMB1(MBEM),RAMB2(MBEM)	SIGBL = Initial bending moment at left section
	SIGBR = Initial bending moment at right section
	D = Overall depth
	B = Lower width
	BSL = Effective slab width
	TSL = Slab thickness
	BC1 = Distance from bottom bars to lower face



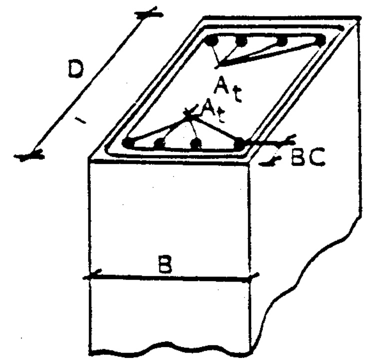
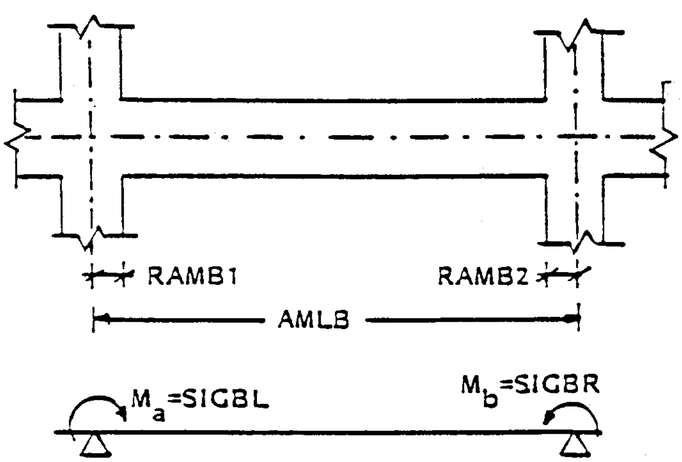


FIGURE A-7 Column Input Details



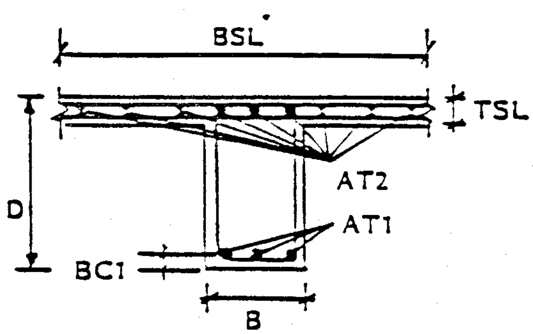


FIGURE A-8 Beam Input Details

AT1 = Area of bottom bars
AT2 = Area of top bars
PE1 = Perimeter of bottom bars
PE2 = Perimeter of top bars
PW = Web reinforcement ratio(%)
RW = Confinement ratio
AMLB = Member length
RAMB1 = Rigid zone length (left)
RAMB2 = Rigid zone length (right)

NOTES: The above input is required for each of the 'MBEM' beams input in card #3.

IMC and IMS define the concrete and steel stress-strain properties previously input in set C and set D, respectively.

SIGBL and SIGBR are the dead load bending moments at the left and right section, respectively. The sign convention for the bending moments is shown in Fig. A-8 where a positive value indicates compression in the top fibers and tension in the bottom fibers.

For beam-slab elements, BSL refers to the effective width of the slab. For simple frame structures without slab units:

1. BSL and B assume the same value;
2. TSL is input as the cover distance from the top bars to the upper face of the beam element

The effect of overhanging cantilevers is not expected to contribute significantly to the overall response and hence their presence may be ignored.

SET G: SHEAR WALL PROPERTIES

NOTE: SKIP THIS INPUT IF THE STRUCTURE HAS NO SHEAR WALLS

M,IMC,IMS,AN,D,B,PT,PW,	Shear wall properties: (Fig. A-9)
DC,BC,AG,AMLW(M)	M = Shear wall type number
.	IMC = Concrete type number
.	IMS = Steel type number
.	AN = Axial load
MWAL,IMC,IMS............	D = Length of shear wall
DC,BC,AG,AMLW(M)	B = Wall thickness
	PT = Vertical reinforcement ratio(%)
	PW = Horizontal reinforcement ratio(%)
	DC = Depth of edge column
	BC = Width of edge column
	AG = Gross steel area of edge columns
	AMLW = Height of shear wall

NOTES: The above input is required for each of the MWAL shear walls (input in card #3 of set A).

Two types of shear walls are possible:

1. shear walls with one or two edge columns

2. shear walls without edge columns

Details of typical shear wall elements are shown in Fig. A-9. In the absence of any edge columns, set the following input parameters to zero: BC, DC and AG.

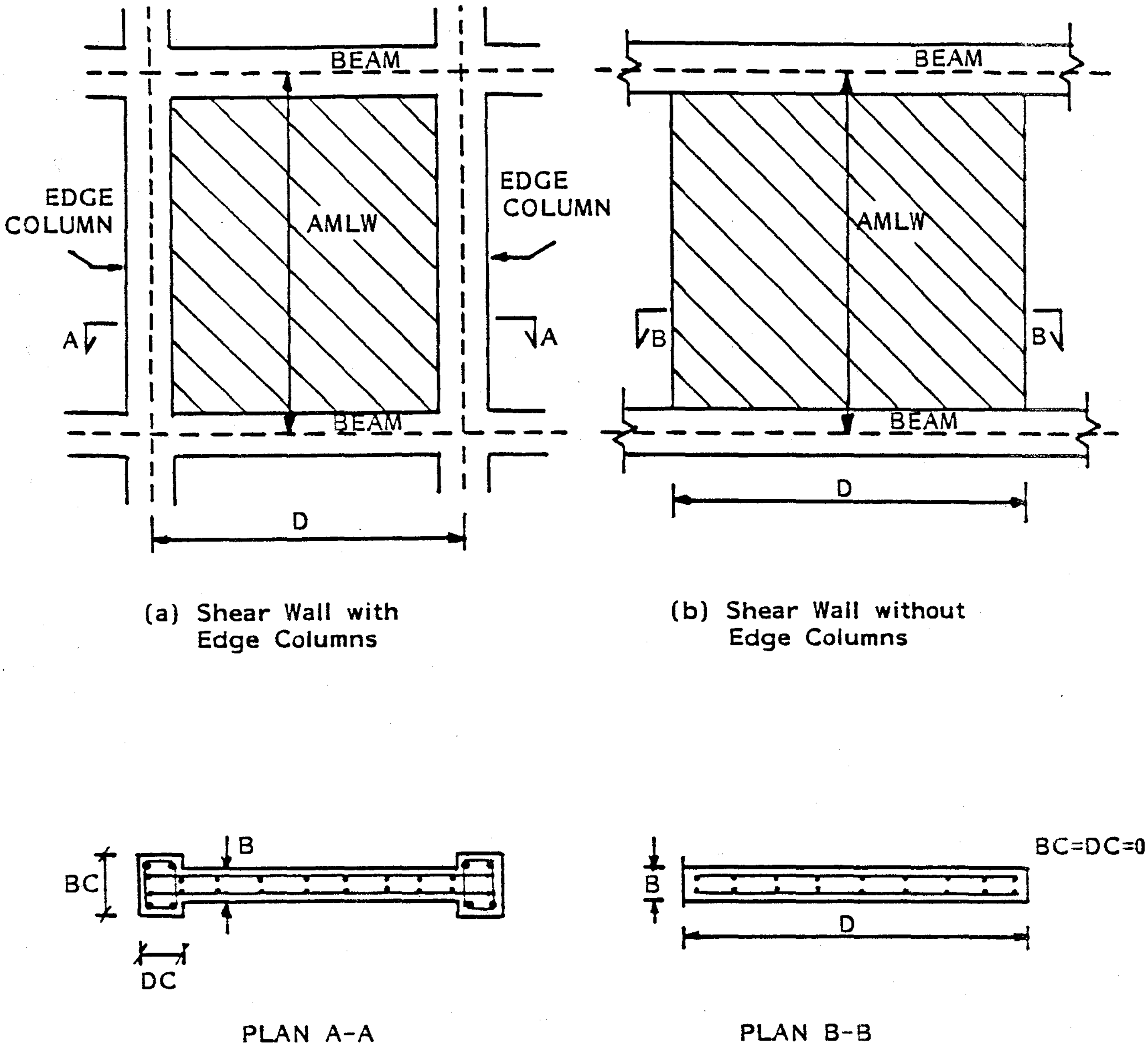


FIGURE A-9 Input Details of Shear Walls

SET H: EDGE COLUMN PROPERTIES

NOTE: SKIP THIS INPUT IF THE STRUCTURE HAS NO EDGE COLUMNS

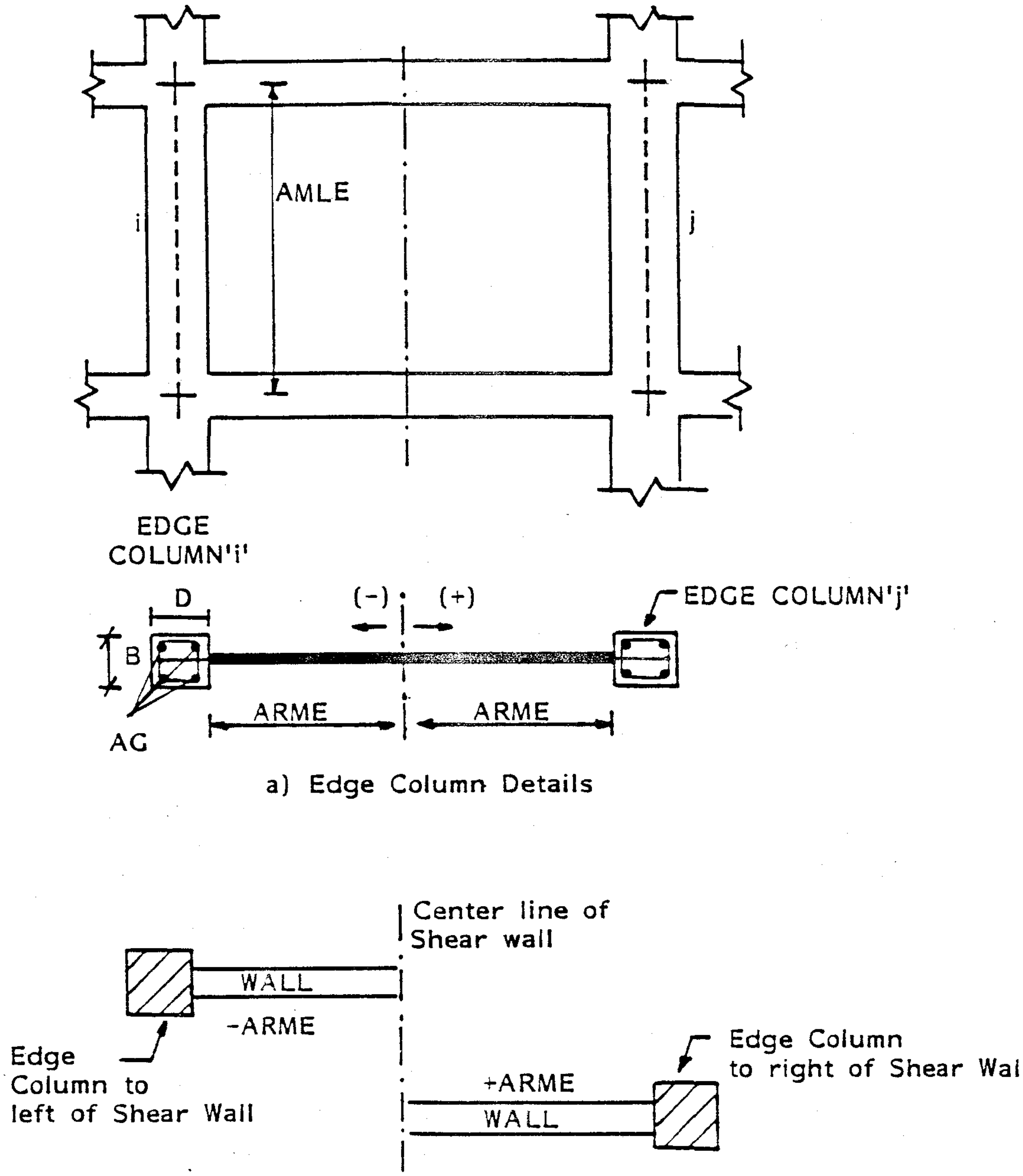
M,IMC,IMS,AN,D,B,AG,AMLE,ARME(M)	Edge column properties:
.	M = Edge column type number
.	IMC = Concrete type number
.	IMS = Steel type number
MEDG,IMC,IMS.........ARME(MEDG)	AN = Axial load
	D = Depth of edge column
	B = Width of edge column
	AG = Gross area of main bars
	AMLE = Member length
	ARME = Arm length

NOTES: Input is required of each of the MEDG edge columns (as specified in card #3 of set A).

Details related to the input of typical edge columns are shown in Fig. A-10.

AMLE refers to the center-to-center height of the edge column, while AG is the total area of all the reinforcing bars in the edge column.

In writing the arm length of an edge column, it is important to consider the sign convention used. The arm length is the distance from the face of the edge column to the center of the shear wall to which it is anchored. For edge columns to the left of the shear wall, a negative arm length should be input (Fig. A-10)



a) Edge Column Details

b) Sign Convention

FIGURE A-10 Edge Column Input Details

SET I: TRANSVERSE BEAM PROPERTIES

NOTE: THIS INPUT NOT REQUIRED IF STRUCTURE HAS NO TRANSVERSE BEAMS

M,AKV(M),ARV(M),ALV(M)	Transverse beam properties:
.	M = Transverse beam type number
.	AKV = Vertical Stiffness
.	ARV = Torsional Stiffness
.	ALV = Arm length
.	
MTRN,AKV(MTRN)....ALV(MTRN)	

NOTES: Input is required for each of the MTRN transverse beams specified in card #3 of set A.

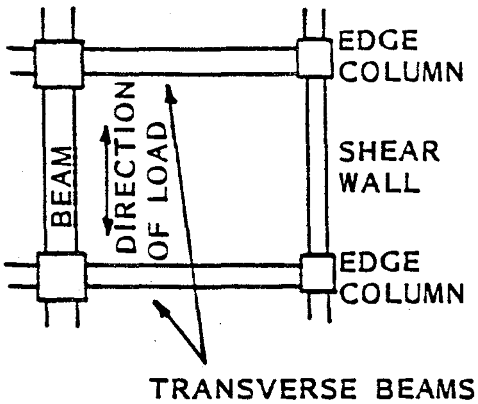
Two types of transverse beams exist:

1. beam-to-wall connections
2. beam-to-beam connections

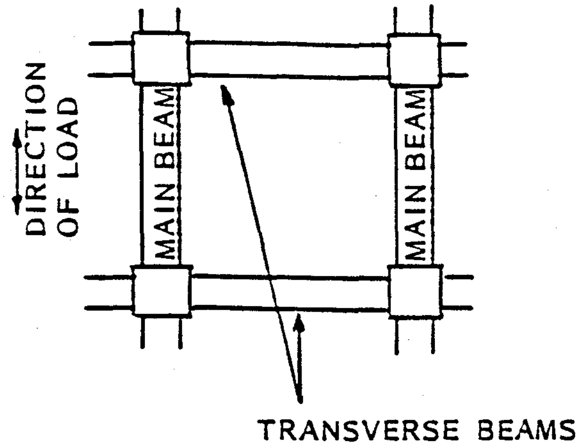
Details of both types of transverse elements are shown in Fig. A-11. The arm length, for beam-to-wall connections, refers to the distance from the beam to the center of the shear wall to which it is connected. This parameter is set to zero for beam-to-beam connections.

The details of the stiffness computations is also shown graphically in Fig. A-11. However, any suitable procedure may be used to arrive at these stiffness values depending upon the nature of the structural joint.

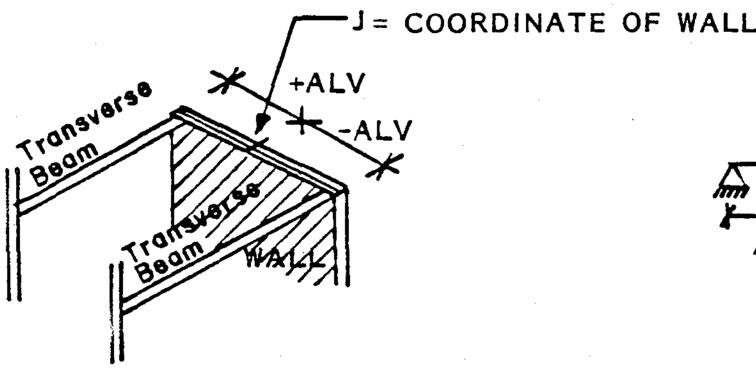
Note also the sign convention for arm length as shown in Fig. A-11.



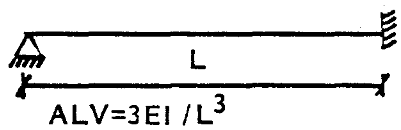
a) Beam-Wall Connection



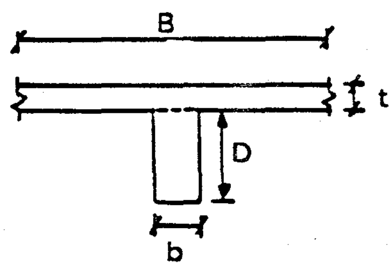
b) Beam-Beam Connection



c) Sign Convention for
Rigid Arm



d) Vertical Stiffness Computation



B = Effective Slab Width
t = Slab thickness
b, D = Width, depth of beam

$$ARV = \frac{1}{3}\,[t^3B + b^3D] \cdot \frac{G}{L}$$

(c) Torsional Stiffness
Computation

G= 0.4E

FIGURE A-11 Input Details of Transverse Beams

ELEMENT CONNECTIVITY INPUT

NOTES: Fig. A-12 (a-c) shows several examples of element connectivity input. The presence of shear walls, in particular, may require special modelling techniques to enable realistic analysis. An example is presented in Fig. A-12b.

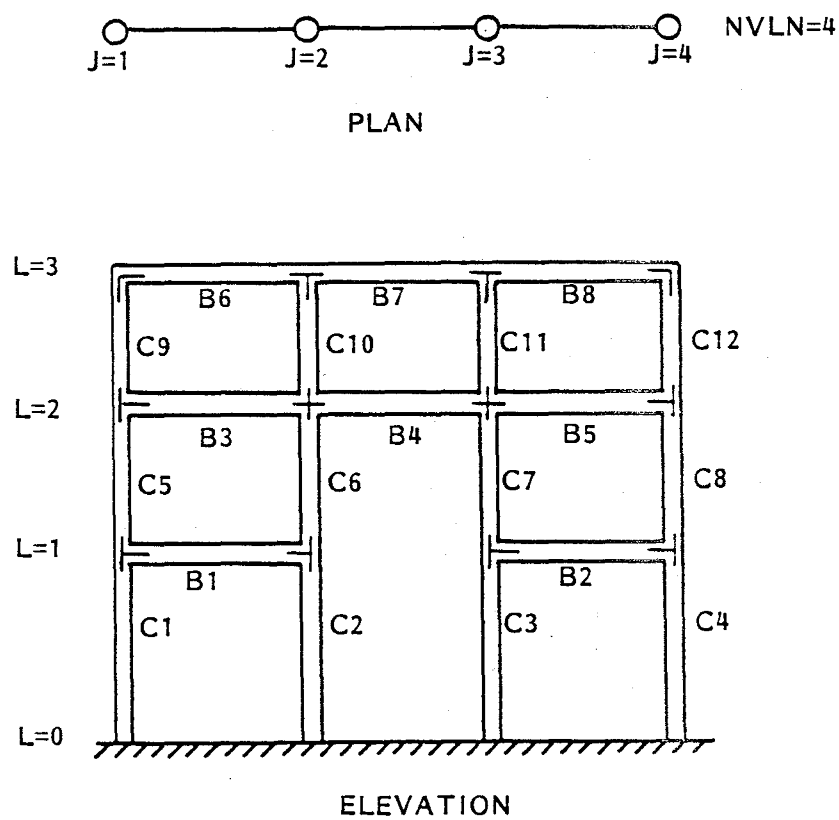
SET J: COLUMN CONNECTIONS

NOTE: SKIP THIS INPUT IF STRUCTURE HAS NO COLUMNS

M,ITC(M),IC(M),JC(M),	Column connectivity data:
LBC(M),LTC(M)	M = Column number
.	ITC = Column type number
.	IC = I-Coordinate
NCOL,ITC(NCOL).......	JC = J-Coordinate
LBC(NCOL),LTC(NCOL)	LBC = Bottom L-coordinate
	LTC = Top L-coordinate

NOTES: Nodal connectivity information is required for all columns in the structure (with the exception of the duplicate frames). Hence, the above input set consists of NCOL cards.

IC refers to the frame number, or the i'th coordinate position of the column. JC is the j'th coordinate position of the column (where 'j' varies from 1 to NVLN(i)). LBC and LTC are the bottom and top L-coordinate position of the column respectively.



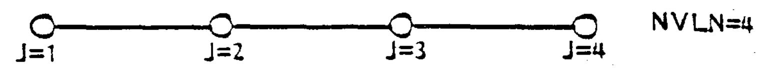
COLUMNS

MEMBER	JC	LBC	LTC
C1	1	0	1
C2	2	0	1
C3	3	0	1
C4	4	0	1
C5	1	1	2
C6	2	1	2
C7	3	1	2
C8	4	1	2
C9	1	2	3
C10	2	2	3
C11	3	2	3
C12	4	2	3

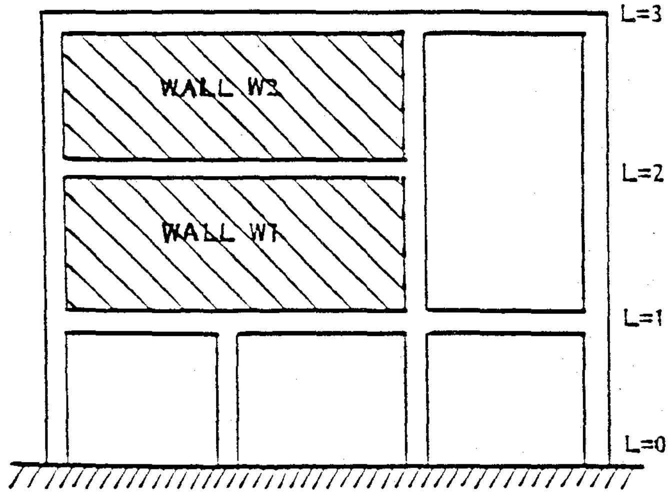
BEAMS

MEMBER	LB	JLB	JRB
B1	1	1	2
B2	1	3	4
B3	2	1	2
B4	2	2	3
B5	2	3	4
B6	3	1	2
B7	3	2	3
B8	3	3	4

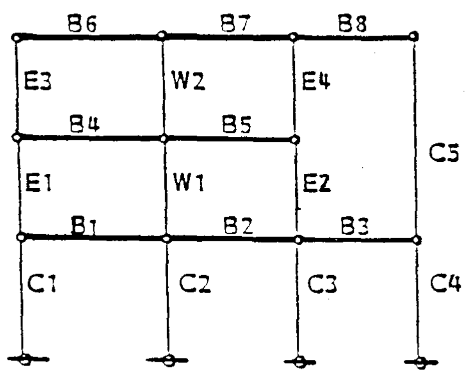
FIGURE A-12a Nodal Connectivity Input: Frame 1



PLAN



ELEVATION



MODELING

SHEAR WALLS

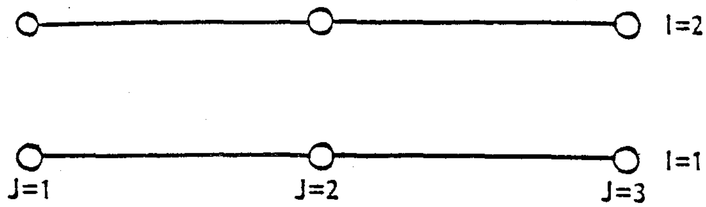
	JW	LBW	LTW
W1	2	1	2
W2	2	2	3

EDGE COLUMNS

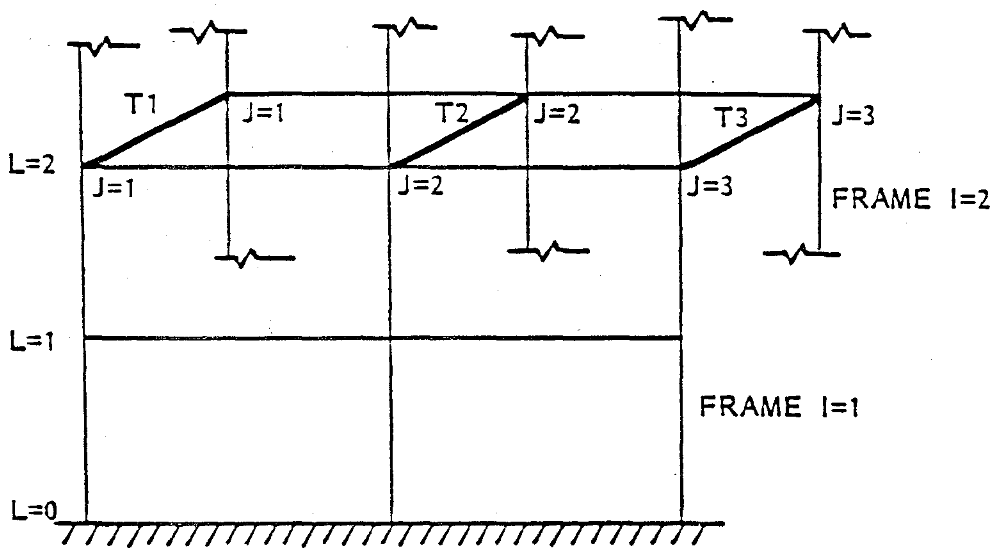
	JE	LBE	LTE
E1	1	1	2
E2	3	1	2
E3	1	2	3
E4	3	2	3

MODIFY INPUT FOR BEAMS B1,B2,B4-B7 SO THAT THEIR STIFFNESSES BECOME INFINITELY LARGE

FIGURE A-12b Modeling of Frame with Shear Wall



PLAN



I,J COORDINATE
OF CONNECTING POINT

I,J COORDINATE
OF ORIGIN OF BEAM

TRANSVERSE BEAMS

MEMBER	LT	IWT	JWT	IFT	JFT
T1	2	2	1	1	1
T2	2	2	2	1	2
T3	2	2	3	1	3

FIGURE A-12c Nodal Connectivity of Transverse Beams

SET K: BEAM CONNECTIVITY

NOTE: SKIP THIS INPUT IF STRUCTURE HAS NO BEAMS

M,ITB(M),LB(M),IB(M),	Beam connectivity data:
JLB(M),JRB(M)	M = Beam number
.	ITB = Beam type number
.	LB = L-Coordinate
.	IB = I-Coordinate
NBEM,ITB(NBEM).......	JLB = Left J-Coordinate
JLB(NBEM),JRB(NBEM)	JRB = Right J-Coordinate

NOTE: Input is required for each NBEM beams as specified in card #4 of set A.

SET L: SHEAR WALL CONNECTIVITY

NOTE: SKIP THIS INPUT IF STRUCTURE HAS NO SHEAR WALLS

M,ITW(M),IW(M),JW(M),	Shear wall connectivity data:
LBW(M),LTW(M)	M = Shear wall number
.	ITW = Shear wall type number
.	IW = I-Coordinate
.	JW = J-Coordinate
NWAL,ITW(NWAL).......	LBW = Bottom L-Coordinate
LBW(NWAL),LTW(NWAL)	LTW = Top L-Coordinate

NOTE: Input is required for each of the NWAL shear walls.

SET M: EDGE COLUMN CONNECTIVITY

NOTE: SKIP THIS INPUT IF STRUCTURE HAS NO EDGE COLUMNS

M,ITE(M),IE(M),JE(M),	Edge column connectivity data:
LBE(M),LTE(M)	M = Edge column number
.	ITE = Edge column type number
.	IE = I-Coordinate
.	JE = J-Coordinate
NEDG,ITE(NEDG).......	LBE = Bottom L-Coordinate
LBE(NEDG),LTE(NEDG)	LTE = Top L-Coordinate

NOTE: Input is required for each of the NEDG edge columns as specified in card #4, set A.

SET N: TRANSVERSE BEAM CONNECTIVITY

NOTE: SKIP THIS INPUT IF STRUCTURE HAS NO TRANSVERSE BEAMS

M,ITT(M),LT(I),IWT(M),	Transverse beam connectivity data:
JWT(M),IFT(M),JFT(M)	M = Transverse beam number
.	ITT = Transverse beam type number
.	LT = L-Coordinate
.	IWT = I-Coordinate of origin of transverse beam*
.	
.	JWT = J-Coordinate of origin of transverse beam*
.	
NTRN,ITT(NTRN).........	IFT = I-Coordinate of connecting wall or column
JWT(NTRN)...JFT(NTRN)	JFT = J-Coordinate of connecting wall or column

NOTES: NTRN cards are required in this input section.

* FOR BEAM-WALL CONNECTIONS, IWT AND JWT REFER TO THE I,J COORDINATE LOCATIONS OF THE SHEAR WALL.

NEXT CARD: DYNAMIC ANALYSIS OPTION

IDYN	Dynamic analysis option =0 , STOP (Do not perform dynamic analysis) =1 , CONTINUE (Dynamic analysis)

THE REMAINING CARDS NEED BE INPUT ONLY IF IDYN .EQ. 1

SET O: DYNAMIC ANALYSIS CONTROL PARAMETERS

CARD #1

GMAXH,GMAXV,DTCAL,TDUR,DAMP	Control parameters for dynamic analysis: GMAXH = Peak horizontal acceleration (g's) GMAXV = Peak vertical acceleration (g's) DTCAL = Time step for response analysis (secs) TDUR = Total time duration of analysis (secs) DAMP = Damping coefficient (% of critical)

NOTES: The input accelerogram is scaled uniformly to achieve the specified peak acceleration. Set GMAXV to zero if the vertical component of the acceleration is not input. DTCAL is the user controlled time step for the response analysis. DTCAL should not exceed the time interval of the input wave. It may be necessary to use smaller time steps depending upon the complexity of the structure and the magnitude of the input wave. For example, the analysis of the 7-story building presented in this report uses a time step of 0.005 secs (which was determined to be the optimum step to produce realistic results).

TDUR must be less than or equal to the total time duration of the input wave. It is preferable to use a value less than the total time of the input wave.

CARD #2: INPUT WAVE

IWV,NDATA,DTINP	IWV	= 0, Vertical component of acceleration not included
		= 1, Vertical component of acceleration included
	NDATA	= No. of points describing earthquake wave
	DTINP	= Time interval of input wave

CARD #3: WAVE TITLE

NAMEW	Alpha-numeric title for input wave upto 80 characters.

NEXT CARD: OUTPUT CONTROL

NSOUT,DTOUT, (ISOUT(I),I=1,NSOUT), (ISTYP(I),I=1,NSOUT)	CONTROL PARAMETERS FOR OUTPUT:	
	NSOUT	= No. of stories for which output of time history is required
	DTOUT	= Output time interval
	ISOUT	= Story numbers for which output is required

ISTYP = Type of time history for each story:
=1, displacement
=2, story drift
=3, story shear
=4, all of above

NOTES: Consider the following example:
A five-story building is analyzed. Output information is required for the top story displacement, the base shear and the displacement of the third floor level at an output interval of 0.05 secs. The OUTPUT CONTROL CARD will consist of the following input:

3,0.05,5,1,3,1,3,1

where: NSOUT = 3; DTOUT = 0.05
ISOUT(1) = 5; ISOUT(2) = 1; ISOUT(3) = 3;
ISTYP(1) = 1; ISTYP(2) = 3; ISTYP(3) = 1;

SET P: HYSTERETIC RULE

CARD #1:

NHYS — Number of types of hysteretic properties

CARD SET #2: HYSTERETIC MODEL PARAMETERS

HC(M),HS(M),HB(M),HP(M)
.
.
.
HC(NHYS)...... HP(NHYS)

HC = Degrading coefficient
HS = Slippage coefficient
HB = Deteriorating coefficient
HP = Post-yielding stiffness ratio

NOTES: HC refers to the parameter 'α' which defines the stiffness degradation (Fig. 2-8a); i.e., the common point on the extrapolated unloading line. As indicated in Fig. 2-8a, all unloading lines are assumed to target this common point until they reach the x-axis.

HS refers to the slippage or pinching coefficient 'γ' shown in Fig. 2-8b. The effect of introducing this parameter is to reduce the target maximum point after crossing the x-axis. If pinching effects are to be ignored, input a large value for HS (>1) which then forces the yield strength value to be the new maximum point.

HB or 'β ' is the rate of strength degradation (Fig. 2-8c). More details on this parameter is outlined in Sections 2.3 and 2.4.

Also note that program IDARC computes the value of the parameter 'β ' for each inelastic component using the formulation described in Section 2.3. Any input for this value will override the defaults computed by the program. If the user should choose to use the defaults, then a zero input is necessary for 'HB'.

Finally, HP defines the post-yielding stiffness ratio. Typical values of this parameter for reinforced concrete vary from 0.01 to 0.02.

NEXT CARD: COLUMN PARAMETERS

NOTE: SKIP THIS INPUT IF STRUCTURE HAS NO COLUMNS

KHYSC(I),I=1,NCOL	Type of hysteretic property for each column

NOTES: For each of NCOL columns, input the number corresponding to the hysteresis rule that is to be used from the hysteretic model parameters input in set #2 above.

NEXT CARD: BEAM PARAMETERS

NOTE: SKIP THIS INPUT IF STRUCTURE HAS NO BEAMS

KHYSB(I),I=1,NBEM	Type of hysteretic property for each beam

NOTES: Specify the hysteresis rule to be used for each of the NBEM beams.

NEXT CARD

NOTE: SKIP THIS INPUT IF STRUCTURE HAS NO SHEAR WALLS

KHYSW(I,1),KHYSW(I,2) . KHYSW(NWAL,1),KHYSW(NWAL,2)	Type of hysteretic property for flexure and shear respectively

NOTES: For each of the NWAL shear walls in the structure, two hysteretic rules are to be defined. The first defines the flexural behavior while the second defines the shear behavior.

SET Q: SUBSTRUCTURE INFORMATION

CARD #1: SUBSTRUCTURE CONTROL

ISUB	Substructure analysis control: ISUB = Frame number for sub-structure analysis = 0, no substructure analysis

NOTES: If no substructure analysis is required, input ISUB=0 and STOP HERE.

Else, input the i-coordinate position of the frame where the substructure is located.

NOTE: ONLY ONE SUBSTRUCTURE CAN BE ANALYSED IN ONE RUN.

THE NEXT CARD NEED NOT BE INPUT IF ISUB .EQ. 0

CARD #2: SUBSTRUCTURE DETAILS

JSUB,LBSUB,CBSUB,LTSUB, CTSUB,KSUBX,KSUBY,KSUBR	Substructure information: JSUB = J-coordinate position of substructure = 0, whole length of frame is regarded as substructure LBSUB = Bottom story no. to be cut CBSUB = Position of lower boundary as a ratio of story height LTSUB = Top story no. to be cut CTSUB = Position of upper boundary as a ratio of story height KSUBX = 1, include horizontal component of response = 0, do not include horizontal component

KSUBY = 1, include vertical component of response
= 0, do not include vertical component

KSUBR = 1, include rotational component of response
= 0, do not include rotational component

NOTES: The two possible types of substructures that can be analyzed by IDARC was outlined in Section 3.5. The first involves a subassemblage with a single vertical axis while the second involves the entire length of the frame.

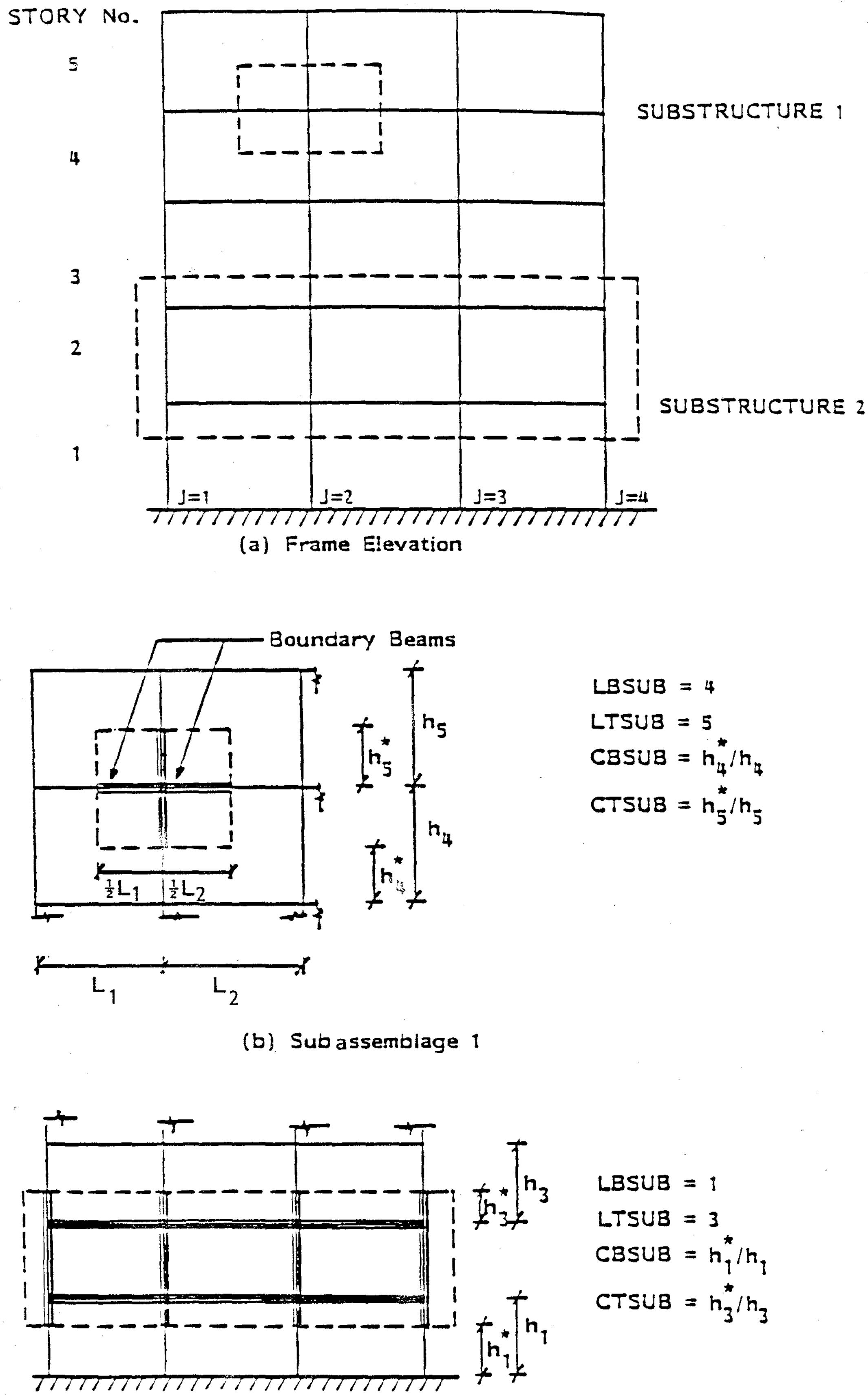
In the former case, JSUB equals the j-coordinate location of the vertical axis, while in the latter JSUB is set to zero.

Fig. A-13 shows clearly the remaining input parameters needed to define the substructure.

KSUBX, KSUBY and KSUBR refer to the three components of response of the subassemblage. For more details on the meaning of the response see Section 3.5.

The boundary beams, computed by the program and listed in the output refer to the beams that form part of the substructure. (see Fig. A-13b) The program uses half-lengths of these connecting beams in establishing the boundary forces.

END OF INPUT FOR FILE IDARC.DAT



(a) Frame Elevation

(b) Subassemblage 1

(c) Subassemblage 2

FIGURE A-13 Substructure Input

WAVE DATA - HORIZONTAL COMPONENT

FILE: WAVEH.DAT

WINPH(I),I=1,NDATA	Horizontal component of earthquake wave (NDATA points to be read sequentially.)

WAVE DATA - VERTICAL COMPONENT

FILE: WAVEV.DAT

NOTE: SKIP THIS INPUT IF IWV .EQ. 0

WINPV(I),I=1,NDATA	Vertical component of earthquake wave (NDATA points to be read sequentially.)

NOTES: Accelerogram data may be input in any system of units. The accelerogram is scaled uniformly to achieve the specified peak value in card #1 of set 'O'.

Since data is read in free format, as many cards as necessary to read the entire wave must be input. The data points of the input wave may, therefore, be entered sequentially until the last (or NDATA) point.

A.2. Current Program Limits

The present version of program IDARC is available for use on DEC/ VAX operating systems.[3]

The use of fixed dimensions for the arrays of the main variables impose the following limitations on the current version of IDARC:

1. Up to 50 beam elements, 50 column elements, 50 transverse beams, 50 edge columns and 20 shear walls;
2. Up to 200 global degrees of freedom;
3. A maximum of 10 stories;
4. A maximum of 10 j-coordinate locations per frame;
5. A maximum of 10 unique frames (i.e. NFR=10);
6. Up to 5 sets of duplicate frames;
7. Up to 10 different concrete types and 5 different steel types.

For buildings with more elements than specified above, it is necessary to change the dimensions of the appropriate arrays.

Two additional parameters that must be checked are the half-band width of the global stiffness matrix and the total number of degrees of freedom of the structure. Current limits are 200 degrees of freedom and a half-band width of 50.

A simple technique to approximate[4] these parameters is described below:

Half-Band Width = CMAX * [NVLN(I)*2 + 1]

------

[3] A version for use on IBM mainframe systems will also be available.

[4] Exact values can be easily determined by numbering the degrees of freedom.

where:

$$CMAX = | LTC(I) - LBC(I) |_{max} + 1$$

LTC(I) and LBC(I) refer to the L-coordinate positions of the column that yields the absolute maximum difference. Typically, this difference is '1', however, for structures with columns extending beyond one story height without intercepting beams, this difference will be greater than unity. Hence, CMAX $\geq$ 2.

Degrees of freedom = Total no. of nodes * 2 + No. of stories
or = NST * [NVLN(I) * 2 + 1]

where:

NST = Number of stories.

The overall stiffness matrix is stored in the array OST(M,N) where:

M = 200, degrees of freedom
N = 50, half-band width

This array dimension must be changed to the values computed (as described above) if M > 200 or N > 50.

A.3. File Creation and Execution

Data is read from a sequential input file where the data elements are separated by conventional delimiters. The following convention is adopted:

These fixed input filenames[5] are used:

-----

5 User-specified files may be used with relatively simple modification of the OPEN and CLOSE file statements in the program.

IDARC.DAT is used for the sequential input of the structure and material data as per format details listed in Appendix A.1.

WAVEH.DAT is used to read the accelerogram data for the horizontal component of the earthquake wave.

WAVEV.DAT is used to read the accelerogram data for the vertical component of the wave. This file need be created only if the vertical component is included in the analysis.

Two output files[5] are generated:

1. IDARC.OUT contains the descriptive input listing; and the results of the static, dynamic and damage analysis.
2. SUB.OUT contains the response of the substructure analysis (if active).

The execution of the program on the DEC/VAX computer at the State University of New York at Buffalo involved the following steps:

STEP A: INSTALLATION

1. Compilation of the program using FORTRAN-77 code.
2. Linking the OBJECT code to the usual FORTRAN libraries.

   The above steps create the executable code necessary for running IDARC.

****** THIS PROCEDURE IS ESSENTIAL FOR INSTALLATION ONLY *****

STEP B: RUNNING IDARC

IDARC may be run on-line on a remote or virtual terminal using the RUN command; or executed as a BATCH job using the SUBMIT command procedure.

It is preferable to run the dynamic and damage analysis option in the BATCH mode.

The program creates a new version of the output files for each run.

APPENDIX B
INPUT/OUTPUT DESCRIPTION

B.1 Input Details

The input details for the sample analysis of the seven story building are listed in the Appendix Listing B.3.

The input corresponds to the format outlined in the INPUT FORMAT guide (Appendix A.1). Each input set is identified at the right of the data input by comments which make reference to the INPUT FORMAT guide.

B.2. Output Details

Although the output is rather self-explanatory, a brief description of each output section is given below. Each section is identified by a number labeled on the output itself.

OUTPUT 1: Lists input data relating to title, building configuration, base shear estimate and system of units.

OUTPUT 2: Lists input data on the height and weight of floor levels, the location of the j-coordinate positions and the material properties of steel and concrete.

OUTPUT 3: Lists input information on properties of all column element types.

OUTPUT 4: Lists input information on properties of all beam element types.

OUTPUT 5: Lists input information on properties of all shear wall element types.

OUTPUT 6: Lists input information on properties of all edge-column element types.

OUTPUT 7: Lists input information on properties of all transverse beam element types.

OUTPUTS 8-12: Lists input data on the nodal connectivity of all columns, beams, shear walls, edge columns and transverse beams respectively.

OUTPUT 13: Shows the view (in plan) of the j-coördinate locations of all unique (NFR) frames

OUTPUT 14: Shows a qualitative view of the elevation of each of the NFR frames along with element type numbers.

OUTPUT 15: Begins the printing of results. Listed here are the fundamental period of the structure, the maximum base shear coefficient and the corresponding top deformation of the building (expressed as a percent of the total building height)

OUTPUT 16: Shows the variation of the base shear coefficient as a function of the top deformation (again, this deformation is expressed as percent of the total building height).

OUTPUT 17: Displays the information listed in OUTPUT 16 in graphical form.

OUTPUT 18: Shows the failure mode of the structure. The final state of stress at each critical section is printed. The stress states are marked as (E)lastic, (C)racked (Y)ielded.

OUTPUTS 19 - 23: Lists the strength parameters of all columns, beams, shear walls, edge columns and transverse beams respectively.

OUTPUT 24: Begins the dynamic analysis option by printing all related data on the input base motion.

OUTPUT 25: Lists the output control information.

OUTPUT 26: Lists the properties of the hysteretic rule followed by the associated rule numbers for each column, beam and shear wall element respectively.

OUTPUT 27: Lists the maximum response values for each floor level of the structure.

OUTPUT 28: Will vary depending upon the type of output selected by the user. The control parameters have been defined in OUTPUT 25. In the present example this output section lists the displacement, story drift and shear for the 7th story at the specified output time interval.

OUTPUT 29: Shows the final stress state of each frame at the completion of the dynamic response analysis.

OUTPUTS 30-32: Lists the parameters computed for the damage index analysis for each column, beam and shear wall element respectively.

OUTPUTS 33-35: Lists the damage index and energy ratio values for each column, beam and shear wall element respectively. The energy ratio corresponds to the weighting factor described in Section II.

OUTPUT 36: Shows the damage index values and their corresponding energy ratios for each element in each frame. This graphical view essentially repeats the information listed in OUTPUTS 33-35.

OUTPUT 37: Lists the damage index values and corresponding energy ratios at each story level. The vertical elements (viz., columns and shear walls) have been separated from the horizontal elements (beams).

Finally, the damage index for the total structure is printed.

OUTPUT 38: Provides listing from file SUB.OUT which provides the input information and final response of the selected substructure.

B.3 INPUT DATA

```
ANALYSIS OF SEVEN STORY BUILDING
7,2,8,5
23,30,7,7,3
42,35,7,28,28
0.4
2
350.0,650.0,950.0,1250.0,1550.0,1850.0,2150.0
183.3,169.5,169.5,169.5,169.5,169.5,152.9
2,1
4,3
0.0,600.0,1100.0,1700.0
0.0,850.0,1700.0
1,.289,238.,.218,0.0
2,.292,236.,.240,0.0
3,.274,221.,.228,0.0
4,.290,211.,.225,0.0
5,.295,234.,.210,0.0
6,.144,139.,.185,0.0
7,.189,174.,.192,0.0
8,.302,239.,.28,0.0
1,3.87,5.67,1840.,0.0,1.8
2,3.65,5.73,1710.,0.0,1.68
3,3.53,5.75,1850.,0.0,1.23
4,3.94,0.0,1930.,0.,0.
5,4.31,0.0,1530.,0.,0.
1,1,3,47.5,50.0,50.0,6.0,11.61,21.0,0.310,0.77,350.0,0.0,25.0
2,1,3,101.8,50.,50.0,6.0,11.61,21.0,0.310,0.77,350.0,0.0,25.0
3,1,3,44.7,50.0,50.0,6.0,11.61,21.0,0.310,0.77,350.0,0.0,25.0
4,2,3,40.1,50.0,50.0,6.0,11.61,21.0,0.310,0.77,300.0,25.0,25.0
5,2,3,86.0,50.0,50.0,6.0,11.61,21.0,0.310,0.77,300.0,25.0,25.0
6,2,3,37.8,50.0,50.0,6.0,11.61,21.0,0.310,0.77,300.0,25.0,25.0
7,3,3,33.3,50.0,50.0,6.0,11.61,21.0,0.310,0.77,300.0,25.0,25.0
8,3,3,71.5,50.0,50.0,6.0,11.61,21.0,0.310,0.77,300.0,25.0,25.0
9,3,3,31.4,50.0,50.0,6.0,11.61,21.0,0.310,0.77,300.0,25.0,25.0
10,4,3,26.5,50.0,50.0,6.0,11.61,21.0,0.310,0.77,300.0,25.0,25.0
11,4,3,56.9,50.0,50.0,6.0,11.61,21.0,0.310,0.77,300.0,25.0,25.0
12,4,3,25.0.50.0,50.0,6.0,11.61,21.0,0.310,0.77,300.0,25.0,25.0
13,5,3,19.7,50.0,50.0,6.0,11.61,21.0,0.310,0.77,300.0,25.0,25.0
14,5,3,42.3,50.0,50.0,6.0,11.61,21.0,0.310,0.77,300.0,25.0,25.0
15,5,3,18.6,50.0,50.0,6.0,11.61,21.0,0.310,0.77,300.0,25.0,25.0
16,6,3,12.9,50.0,50.0,6.0,11.61,21.0,0.310,0.77,300.0,25.0,25.0
17,6,3,27.7,50.0,50.0,6.0,11.61,21.0,0.310,0.77,300.0,25.0,25.0
18,6,3,12.2,50.0,50.0,6.0,11.61,21.0,0.310,0.77,300.0,25.0,25.0
19,7,3,06.1,50.0,50.0,6.0,11.61,21.0,0.310,0.77,300.0,25.0,25.0
20,7,3,13.1,50.0,50.0,6.0,11.61,21.0,0.310,0.77,300.0,25.0,25.0
21,7,3,05.8,50.0,50.0,6.0,11.61,21.0,0.310,0.77,300.0,25.0,25.0
22,8,5,20.5,50.,50.,6.2,22.64,29.4,0.31,0.77,300.,25.,25.
23,8,5,17.3,50.,50.,6.2,22.64,29.4,0.31,0.77,300.,25.,25.
```

Set A

Set B

Set C

Set D

Set E

```
1,1,2,-500.,-500.,50.,30.,200.,12.,6.,5.74,24.3,6.,84.,0.477,1.06,600.,25.,25.
2,1,2,-390.,-390.,50.,30.,200.,12.,6.,5.74,24.3,6.,84.,0.477,1.06,500.,25.,25.
3,1,2,-955.,-955.,50.,30.,300.,12.,6.,5.74,31.43,6.,114.,0.477,1.06,850.,25.,275.
4,1,2,-955.,-955.,50.,30.,300.,12.,6.,5.74,31.43,6.,114.,0.477,1.06,850.,275.,25.
5,2,2,-500.,-500.,50.,30.,200.,12.,6.,5.74,24.3,6.,84.,0.477,1.06,600.,25.,25.
6,2,2,-390.,-390.,50.,30.,200.,12.,6.,5.74,24.3,6.,84.,0.477,1.06,500.,25.,25.
7,2,2,-955.,-955.,50.,30.,300.,12.,6.,5.74,31.43,6.,114.,0.477,1.06,850.,25.,275.
8,2,2,-955.,-955.,50.,30.,300.,12.,6.,5.74,31.43,6.,114.,0.477,1.06,850.,275.,25.
9,3,2,-500.,-500.,50.,30.,200.,12.,6.,5.74,24.3,6.,84.,0.477,1.06,600.,25.,25.
10,3,2,-390.,-390.,50.,30.,200.,12.,6.,5.74,24.3,6.,84.,0.477,1.06,500.,25.,25.
11,3,2,-955.,-955.,50.,30.,300.,12.,6.,5.74,31.43,6.,114.,0.477,1.06,850.,25.,275.
12,3,2,-955.,-955.,50.,30.,300.,12.,6.,5.74,31.43,6.,114.,0.477,1.06,850.,275.,25.
13,4,2,-500.,-500.,50.,30.,200.,12.,6.,5.74,24.3,6.,84.,0.477,1.06,600.,25.,25.
14,4,2,-390.,-390.,50.,30.,200.,12.,6.,5.74,24.3,6.,84.,0.477,1.06,500.,25.,25.
15,4,2,-955.,-955.,50.,30.,300.,12.,6.,5.74,31.43,6.,114.,0.477,1.06,850.,25.,275.
16,4,2,-955.,-955.,50.,30.,300.,12.,6.,5.74,31.43,6.,114.,0.477,1.06,850.,275.,25.
17,5,2,-500.,-500.,50.,30.,200.,12.,6.,5.74,24.3,6.,84.,0.477,1.06,600.,25.,25.
18,5,2,-390.,-390.,50.,30.,200.,12.,6.,5.74,24.3,6.,84.,0.477,1.06,500.,25.,25.
19,5,2,-955.,-955.,50.,30.,300.,12.,6.,5.74,31.43,6.,114.,0.477,1.06,850.,25.,275.
20,5,2,-955.,-955.,50.,30.,300.,12.,6.,5.74,31.43,6.,114.,0.477,1.06,850.,275.,25.
21,6,2,-500.,-500.,50.,30.,200.,12.,6.,5.74,24.3,6.,84.,0.477,1.06,600.,25.,25.
22,6,2,-390.,-390.,50.,30.,200.,12.,6.,5.74,24.3,6.,84.,0.477,1.06,500.,25.,25.
23,6,2,-955.,-955.,50.,30.,300.,12.,6.,5.74,31.43,6.,114.,0.477,1.06,850.,25.,275.
24,6,2,-955.,-955.,50.,30.,300.,12.,6.,5.74,31.43,6.,114.,0.477,1.06,850.,275.,25.
25,7,2,-500.,-500.,50.,30.,200.,12.,6.,5.74,24.3,6.,84.,0.477,1.06,600.,25.,25.
26,7,2,-390.,-390.,50.,30.,200.,12.,6.,5.74,24.3,6.,84.,0.477,1.06,500.,25.,25.
27,7,2,-955.,-955.,50.,30.,300.,12.,6.,5.74,31.43,6.,114.,0.477,1.06,850.,25.,275.
28,7,2,-955.,-955.,50.,30.,300.,12.,6.,5.74,31.43,6.,114.,0.477,1.06,850.,275.,25.
29,8,4,-500.,-500.,50.,30.,187.5,12.5,6.2,8.59,26.28,6.,56.7,0.477,1.06,600.,25.,25.
30,8,4,-390.,-390.,50.,30.,187.5,12.5,6.2,8.59,26.28,6.,56.7,0.477,1.06,600.,25.,25.
```

Set F

```
1,1,1,269.9,500.,20.,0.358,0.358,50.,50.,30.96,350.
2,2,1,228.1,500.,20.,0.358,0.358,50.,50.,30.96,300.
3,3,1,189.4,500.,20.,0.358,0.358,50.,50.,30.96,300.
4,4,1,150.8,500.,20.,0.358,0.358,50.,50.,30.96,300.
5,5,1,112.2,500.,20.,0.358,0.358,50.,50.,30.96,300.
6,6,1,73.5,500.,20.,0.358,0.358,50.,50.,30.96,300.
7,7,1,34.9,500.,20.,0.358,0.358,50.,50.,30.96,300.
```

Set G

```
1,1,3,37.9,266.7,15.,8.,350.,0.
2,2,3,32.0,266.7,15.,8.,350.,0.
3,3,3,26.6,266.7,15.,8.,350.,0.
4,4,3,21.2,266.7,15.,8.,350.,0.
5,5,3,15.7,266.7,15.,8.,350.,0.
6,6,3,10.3,266.7,15.,8.,350.,0.
7,7,3,4.9,266.7,15.,8.,350.,0.
```

Set H

```
1,3.45,28000.,-250.
2,3.45,28000.,250.
3,0.0,28000.,0.0
```

Set I

1,1,1,1,0,1
2,2,1,2,0,1
3,2,1,3,0,1
4,1,1,4,0,1
5,3,2,1,0,1
6,3,2,3,0,1
7,4,1,1,1,2
8,5,1,2,1,2
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10,4,1,4,1,2
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12,6,2,3,1,2
13,7,1,1,2,3
14,8,1,2,2,3
15,8,1,3,2,3
16,7,1,4,2,3
17,9,2,1,2,3
18,9,2,3,2,3
19,10,1,1,3,4
20,22,1,2,3,4
21,11,1,3,3,4
22,10,1,4,3,4
23,12,2,1,3,4
24,12,2,3,3,4
25,13,1,1,4,5
26,23,1,2,4,5
27,14,1,3,4,5
28,13,1,4,4,5
29,15,2,1,4,5
30,15,2,3,4,5
31,16,1,1,5,6
32,17,1,2,5,6
33,17,1,3,5,6
34,16,1,4,5,6
35,18,2,1,5,6
36,18,2,3,5,6
37,19,1,1,6,7
38,20,1,2,6,7
39,20,1,3,6,7
40,19,1,4,6,7
41,21,2,1,6,7
42,21,2,3,6,7

Set J

1,1,1,1,1,2
2,2,1,1,2,3
3,1,1,1,3,4
4,3,1,2,1,2
5,4,1,2,2,3
6,5,2,1,1,2
7,6,2,1,2,3
8,5,2,1,3,4
9,7,2,2,1,2
10,8,2,2,2,3
11,9,3,1,1,2
12,10,3,1,2,3
13,9,3,1,3,4
14,11,3,2,1,2
15,12,3,2,2,3
16,29,4,1,1,2
17,30,4,1,2,3
18,13,4,1,3,4
19,15,4,2,1,2
20,16,4,2,2,3
21,17,5,1,1,2
22,18,5,1,2,3
23,17,5,1,3,4
24,19,5,2,1,2
25,20,5,2,2,3
26,21,6,1,1,2
27,22,6,1,2,3
28,21,6,1,3,4
29,23,6,2,1,2
30,24,6,2,2,3
31,25,7,1,1,2
32,26,7,1,2,3
33,25,7,1,3,4
34,27,7,2,1,2
35,28,7,2,2,3

Set K

1,1,2,2,0,1	Set L
2,2,2,2,1,2	
3,3,2,2,2,3	
4,4,2,2,3,4	
5,5,2,2,4,5	
6,6,2,2,5,6	
7,7,2,2,6,7	
1,1,1,1,0,1	Set M
2,1,1,4,0,1	
3,1,2,1,0,1	
4,1,2,3,0,1	
5,2,1,1,1,2	
6,2,1,4,1,2	
7,2,2,1,1,2	
8,2,2,3,1,2	
9,3,1,1,2,3	
10,3,1,4,2,3	
11,3,2,1,2,3	
12,3,2,3,2,3	
13,4,1,1,3,4	
14,4,1,4,3,4	
15,4,2,1,3,4	
16,4,2,3,3,4	
17,5,1,1,4,5	
18,5,1,4,4,5	
19,5,2,1,4,5	
20,5,2,3,4,5	
21,6,1,1,5,6	
22,6,1,4,5,6	
23,6,2,1,5,6	
24,6,2,3,5,6	
25,7,1,1,6,7	
26,7,1,4,6,7	
27,7,2,1,6,7	
28,7,2,3,6,7	

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6,2,3,2,2,1,3
7,1,4,2,2,1,2
8,2,4,2,2,1,3
9,1,5,2,2,1,2
10,2,5,2,2,1,3
11,1,6,2,2,1,2
12,2,6,2,2,1,3
13,1,7,2,2,1,2
14,2,7,2,2,1,3
15,3,1,1,1,2,1
16,3,1,1,4,2,3
17,3,2,1,1,2,1
18,3,2,1,4,2,3
19,3,3,1,1,2,1
20,3,3,1,4,2,3
21,3,4,1,1,2,1
22,3,4,1,4,2,3
23,3,5,1,1,2,1
24,3,5,1,4,2,3
25,3,6,1,1,2,1
26,3,6,1,4,2,3
27,3,7,1,1,2,1
28,3,7,1,4,2,3
1
```

Set N

```
0.357,0.,0.005,25.0,2.
0,1700,0.02
TOCKACHI OKI  0.357g
2,0.02,1,7,3,1
```

Set O

```
3
2.,1000.,.0,.015
2.,1000.,.0,.015
.01,.01,0.0,.015
1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1
1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1
2,2,2,2,2,2,2,2,2,2,2,2,2,2,2,2,2,2,2,2,2,2,2,2,2,2,2,2,2,2,2,2,2,2,2
1,3
1,3
1,3
1,3
1,3
1,3
1,3
```

Set P

```
1
3,4,0.5,5,0.5,1,0,0
$
```

Set Q

FILE: WAVEH.DAT

```
   0.10    1.30    1.90    1.60   -0.60   -0.50    6.60   21.00   32.70   34.90
  33.80   34.60   22.70    5.10   -7.60  -10.10   -2.60   -3.80   -0.80   -6.60
  -2.40   12.90   24.30   29.00   31.60   34.60   37.10   37.90   37.80   36.70
  29.10   13.70    1.50   -6.60  -12.10  -16.30  -14.80  -13.70  -27.10  -42.70
 -50.40  -40.30  -19.20  -13.20  -30.30  -53.30  -66.70  -74.50  -79.80  -66.30
 -44.40  -28.40  -34.90  -32.20   -4.10   33.90   74.20  104.00  119.00  123.00
 109.00   90.30   75.50   66.30   57.10   50.20   44.00   32.80    1.70  -34[illegible]
 -62.20  -72.60  -77.20  -82.60  -95.60 -111.00 -119.00 -115.00  -96.80  -82.50
 -73.80  -62.50  -56.40  -76.30  -97.50 -121.00 -130.00 -134.00 -140.00 -145.00
-138.00 -111.00  -79.00  -43.70  -13.60   14.90   40.70   67.40   94.00  126.00
   .
   .
   .
   1.50    4.50    5.30    3.50    4.80    9.40    8.00    1.60   -4.00   -4.10
   0.00    1.30    1.50    2.30    2.60   -0.20   -2.70   -8.60  -12.30  -12.50
 -13.90  -17.70  -25.00  -31.90  -37.80  -44.30  -48.00  -45.70  -40.30  -36.50
 -35.30  -34.50  -33.90  -39.70  -45.80  -46.30  -43.60  -39.50  -33.90  -24.40
 -13.10    0.90   12.70   22.40   23.80   17.70    6.90    6.20   11.30   13.30
  13.20    7.00   -4.50  -15.10  -19.20  -18.00  -14.50   -6.80   -6.40   -9.70
  -6.40   -0.70    8.90   15.30   20.30   18.00   12.00    7.80    2.30   -1.70
  -2.00   -0.50   -3.10   -9.70   -5.10    7.40   21.60   29.50   29.90   18.80
```

APPENDIX B.4 OUTPUT OF RESULTS

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IIIIIIIIIIIIII   DDDDDDDDDDDDD     AAAAAAAAAAAA    RRRRRRRRRRRRR     CCCCCCCCCCCCC
IIIIIIIIIIIIII   DDDDDDDDDDDDDD   AAAAAAAAAAAAAA   RRRRRRRRRRRRRR   CCCCCCCCCCCCCC
      II         DD          DD   AA          AA   RR          RR   CC
      II         DD          DD   AA          AA   RR          RR   CC
      II         DD          DD   AA          AA   RR          RR   CC
      II         DD          DD   AA          AA   RR          RR   CC
      II         DD          DD   AA          AA   RR          RR   CC
      II         DD          DD   AA          AA   RR          RR   CC
      II         DD          DD   AA          AA   RR          RR   CC
      II         DD          DD   AAAAAAAAAAAAAA   RRRRRRRRRRRRRR   CC
      II         DD          DD   AAAAAAAAAAAAAA   RRRRRRRRRRRRR    CC
      II         DD          DD   AA          AA   RR        RR     CC
      II         DD          DD   AA          AA   RR        RR     CC
      II         DD          DD   AA          AA   RR         RR    CC
      II         DD          DD   AA          AA   RR         RR    CC
IIIIIIIIIIIIII   DDDDDDDDDDDDDD   AA          AA   RR          RR   CCCCCCCCCCCCCC
IIIIIIIIIIIIII   DDDDDDDDDDDDD    AA          AA   RR          RR    CCCCCCCCCCCCC
```

INELASTIC DAMAGE ANALYSIS OF REINFORCED CONCRETE STRUCTURES

STATE UNIVERSITY OF NEW YORK AT BUFFALO
DEPARTMENT OF CIVIL ENGINEERING

OCTOBER 1986

INPUT DATA:

JOB TITLE: ANALYSIS OF SEVEN STORY BUILDING

********** BUILDING CONFIGURATION AND MATERIAL INFORMATION **********

NUMBER OF STORIES 7
NUMBER OF FRAMES 2

NO. OF TYPES OF CONCRETE 8
NO. OF TYPES OF STEEL 5

********** ELEMENT INFORMATION **********

NO. OF TYPES OF COLUMNS 23
NO. OF TYPES OF BEAMS 30
NO. OF TYPES OF SHEAR WALLS 7
NO. OF TYPES OF EDGE COLUMNS 7
NO. OF TYPES OF TRANSVERSE BEAMS 3

NUMBER OF COLUMNS 42
NUMBER OF BEAMS 35
NUMBER OF SHEAR WALLS 7
NUMBER OF EDGE COLUMNS 28
NUMBER OF TRANSVERSE BEAMS 28

ESTIMATED BASE SHEAR COEFFICIENT : 0.4
(% OF TOTAL WEIGHT)

SYSTEM OF UNITS: CMS, METRIC TONNES

OUTPUT 1

********** STORY HEIGHT AND FLOOR WEIGHTS **********

STORY	HEIGHT FROM BASE	FLOOR WEIGHT
7	2150.000	152.900
6	1850.000	169.500
5	1550.000	169.500
4	1250.000	169.500
3	950.000	169.500
2	650.000	169.500
1	350.000	183.300

********** X CO-ORDINATE DISTANCE OF COLUMN FROM REFERENCE POINT **********

FRAME	COLUMN COORDINATE (IN ORDER)			
1	0.00	600.00	1100.00	1700.00
2	0.00	850.00	1700.00	

********** CONCRETE PROPERTIES **********

TYPE	STRENGTH	MODULUS	STRAIN AT MAX STRENGTH (%)	BOND STRENGTH
1	0.289	238.000	0.218	0.000
2	0.292	236.000	0.240	0.000
3	0.274	221.000	0.228	0.000
4	0.290	211.000	0.225	0.000
5	0.295	234.000	0.210	0.000
6	0.144	139.000	0.185	0.000
7	0.189	174.000	0.192	0.000
8	0.302	239.000	0.280	0.000

********** REINFORCEMENT PROPERTIES **********

TYPE	YIELD STRENGTH	ULTIMATE STRENGTH	YOUNGS MODULUS	MODULUS AT HARDENING	STRAIN AT HARDENING
1	3.870	5.670	1840.000	0.000	1.800
2	3.650	5.730	1710.000	0.000	1.680
3	3.530	5.750	1850.000	0.000	1.230
4	3.940	0.000	1930.000	0.000	0.000
5	4.310	0.000	1530.000	0.000	0.000

OUTPUT 2

********** COLUMN TYPES **********

COLUMN TYPE	CONCRETE TYPE	STEEL TYPE	DEPTH	WIDTH	COVER	LENGTH	RIGID ZONE (BOT)	RIGID ZONE (TOP)
1	1	3	50.000	50.000	6.000	350.000	0.000	25.000
2	1	3	50.000	50.000	6.000	350.000	0.000	25.000
3	1	3	50.000	50.000	6.000	350.000	0.000	25.000
4	2	3	50.000	50.000	6.000	300.000	25.000	25.000
5	2	3	50.000	50.000	6.000	300.000	25.000	25.000
6	2	3	50.000	50.000	6.000	300.000	25.000	25.000
7	3	3	50.000	50.000	6.000	300.000	25.000	25.000
8	3	3	50.000	50.000	6.000	300.000	25.000	25.000
9	3	3	50.000	50.000	6.000	300.000	25.000	25.000
10	4	3	50.000	50.000	6.000	300.000	25.000	25.000
11	4	3	50.000	50.000	6.000	300.000	25.000	25.000
12	4	3	50.000	50.000	6.000	300.000	25.000	25.000
13	5	3	50.000	50.000	6.000	300.000	25.000	25.000
14	5	3	50.000	50.000	6.000	300.000	25.000	25.000
15	5	3	50.000	50.000	6.000	300.000	25.000	25.000
16	6	3	50.000	50.000	6.000	300.000	25.000	25.000
17	6	3	50.000	50.000	6.000	300.000	25.000	25.000
18	6	3	50.000	50.000	6.000	300.000	25.000	25.000
19	7	3	50.000	50.000	6.000	300.000	25.000	25.000
20	7	3	50.000	50.000	6.000	300.000	25.000	25.000
21	7	3	50.000	50.000	6.000	300.000	25.000	25.000
22	8	5	50.000	50.000	6.200	300.000	25.000	25.000
23	8	5	50.000	50.000	6.200	300.000	25.000	25.000

OUTPUT 3

***** AXIAL LOAD AND REINFORCEMENT OF COLUMNS *****

TYPE	AXIAL LOAD	STEEL AREA	PERIMETER OF BARS	WEB REINF RATIO	CONFINEMENT RATIO
1	47.500	11.610	21.0000	0.3100	0.7700
2	101.800	11.610	21.0000	0.3100	0.7700
3	44.700	11.610	21.0000	0.3100	0.7700
4	40.100	11.610	21.0000	0.3100	0.7700
5	86.000	11.610	21.0000	0.3100	0.7700
6	37.800	11.610	21.0000	0.3100	0.7700
7	33.300	11.610	21.0000	0.3100	0.7700
8	71.500	11.610	21.0000	0.3100	0.7700
9	31.400	11.610	21.0000	0.3100	0.7700
10	26.500	11.610	21.0000	0.3100	0.7700
11	56.900	11.610	21.0000	0.3100	0.7700
12	25.000	11.610	21.0000	0.3100	0.7700
13	19.700	11.610	21.0000	0.3100	0.7700
14	42.300	11.610	21.0000	0.3100	0.7700
15	18.600	11.610	21.0000	0.3100	0.7700
16	12.900	11.610	21.0000	0.3100	0.7700
17	27.700	11.610	21.0000	0.3100	0.7700
18	12.200	11.610	21.0000	0.3100	0.7700
19	6.100	11.610	21.0000	0.3100	0.7700
20	13.100	11.610	21.0000	0.3100	0.7700
21	5.800	11.610	21.0000	0.3100	0.7700
22	20.500	22.640	29.4000	0.3100	0.7700
23	17.300	22.640	29.4000	0.3100	0.7700

OUTPUT 3 (CONT'D)

********** BEAM TYPES **********

BEAM TYPE	CONCRETE TYPE	STEEL TYPE	DEPTH	WIDTH	SLAB WIDTH	SLAB THICKNESS	COVER	MEMBER LENGTH	RIGID ZONE (LEFT)	RIGID ZONE (RIGHT)
1	1	2	50.000	30.000	200.000	12.000	6.000	600.000	25.000	25.000
2	1	2	50.000	30.000	200.000	12.000	6.000	500.000	25.000	25.000
3	1	2	50.000	30.000	300.000	12.000	6.000	850.000	25.000	275.000
4	1	2	50.000	30.000	300.000	12.000	6.000	850.000	275.000	25.000
5	2	2	50.000	30.000	200.000	12.000	6.000	600.000	25.000	25.000
6	2	2	50.000	30.000	200.000	12.000	6.000	500.000	25.000	25.000
7	2	2	50.000	30.000	300.000	12.000	6.000	850.000	25.000	275.000
8	2	2	50.000	30.000	300.000	12.000	6.000	850.000	275.000	25.000
9	3	2	50.000	30.000	200.000	12.000	6.000	600.000	25.000	25.000
10	3	2	50.000	30.000	200.000	12.000	6.000	500.000	25.000	25.000
11	3	2	50.000	30.000	300.000	12.000	6.000	850.000	25.000	275.000
12	3	2	50.000	30.000	300.000	12.000	6.000	850.000	275.000	25.000
13	4	2	50.000	30.000	200.000	12.000	6.000	600.000	25.000	25.000
14	4	2	50.000	30.000	200.000	12.000	6.000	500.000	25.000	25.000
15	4	2	50.000	30.000	300.000	12.000	6.000	850.000	25.000	275.000
16	4	2	50.000	30.000	300.000	12.000	6.000	850.000	275.000	25.000
17	5	2	50.000	30.000	200.000	12.000	6.000	600.000	25.000	25.000
18	5	2	50.000	30.000	200.000	12.000	6.000	500.000	25.000	25.000
19	5	2	50.000	30.000	300.000	12.000	6.000	850.000	25.000	275.000
20	5	2	50.000	30.000	300.000	12.000	6.000	850.000	275.000	25.000
21	6	2	50.000	30.000	200.000	12.000	6.000	600.000	25.000	25.000
22	6	2	50.000	30.000	200.000	12.000	6.000	500.000	25.000	25.000
23	6	2	50.000	30.000	300.000	12.000	6.000	850.000	25.000	275.000
24	6	2	50.000	30.000	300.000	12.000	6.000	850.000	275.000	25.000
25	7	2	50.000	30.000	200.000	12.000	6.000	600.000	25.000	25.000
26	7	2	50.000	30.000	200.000	12.000	6.000	500.000	25.000	25.000
27	7	2	50.000	30.000	300.000	12.000	6.000	850.000	25.000	275.000
28	7	2	50.000	30.000	300.000	12.000	6.000	850.000	275.000	25.000
29	8	4	50.000	30.000	187.500	12.500	6.200	600.000	25.000	25.000
30	8	4	50.000	30.000	187.500	12.500	6.200	600.000	25.000	25.000

OUTPUT 4

***** INITIAL MOMENTS AND REINFORCEMENT OF BEAMS *****

BEAM TYPE	MOMENT (LEFT)	MOMENT (RIGHT)	STEEL AREA (BOTTOM)	STEEL AREA (TOP)	PERIMETER OF BARS (BOT)	PERIMETER OF BARS (TOP)	WEB REINF RATIO	CONFINEMENT RATIO
1	-500.000	-500.000	5.740	24.300	6.0000	84.0000	0.477	1.0600
2	-390.000	-390.000	5.740	24.300	6.0000	84.0000	0.477	1.0600
3	-955.000	-955.000	5.740	31.430	6.0000	114.0000	0.477	1.0600
4	-955.000	-955.000	5.740	31.430	6.0000	114.0000	0.477	1.0600
5	-500.000	-500.000	5.740	24.300	6.0000	84.0000	0.477	1.0600
6	-390.000	-390.000	5.740	24.300	6.0000	84.0000	0.477	1.0600
7	-955.000	-955.000	5.740	31.430	6.0000	114.0000	0.477	1.0600
8	-955.000	-955.000	5.740	31.430	6.0000	114.0000	0.477	1.0600
9	-500.000	-500.000	5.740	24.300	6.0000	84.0000	0.477	1.0600
10	-390.000	-390.000	5.740	24.300	6.0000	84.0000	0.477	1.0600
11	-955.000	-955.000	5.740	31.430	6.0000	114.0000	0.477	1.0600
12	-955.000	-955.000	5.740	31.430	6.0000	114.0000	0.477	1.0600
13	-500.000	-500.000	5.740	24.300	6.0000	84.0000	0.477	1.0600
14	-390.000	-390.000	5.740	24.300	6.0000	84.0000	0.477	1.0600
15	-955.000	-955.000	5.740	31.430	6.0000	114.0000	0.477	1.0600
16	-955.000	-955.000	5.740	31.430	6.0000	114.0000	0.477	1.0600
17	-500.000	-500.000	5.740	24.300	6.0000	84.0000	0.477	1.0600
18	-390.000	-390.000	5.740	24.300	6.0000	84.0000	0.477	1.0600
19	-955.000	-955.000	5.740	31.430	6.0000	114.0000	0.477	1.0600
20	-955.000	-955.000	5.740	31.430	6.0000	114.0000	0.477	1.0600
21	-500.000	-500.000	5.740	24.300	6.0000	84.0000	0.477	1.0600
22	-390.000	-390.000	5.740	24.300	6.0000	84.0000	0.477	1.0600
23	-955.000	-955.000	5.740	31.430	6.0000	114.0000	0.477	1.0600
24	-955.000	-955.000	5.740	31.430	6.0000	114.0000	0.477	1.0600
25	-500.000	-500.000	5.740	24.300	6.0000	84.0000	0.477	1.0600
26	-390.000	-390.000	5.740	24.300	6.0000	84.0000	0.477	1.0600
27	-955.000	-955.000	5.740	31.430	6.0000	114.0000	0.477	1.0600
28	-955.000	-955.000	5.740	31.430	6.0000	114.0000	0.477	1.0600
29	-500.000	-500.000	8.590	26.280	6.0000	56.7000	0.477	1.0600
30	-390.000	-390.000	8.590	26.280	6.0000	56.7000	0.477	1.0600

OUTPUT 4 (CONT'D)

********** SHEAR WALL TYPES **********

WALL TYPE	CONCRETE TYPE	STEEL TYPE	DIST BET. EDGE COLS	WALL THICKNESS	DEPTH OF EDGE COL	WIDTH OF EDGE COL	DEPTH OF WALL
1	1	1	500.000	20.000	50.000	50.000	350.000
2	2	1	500.000	20.000	50.000	50.000	300.000
3	3	1	500.000	20.000	50.000	50.000	300.000
4	4	1	500.000	20.000	50.000	50.000	300.000
5	5	1	500.000	20.000	50.000	50.000	300.000
6	6	1	500.000	20.000	50.000	50.000	300.000
7	7	1	500.000	20.000	50.000	50.000	300.000

***** AXIAL LOAD AND REINFORCEMENT OF SHEAR WALLS *****

WALL TYPE	AXIAL LOAD	VERTICAL REINF RATIO	HORIZONTAL REINF RATIO	GROSS STEEL AREA IN EDGE COL
1	269.900	0.3580	0.3580	30.9600
2	228.100	0.3580	0.3580	30.9600
3	189.400	0.3580	0.3580	30.9600
4	150.800	0.3580	0.3580	30.9600
5	112.200	0.3580	0.3580	30.9600
6	73.500	0.3580	0.3580	30.9600
7	34.900	0.3580	0.3580	30.9600

OUTPUT 5

********** EDGE COLUMN TYPES **********

TYPE	CONCRETE TYPE	STEEL TYPE	AXIAL LOAD	DEPTH	WIDTH	GROSS STEEL AREA	MEMBER LENGTH	ARM LENGTH
1	1	3	37.900	266.700	15.000	8.000	350.000	0.000
2	2	3	32.000	266.700	15.000	8.000	350.000	0.000
3	3	3	26.600	266.700	15.000	8.000	350.000	0.000
4	4	3	21.200	266.700	15.000	8.000	350.000	0.000
5	5	3	15.700	266.700	15.000	8.000	350.000	0.000
6	6	3	10.300	266.700	15.000	8.000	350.000	0.000
7	7	3	4.900	266.700	15.000	8.000	350.000	0.000

OUTPUT 6

********** TRANSVERSE BEAMS **********

TYPE	STIFFNESS	STIFFNESS (TORSIONAL)	ARM LENGTH
1	3.450	28000.000	-250.000
2	3.450	28000.000	250.000
3	0.000	28000.000	0.000

OUTPUT 7

*************** NODAL CONNECTIVITY INFORMATION ***************

********** COLUMN ELEMENTS **********

COL. NO.	TYPE	I-COORD	J-COORD	L-COORD (BOT)	L-COORD (TOP)
1	1	1	1	0	1
2	2	1	2	0	1
3	2	1	3	0	1
4	1	1	4	0	1
5	3	2	1	0	1
6	3	2	3	0	1
7	4	1	1	1	2
8	5	1	2	1	2
9	5	1	3	1	2
10	4	1	4	1	2
11	6	2	1	1	2
12	6	2	3	1	2
13	7	1	1	2	3
14	8	1	2	2	3
15	8	1	3	2	3
16	7	1	4	2	3
17	9	2	1	2	3
18	9	2	3	2	3
19	10	1	1	3	4
20	22	1	2	3	4
21	11	1	3	3	4
22	10	1	4	3	4
23	12	2	1	3	4
24	12	2	3	3	4
25	13	1	1	4	5
26	23	1	2	4	5
27	14	1	3	4	5
28	13	1	4	4	5
29	15	2	1	4	5
30	15	2	3	4	5
31	16	1	1	5	6
32	17	1	2	5	6
33	17	1	3	5	6
34	16	1	4	5	6
35	18	2	1	5	6
36	18	2	3	5	6
37	19	1	1	6	7
38	20	1	2	6	7
39	20	1	3	6	7
40	19	1	4	6	7
41	21	2	1	6	7
42	21	2	3	6	7

OUTPUT 8

********** BEAM ELEMENTS **********

BEAM NO.	TYPE	L-COORD	I-COORD	J-COORD (LEFT)	J-COORD (RIGHT)
1	1	1	1	1	2
2	2	1	1	2	3
3	1	1	1	3	4
4	3	1	2	1	2
5	4	1	2	2	3
6	5	2	1	1	2
7	6	2	1	2	3
8	5	2	1	3	4
9	7	2	2	1	2
10	8	2	2	2	3
11	9	3	1	1	2
12	10	3	1	2	3
13	9	3	1	3	4
14	11	3	2	1	2
15	12	3	2	2	3
16	29	4	1	1	2
17	30	4	1	2	3
18	13	4	1	3	4
19	15	4	2	1	2
20	16	4	2	2	3
21	17	5	1	1	2
22	18	5	1	2	3
23	17	5	1	3	4
24	19	5	2	1	2
25	20	5	2	2	3
26	21	6	1	1	2
27	22	6	1	2	3
28	21	6	1	3	4
29	23	6	2	1	2
30	24	6	2	2	3
31	25	7	1	1	2
32	26	7	1	2	3
33	25	7	1	3	4
34	27	7	2	1	2
35	28	7	2	2	3

OUTPUT 9

********** SHEAR WALL ELEMENTS **********

WALL NO.	TYPE	I-COORD	J-COORD	L-COORD (BOTTOM)	L-COORD (TOP)
1	1	2	2	0	1
2	2	2	2	1	2
3	3	2	2	2	3
4	4	2	2	3	4
5	5	2	2	4	5
6	6	2	2	5	6
7	7	2	2	6	7

OUTPUT 10

********** EDGE COLUMN ELEMENTS **********

NO.	TYPE	I-COORD	J-COORD	L-COORD (BOTTOM)	L-COORD (TOP)
1	1	1	1	0	1
2	1	1	4	0	1
3	1	2	1	0	1
			3	0	1
5	2	1	1	1	2
6	2	1	4	1	2
7	2	2	1	1	2
8	2	2	3	1	2
9	3	1	1	2	3
10	3	1	4	2	3
11	3	2	1	2	3
12	3	2	3	2	3
13	4	1	1	3	4
14	4	1	4	3	4
15	4	2	1	3	4
16	4	2	3	3	4
17	5	1	1	4	5
18	5	1	4	4	5
19	5	2	1	4	5
20	5	2	3	4	5
21	6	1	1	5	6
22	6	1	4	5	6
23	6	2	1	5	6
24	6	2	3	5	6
25	7	1	1	6	7
26	7	1	4	6	7
27	7	2	1	6	7
28	7	2	3	6	7

OUTPUT 11

********** TRANSVERSE BEAM ELEMENTS **********

NO.	TYPE	L-COORD	I-COORD	J-COORD	I-COORD	J-COORD
			----(SHEAR WALL)---		------(COLUMN)-----	
1	1	1	2	2	1	2
2	2	1	2	2	1	3
3	1	2	2	2	1	2
4	2	2	2	2	1	3
5	1	3	2	2	1	2
6	2	3	2	2	1	3
7	1	4	2	[illegible]	1	2
8	2	4	2	[illegible]	1	3
9	1	5	2	2	1	2
10	2	5	2	2	1	3
11	1	6	2	2	1	2
12	2	6	2	2	1	3
13	1	7	2	2	1	2
14	2	7	2	2	1	3
15	3	1	1	1	2	1
16	3	1	1	4	2	3
17	3	2	1	1	2	1
18	3	2	1	4	2	3
19	3	3	1	1	2	1
20	3	3	1	4	2	3
21	3	4	1	1	2	1
22	3	4	1	4	2	3
23	3	5	1	1	2	1
24	3	5	1	4	2	3
25	3	6	1	1	2	1
26	3	6	1	4	2	3
27	3	7	1	1	2	1
28	3	7	1	4	2	3

OUTPUT 12

```
*************** CONFIGURATION OF PLAN ***************



PLAN OF FRAME  2:     0----------------------------0-----------------------------0

                      NO. OF THESE FRAMES ...  1



PLAN OF FRAME  1:     0-------------------0----------------0---------------------0

                      NO. OF THESE FRAMES ...  2
```

OUTPUT 13

********** FRAME ELEVATION AND ELEMENT TYPES **********

ELEVATION OF FRAME NO. 1

```
+-----------+-----------+-----------+
!I    25    !     26    !     25    !I
!I          !           !           !I
!I19        ! 20        ! 20        !I19
!I07        !           !           !I07
!I          !           !           !I
+-----------+-----------+-----------+
!I    21    !     22    !     21    !I
!I          !           !           !I
!I16        ! 17        ! 17        !I16
!I06        !           !           !I06
!I          !           !           !I
+-----------+-----------+-----------+
!I    17    !     18    !     17    !I
!I          !           !           !I
!I13        ! 23        ! 14        !I13
!I05        !           !           !I05
!I          !           !           !I
+-----------+-----------+-----------+
!I    29    !     30    !     13    !I
!I          !           !           !I
!I10        ! 22        ! 11        !I10
!I04        !           !           !I04
!I          !           !           !I
+-----------+-----------+-----------+
!I    09    !     10    !     09    !I
!I          !           !           !I
!I07        ! 08        ! 08        !I07
!I03        !           !           !I03
!I          !           !           !I
+-----------+-----------+-----------+
!I    05    !     06    !     05    !I
!I          !           !           !I
!I04        ! 05        ! 05        !I04
!I02        !           !           !I02
!I          !           !           !I
+-----------+-----------+-----------+
!I    01    !     02    !     01    !I
!I          !           !           !I
!I01        ! 02        ! 02        !I01
!I01        !           !           !I01
!I          !           !           !I
```

NOTATION:

```
-  =  BEAM            NUMBERS INDICATE ELEMENT TYPES
!  =  COLUMN          COLUMN TYPE NUMBERS ON RIGHT
W  =  SHEAR WALL      SHEAR WALL NUMBERS ON LEFT, AND
I  =  EDGE COLUMN     EDGE COLUMN NUMBERS BELOW COLUMN TYPES
```

OUTPUT 14

ELEVATION OF FRAME NO. 2

```
+------------+-----------+
!I    27    W    28    !I
!I          W          !I
!I21       07W         !I21
!I07        W          !I07
!I          W          !I
+------------+-----------+
!I    23    W    24    !I
!I          W          !I
!I18       06W         !I18
!I06        W          !I06
!I          W          !I
+------------+-----------+
!I    19    W    20    !I
!I          W          !I
!I15       05W         !I15
!I05        W          !I05
!I          W          !I
+------------+-----------+
!I    15    W    16    !I
!I          W          !I
!I12       04W         !I12
!I04        W          !I04
!I          W          !I
+------------+-----------+
!I    11    W    12    !I
!I          W          !I
!I09       03W         !I09
!I03        W          !I03
!I          W          !I
+------------+-----------+
!I    07    W    08    !I
!I          W          !I
!I06       02W         !I06
!I02        W          !I02
!I          W          !I
+------------+-----------+
!I    03    W    04    !I
!I          W          !I
!I03       01W         !I03
!I01        W          !I01
!I          W          !I
```

NOTATION:

```
-  =  BEAM            NUMBERS INDICATE ELEMENT TYPES
!  =  COLUMN          COLUMN TYPE NUMBERS ON RIGHT
W  =  SHEAR WALL      SHEAR WALL NUMBERS ON LEFT, AND
I  =  EDGE COLUMN     EDGE COLUMN NUMBERS BELOW COLUMN TYPES
```

$

OUTPUT 14 (CONT'D)

*************** O U T P U T   O F   R E S U L T S ***************

ACTIVE SYSTEM OF UNITS: CMS, METRIC TONNES

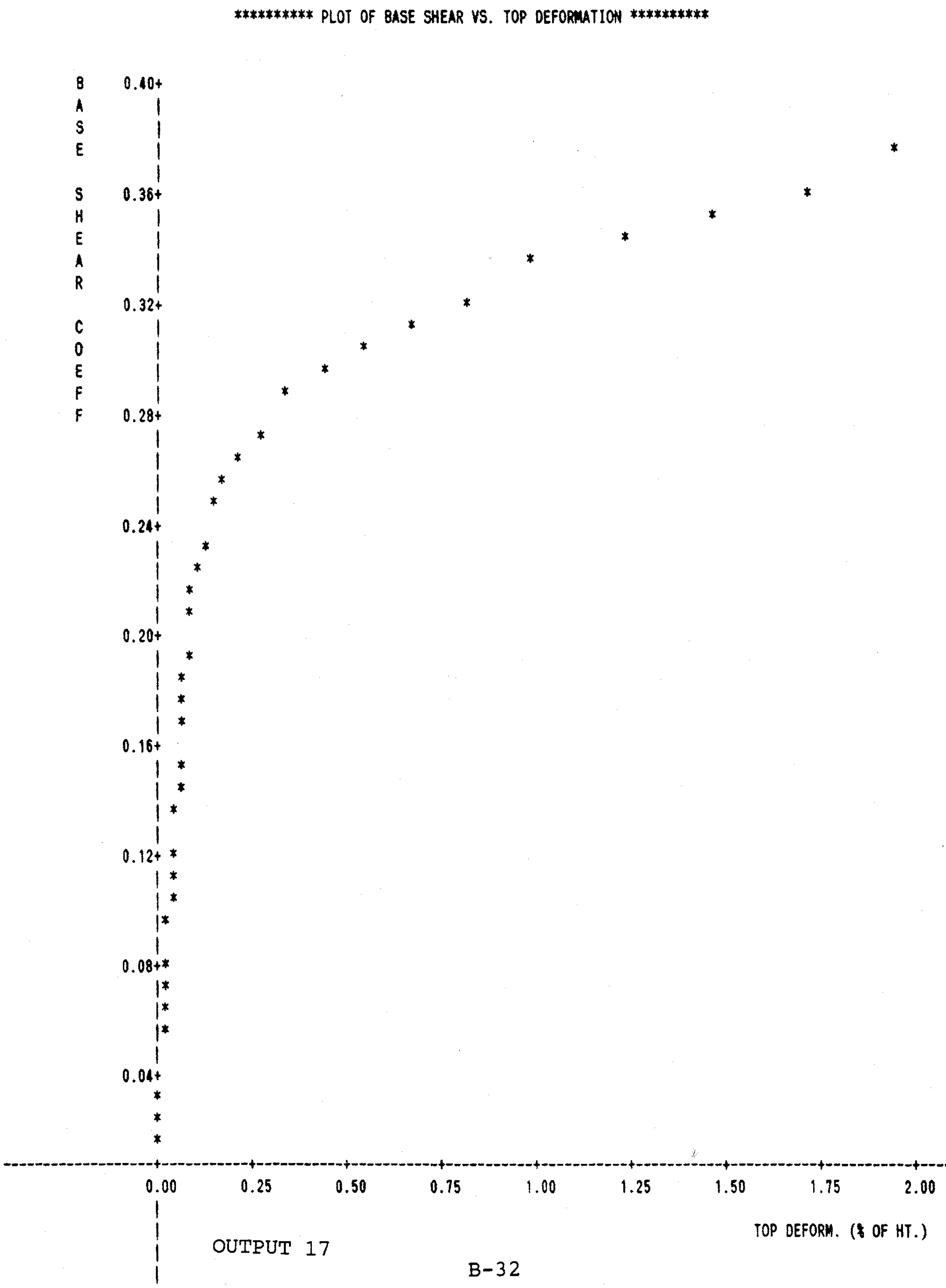
FUNDAMENTAL PERIOD OF STRUCTURE (SEC):	0.457
MAXIMUM BASE SHEAR COEFFICIENT:	0.370
MAXIMUM DEFORMATION AT TOP: (AS % OF BUILDING HEIGHT)	1.879

OUTPUT 15

********** VARIATION OF BASE SHEAR VS. OVERALL DEFORMATION (PERCENT) **********

NO.	BASE SHEAR COEFFICIENT	OVERALL DEFORMATION (%)
1	0.0100	0.0044
2	0.0200	0.0088
3	0.0300	0.0132
4	0.0400	0.0176
5	0.0500	0.0220
6	0.0600	0.0264
7	0.0700	0.0308
8	0.0800	0.0352
9	0.0900	0.0396
10	0.1000	0.0440
11	0.1100	0.0484
12	0.1200	0.0528
13	0.1300	0.0572
14	0.1400	0.0616
15	0.1500	0.0660
16	0.1600	0.0704
17	0.1700	0.0749
18	0.1800	0.0793
19	0.1900	0.0838
20	0.2000	0.0884
21	0.2100	0.0981
22	0.2200	0.1093
23	0.2300	0.1230
24	0.2400	0.1426
25	0.2500	0.1721
26	0.2600	0.2111
27	0.2700	0.2638
28	0.2800	0.3348
29	0.2900	0.4244
30	0.3000	0.5315
31	0.3100	0.6504
32	0.3200	0.7850
33	0.3300	0.9536
34	0.3400	1.1849
35	0.3500	1.4161
36	0.3600	1.6473
37	0.3700	1.8795

OUTPUT 16


********** PLOT OF BASE SHEAR VS. TOP DEFORMATION **********
BASE SHEAR COEFF
0.40
0.36
0.32
0.28
0.24
0.20
0.16
0.12
0.08
0.04
0.00
0.25
0.50
0.75
1.00
1.25
1.50
1.75
2.00
TOP DEFORM. (% OF HT.)

OUTPUT 17

```
********************* U L T I M A T E   F A I L U R E   M O D E *********************

 FAILURE MODE OF FRAME NO.  1


        +Y---------E+E---------E+Y---------E+
        EI         Y           Y          YI
        !I         !           !          !I
        !C         !           !          !C
        !I         !           !          !I
        EI         E           Y          EI
        +Y---------Y+Y---------Y+Y---------Y+
        EI         E           E          EI
        !I         !           !          !I
        !C         !           !          !C
        !I         !           !          !I
        EI         E           E          EI
        +Y---------Y+Y---------Y+Y---------Y+
        EI         E           Y          EI
        !I         !           !          !I
        !C         !           !          !C
        !I         !           !          !I
        EI         E           E          EI
        +Y---------Y+Y---------Y+Y---------Y+
        EI         E           E          EI
        !I         !           !          !I
        !C         !           !          !C
        !I         !           !          !I
        EI         E           E          EI
        +Y---------Y+Y---------Y+Y---------Y+
        EI         E           E          EI
        !I         !           !          !I
        !C         !           !          !C
        !I         !           !          !I
        EI         E           E          EI
        +Y---------Y+Y---------Y+Y---------Y+
        EI         E           E          EI
        !I         !           !          !I
        !C         !           !          !C
        !I         !           !          !I      NOTATION:
        EI         E           E          EI
        +Y---------Y+Y---------Y+Y---------Y+     -  =  BEAM              E  =  ELASTIC
        EI         E           E          EI      !  =  COLUMN            C  =  CRACK
        !I         !           !          !I      W  =  SHEAR WALL        Y  =  YIELD
        !C         !           !          !C      I  =  EDGE COLUMN
        !I         !           !          !I
        YI         Y           Y          YI
```

OUTPUT 18

FAILURE MODE OF FRAME NO. 2

```
+Y---------Y+Y---------Y+
YI           E          YI
!I           W          !I
!C           E          !C
!I           W          !I
EI           E          EI
+Y---------Y+Y---------Y+
EI           E          EI
!I           W          !I
!C           E          !C
!I           W          !I
EI           E          EI
+Y---------Y+Y---------Y+
EI           E          EI
!I           W          !I
!C           E          !C
!I           W          !I
EI           E          EI
+Y---------Y+Y---------Y+
EI           E          EI
!I           W          !I
!C           E          !C
!I           W          !I
EI           E          EI
+Y---------Y+Y---------Y+
EI           E          EI
!I           W          !I
!C           E          !C
!I           W          !I
EI           E          EI
+Y---------Y+Y---------Y+
EI           E          EI
!I           W          !I
!C           E          !C
!I           W          !I
EI           E          EI
+Y---------Y+Y---------Y+
EI           E          EI
!I           W          !I
!T           E          !C
!I           W          !I
YI           Y          YI
```

NOTATION:

- = BEAM		E = ELASTIC	
! = COLUMN		C = CRACK	
W = SHEAR WALL		Y = YIELD	
I = EDGE COLUMN			

OUTPUT 18 (CONT'D)

OUTPUT NOTATION:

AXIAL STIFFNESS = (E A)/L ; TONNES/CM OR KIP/IN
FLEXURAL STIFFNESS = (EI) ; TONNES/SQCM OR KSI

********** COLUMN PROPERTIES **********

NO.	MEMBER LENGTH	AXIAL STIFFNESS	CRACKING MOMENT	YIELD MOMENT	INITIAL FLEXURAL STIFFNESS	POST YIELDING STIFFNESS	YIELD CURVATURE
1	0.3252E+03	0.1703E+04	0.1562E+04	0.2549E+04	0.3065E+07	0.1659E+05	0.1267E-03
2	0.3252E+03	0.1703E+04	0.2016E+04	0.3499E+04	0.3065E+07	0.2677E+05	0.1416E-03
3	0.3252E+03	0.1703E+04	0.2016E+04	0.3499E+04	0.3065E+07	0.2675E+05	0.1419E-03
4	0.3252E+03	0.1703E+04	0.1562E+04	0.2549E+04	0.3065E+07	0.1647E+05	0.1222E-03
5	0.3252E+03	0.1703E+04	0.1539E+04	0.2497E+04	0.3065E+07	0.1576E+05	0.1224E-03
6	0.3252E+03	0.1703E+04	0.1539E+04	0.2497E+04	0.3065E+07	0.1570E+05	0.1248E-03
7	0.2502E+03	0.1970E+04	0.1508E+04	0.2413E+04	0.2820E+07	0.1419E+05	0.1515E-03
8	0.2502E+03	0.1970E+04	0.1891E+04	0.3238E+04	0.2820E+07	0.2381E+05	0.1656E-03
9	0.2502E+03	0.1970E+04	0.1891E+04	0.3238E+04	0.2820E+07	0.2381E+05	0.1656E-03
10	0.2502E+03	0.1970E+04	0.1508E+04	0.2413E+04	0.2820E+07	0.1421E+05	0.1495E-03
11	0.2502E+03	0.1970E+04	0.1489E+04	0.2370E+04	0.2820E+07	0.1410E+05	0.1512E-03
12	0.2502E+03	0.1970E+04	0.1489E+04	0.2370E+04	0.2820E+07	0.1410E+05	0.1531E-03
13	0.2502E+03	0.1845E+04	0.1423E+04	0.2277E+04	0.2657E+07	0.1329E+05	0.1583E-03
14	0.2502E+03	0.1845E+04	0.1742E+04	0.2968E+04	0.2657E+07	0.2135E+05	0.1728E-03
15	0.2502E+03	0.1845E+04	0.1742E+04	0.2968E+04	0.2657E+07	0.2137E+05	0.1709E-03
16	0.2502E+03	0.1845E+04	0.1423E+04	0.2277E+04	0.2657E+07	0.1329E+05	0.1595E-03
17	0.2502E+03	0.1845E+04	0.1407E+04	0.2241E+04	0.2657E+07	0.1329E+05	0.1608E-03
18	0.2502E+03	0.1845E+04	0.1407E+04	0.2241E+04	0.2657E+07	0.1329E+05	0.1610E-03
19	0.2502E+03	0.1761E+04	0.1406E+04	0.2155E+04	0.2549E+07	0.1275E+05	0.1540E-03
20	0.2502E+03	0.1995E+04	0.1439E+04	0.4146E+04	0.3003E+07	0.3048E+05	0.2776E-03
21	0.2502E+03	0.1761E+04	0.1660E+04	0.2721E+04	0.2549E+07	0.1813E+05	0.1724E-03
22	0.2502E+03	0.1761E+04	0.1406E+04	0.2155E+04	0.2549E+07	0.1275E+05	0.1614E-03
23	0.2502E+03	0.1761E+04	0.1393E+04	0.2126E+04	0.2549E+07	0.1275E+05	0.1608E-03
24	0.2502E+03	0.1761E+04	0.1393E+04	0.2126E+04	0.2549E+07	0.1275E+05	0.1604E-03
25	0.2502E+03	0.1953E+04	0.1345E+04	0.2027E+04	0.2798E+07	0.1399E+05	0.1519E-03
26	0.2502E+03	0.1995E+04	0.1412E+04	0.4089E+04	0.3003E+07	0.3043E+05	0.2802E-03
27	0.2502E+03	0.1953E+04	0.1533E+04	0.2456E+04	0.2798E+07	0.1460E+05	0.1596E-03
28	0.2502E+03	0.1953E+04	0.1345E+04	0.2027E+04	0.2798E+07	0.1399E+05	0.1460E-03
29	0.2502E+03	0.1953E+04	0.1336E+04	0.2005E+04	0.2798E+07	0.1399E+05	0.1446E-03
30	0.2502E+03	0.1953E+04	0.1336E+04	0.2005E+04	0.2798E+07	0.1399E+05	0.1450E-03
31	0.2502E+03	0.1160E+04	0.9959E+03	0.1839E+04	0.1769E+07	0.1061E+05	0.1774E-03
32	0.2502E+03	0.1160E+04	0.1119E+04	0.2097E+04	0.1769E+07	0.1450E+05	0.1819E-03
33	0.2502E+03	0.1160E+04	0.1119E+04	0.2097E+04	0.1769E+07	0.1449E+05	0.1831E-03
34	0.2502E+03	0.1160E+04	0.9959E+03	0.1839E+04	0.1769E+07	0.1062E+05	0.1746E-03
35	0.2502E+03	0.1160E+04	0.9901E+03	0.1826E+04	0.1769E+07	0.1059E+05	0.1770E-03
36	0.2502E+03	0.1160E+04	0.9901E+03	0.1826E+04	0.1769E+07	0.1069E+05	0.1638E-03
37	0.2502E+03	0.1453E+04	0.1032E+04	0.1733E+04	0.2148E+07	0.1074E+05	0.1441E-03
38	0.2502E+03	0.1453E+04	0.1091E+04	0.1864E+04	0.2148E+07	0.1081E+05	0.1628E-03
39	0.2502E+03	0.1453E+04	0.1091E+04	0.1864E+04	0.2148E+07	0.1079E+05	0.1652E-03
40	0.2502E+03	0.1453E+04	0.1032E+04	0.1733E+04	0.2148E+07	0.1074E+05	0.1518E-03
41	0.2502E+03	0.1453E+04	0.1030E+04	0.1727E+04	0.2148E+07	0.1074E+05	0.1498E-03
42	0.2502E+03	0.1453E+04	0.1030E+04	0.1727E+04	0.2148E+07	0.1074E+05	0.1522E-03

OUTPUT 19

********** BEAM PROPERTIES ********** ***** POSITIVE MOMENTS,CURVATURES *****

BEAM NO.	MEMBER LENGTH	INITIAL MOMENT (LEFT)	INITIAL MOMENT (RIGHT)	CRACKING MOMENT (+)	YIELD MOMENT (+)	CRACK CLOSING MOMENT	INITIAL FLEXURAL STIFFNESS	POST YIELDING STIFFNESS (+)	YIELD CURVATURE (+)
1	0.5504E+03	-0.5008E+03	-0.5008E+03	0.8509E+03	0.9455E+03	-0.9455E+03	0.3520E+07	0.1760E+05	0.1084E-03
2	0.4503E+03	-0.3906E+03	-0.3906E+03	0.8509E+03	0.9455E+03	-0.9455E+03	0.3427E+07	0.1713E+05	0.1232E-03
3	0.5504E+03	-0.5008E+03	-0.5008E+03	0.8509E+03	0.9455E+03	-0.9455E+03	0.3520E+07	0.1760E+05	0.1084E-03
4	0.5504E+03	-0.9566E+03	-0.9566E+03	0.9121E+03	0.1013E+04	-0.1013E+04	0.3889E+07	0.1945E+05	0.1077E-03
5	0.5504E+03	-0.9566E+03	-0.9566E+03	0.9121E+03	0.1013E+04	-0.1013E+04	0.3889E+07	0.1945E+05	0.1077E-03
6	0.5504E+03	-0.5008E+03	-0.5008E+03	0.8457E+03	0.9397E+03	-0.9397E+03	0.3491E+07	0.1745E+05	0.1085E-03
7	0.4503E+03	-0.3906E+03	-0.3906E+03	0.8457E+03	0.9397E+03	-0.9397E+03	0.3398E+07	0.1699E+05	0.1233E-03
8	0.5504E+03	-0.5008E+03	-0.5008E+03	0.8457E+03	0.9397E+03	-0.9397E+03	0.3491E+07	0.1745E+05	0.1085E-03
9	0.5504E+03	-0.9566E+03	-0.9566E+03	0.9035E+03	0.1004E+04	-0.1004E+04	0.3857E+07	0.1928E+05	0.1078E-03
10	0.5504E+03	-0.9566E+03	-0.9566E+03	0.9035E+03	0.1004E+04	-0.1004E+04	0.3857E+07	0.1928E+05	0.1078E-03
11	0.5504E+03	-0.5008E+03	-0.5008E+03	0.8440E+03	0.9378E+03	-0.9378E+03	0.3269E+07	0.1634E+05	0.1100E-03
12	0.4503E+03	-0.3906E+03	-0.3906E+03	0.8440E+03	0.9378E+03	-0.9378E+03	0.3182E+07	0.1591E+05	0.1248E-03
13	0.5504E+03	-0.5008E+03	-0.5008E+03	0.8440E+03	0.9378E+03	-0.9378E+03	0.3269E+07	0.1634E+05	0.1100E-03
14	0.5504E+03	-0.9566E+03	-0.9566E+03	0.9010E+03	0.1001E+04	-0.1001E+04	0.3612E+07	0.1806E+05	0.1091E-03
15	0.5504E+03	-0.9566E+03	-0.9566E+03	0.9010E+03	0.1001E+04	-0.1001E+04	0.3612E+07	0.1806E+05	0.1091E-03
16	0.5504E+03	-0.5008E+03	-0.5008E+03	0.9094E+03	0.1436E+04	-0.1436E+04	0.3474E+07	0.1737E+05	0.1560E-03
17	0.5504E+03	-0.3906E+03	-0.3906E+03	0.9094E+03	0.1436E+04	-0.1436E+04	0.3474E+07	0.1737E+05	0.1560E-03
18	0.5504E+03	-0.5008E+03	-0.5008E+03	0.8492E+03	0.9436E+03	-0.9436E+03	0.3121E+07	0.1560E+05	0.1111E-03
19	0.5504E+03	-0.9566E+03	-0.9566E+03	0.9092E+03	0.1010E+04	-0.1010E+04	0.3448E+07	0.1724E+05	0.1103E-03
20	0.5504E+03	-0.9566E+03	-0.9566E+03	0.9092E+03	0.1010E+04	-0.1010E+04	0.3448E+07	0.1724E+05	0.1103E-03
21	0.5504E+03	-0.5008E+03	-0.5008E+03	0.8550E+03	0.9499E+03	-0.9499E+03	0.3461E+07	0.1731E+05	0.1088E-03
22	0.4503E+03	-0.3906E+03	-0.3906E+03	0.8550E+03	0.9499E+03	-0.9499E+03	0.3369E+07	0.1685E+05	0.1236E-03
23	0.5504E+03	-0.5008E+03	-0.5008E+03	0.8550E+03	0.9499E+03	-0.9499E+03	0.3461E+07	0.1731E+05	0.1088E-03
24	0.5504E+03	-0.9566E+03	-0.9566E+03	0.9186E+03	0.1021E+04	-0.1021E+04	0.3824E+07	0.1912E+05	0.1082E-03
25	0.5504E+03	-0.9566E+03	-0.9566E+03	0.9186E+03	0.1021E+04	-0.1021E+04	0.3824E+07	0.1912E+05	0.1082E-03
26	0.5504E+03	-0.5008E+03	-0.5008E+03	0.6339E+03	0.9006E+03	-0.9006E+03	0.2056E+07	0.1028E+05	0.1223E-03
27	0.4503E+03	-0.3906E+03	-0.3906E+03	0.6339E+03	0.9006E+03	-0.9006E+03	0.2001E+07	0.1001E+05	0.1374E-03
28	0.5504E+03	-0.5008E+03	-0.5008E+03	0.6339E+03	0.9006E+03	-0.9006E+03	0.2056E+07	0.1028E+05	0.1223E-03
29	0.5504E+03	-0.9566E+03	-0.9566E+03	0.6669E+03	0.9435E+03	-0.9435E+03	0.2272E+07	0.1136E+05	0.1204E-03
30	0.5504E+03	-0.9566E+03	-0.9566E+03	0.6669E+03	0.9435E+03	-0.9435E+03	0.2272E+07	0.1136E+05	0.1204E-03
31	0.5504E+03	-0.5008E+03	-0.5008E+03	0.7263E+03	0.9191E+03	-0.9191E+03	0.2574E+07	0.1287E+05	0.1157E-03
32	0.4503E+03	-0.3906E+03	-0.3906E+03	0.7263E+03	0.9191E+03	-0.9191E+03	0.2505E+07	0.1253E+05	0.1306E-03
33	0.5504E+03	-0.5008E+03	-0.5008E+03	0.7263E+03	0.9191E+03	-0.9191E+03	0.2574E+07	0.1287E+05	0.1157E-03
34	0.5504E+03	-0.9566E+03	-0.9566E+03	0.7641E+03	0.9721E+03	-0.9721E+03	0.2843E+07	0.1422E+05	0.1144E-03
35	0.5504E+03	-0.9566E+03	-0.9566E+03	0.7641E+03	0.9721E+03	-0.9721E+03	0.2843E+07	0.1422E+05	0.1144E-03

OUTPUT 20

***** NEGATIVE MOMENTS, CURVATURES *****

BEAM NO.	CRACKING MOMENT (-)	YIELD MOMENT (-)	POST YIELDING STIFFNESS (-)	YIELD CURVATURE (-)
1	-0.2298E+04	-0.3216E+04	0.1760E+05	-0.1124E-03
2	-0.2298E+04	-0.3216E+04	0.1713E+05	-0.1166E-03
3	-0.2298E+04	-0.3216E+04	0.1760E+05	-0.1124E-03
4	-0.2988E+04	-0.3905E+04	0.1945E+05	-0.1356E-03
5	-0.2988E+04	-0.3905E+04	0.1945E+05	-0.1356E-03
6	-0.2310E+04	-0.3213E+04	0.1745E+05	-0.1143E-03
7	-0.2310E+04	-0.3213E+04	0.1699E+05	-0.1182E-03
8	-0.2310E+04	-0.3213E+04	0.1745E+05	-0.1143E-03
9	-0.3003E+04	-0.3903E+04	0.1928E+05	-0.1378E-03
10	-0.3003E+04	-0.3903E+04	0.1928E+05	-0.1378E-03
11	-0.2237E+04	-0.3184E+04	0.1634E+05	-0.1167E-03
12	-0.2237E+04	-0.3184E+04	0.1591E+05	-0.1217E-03
13	-0.2237E+04	-0.3184E+04	0.1634E+05	-0.1167E-03
14	-0.2909E+04	-0.3843E+04	0.1806E+05	-0.1430E-03
15	-0.2909E+04	-0.3843E+04	0.1806E+05	-0.1430E-03
16	-0.2258E+04	-0.3666E+04	0.1737E+05	-0.1253E-03
17	-0.2258E+04	-0.3666E+04	0.1737E+05	-0.1253E-03
18	-0.2302E+04	-0.3215E+04	0.1560E+05	-0.1130E-03
19	-0.2993E+04	-0.3904E+04	0.1724E+05	-0.1363E-03
20	-0.2993E+04	-0.3904E+04	0.1724E+05	-0.1363E-03
21	-0.2322E+04	-0.3229E+04	0.1731E+05	-0.1104E-03
22	-0.2322E+04	-0.3229E+04	0.1685E+05	-0.1143E-03
23	-0.2322E+04	-0.3229E+04	0.1731E+05	-0.1104E-03
24	-0.3019E+04	-0.3930E+04	0.1912E+05	-0.1323E-03
25	-0.3019E+04	-0.3930E+04	0.1912E+05	-0.1323E-03
26	-0.1622E+04	-0.2714E+04	0.1028E+05	-0.1767E-03
27	-0.1622E+04	-0.2714E+04	0.1001E+05	-0.1818E-03
28	-0.1622E+04	-0.2714E+04	0.1028E+05	-0.1767E-03
29	-0.2109E+04	-0.2819E+04	0.1136E+05	-0.2033E-03
30	-0.2109E+04	-0.2819E+04	0.1136E+05	-0.2033E-03
31	-0.1858E+04	-0.2961E+04	0.1287E+05	-0.1442E-03
32	-0.1858E+04	-0.2961E+04	0.1253E+05	-0.1495E-03
33	-0.1858E+04	-0.2961E+04	0.1287E+05	-0.1442E-03
34	-0.2416E+04	-0.3363E+04	0.1422E+05	-0.1739E-03
35	-0.2416E+04	-0.3363E+04	0.1422E+05	-0.1739E-03

OUTPUT 20 (CONT'D)

********** SHEAR WALL PROPERTIES **********   ***** FLEXURAL PROPERTIES *****

WALL NO.	MEMBER LENGTH	AXIAL STIFFNESS	CRACKING MOMENT	YIELD MOMENT	INITIAL FLEXURAL STIFFNESS	POST YIELDING STIFFNESS	YIELD CURVATURE
1	0.3503E+03	0.9537E+04	0.7073E+05	0.1770E+06	0.2666E+10	0.1035E+07	0.5310E-05
2	0.3002E+03	0.1103E+05	0.7215E+05	0.1804E+06	0.2644E+10	0.6293E+05	0.5745E-05
3	0.3002E+03	0.1033E+05	0.6575E+05	0.1644E+06	0.2476E+10	0.2871E+06	0.5790E-05
4	0.3002E+03	0.9864E+04	0.5945E+05	0.1487E+06	0.2364E+10	0.2319E+06	0.5900E-05
5	0.3002E+03	0.1094E+05	0.5555E+05	0.1389E+06	0.2621E+10	0.1602E+06	0.5470E-05
6	0.3002E+03	0.6498E+04	0.4733E+05	0.1185E+06	0.1557E+10	0.7069E+06	0.6621E-05
7	0.3002E+03	0.8134E+04	0.4468E+05	0.1117E+06	0.1949E+10	0.1128E+06	0.6063E-05

***** SHEAR PROPERTIES *****

NOTATION:

SHEAR STIFFNESS   = (GA) ; TONNES OR KIPS
SHEAR DEFORMATION = NONDIMENSIONAL AV. STRAIN

WALL NO.	CRACKING SHEAR	YIELD SHEAR	INITIAL SHEAR STIFFNESS	POST YIELD SHEAR STIFFNESS	YIELD SHEAR DEFORMATION
1	0.2570E+03	0.3510E+03	0.9544E+06	0.4772E+04	0.1049E-02
2	0.3052E+03	0.4507E+03	0.9464E+06	0.4732E+04	0.2067E-02
3	0.3512E+03	0.6249E+03	0.8862E+06	0.4431E+04	0.5352E-02
4	0.3733E+03	0.7215E+03	0.8461E+06	0.4231E+04	0.7782E-02
5	0.3103E+03	0.4530E+03	0.9384E+06	0.4692E+04	0.2172E-02
6	0.2228E+03	0.2860E+03	0.5574E+06	0.2787E+04	0.1683E-02
7	0.1831E+03	0.2284E+03	0.6978E+06	0.3489E+04	0.6228E-03

OUTPUT 21

********** EDGE COLUMN PROPERTIES **********

NOTATION:
STRENGTH = AXIAL FORCE (KIPS OR TONNES)
STIFFNESS UNITS (KIPS/IN OR TONNES/CM)

NO.	STRENGTH (TENSION)	STRENGTH (COMP)	STIFFNESS (TENSION)	STIFFNESS (COMP)	POST YIELDING STIFFNESS (TENSION)
1	0.2831E+02	0.1159E+04	0.4236E+02	0.2725E+04	0.4236E+01
2	0.2831E+02	0.1159E+04	0.4236E+02	0.2725E+04	0.4236E+01
3	0.2831E+02	0.1159E+04	0.4236E+02	0.2725E+04	0.4236E+01
4	0.2831E+02	0.1159E+04	0.4236E+02	0.2725E+04	0.4236E+01
5	0.2831E+02	0.1171E+04	0.4236E+02	0.2702E+04	0.4236E+01
6	0.2831E+02	0.1171E+04	0.4236E+02	0.2702E+04	0.4236E+01
7	0.2831E+02	0.1171E+04	0.4236E+02	0.2702E+04	0.4236E+01
8	0.2831E+02	0.1171E+04	0.4236E+02	0.2702E+04	0.4236E+01
9	0.2831E+02	0.1099E+04	0.4236E+02	0.2531E+04	0.4236E+01
10	0.2831E+02	0.1099E+04	0.4236E+02	0.2531E+04	0.4236E+01
11	0.2831E+02	0.1099E+04	0.4236E+02	0.2531E+04	0.4236E+01
12	0.2831E+02	0.1099E+04	0.4236E+02	0.2531E+04	0.4236E+01
13	0.2831E+02	0.1163E+04	0.4236E+02	0.2416E+04	0.4236E+01
14	0.2831E+02	0.1163E+04	0.4236E+02	0.2416E+04	0.4236E+01
15	0.2831E+02	0.1163E+04	0.4236E+02	0.2416E+04	0.4236E+01
16	0.2831E+02	0.1163E+04	0.4236E+02	0.2416E+04	0.4236E+01
17	0.2831E+02	0.1183E+04	0.4236E+02	0.2679E+04	0.4236E+01
18	0.2831E+02	0.1183E+04	0.4236E+02	0.2679E+04	0.4236E+01
19	0.2831E+02	0.1183E+04	0.4236E+02	0.2679E+04	0.4236E+01
20	0.2831E+02	0.1183E+04	0.4236E+02	0.2679E+04	0.4236E+01
21	0.2831E+02	0.5775E+03	0.4236E+02	0.1592E+04	0.4236E+01
22	0.2831E+02	0.5775E+03	0.4236E+02	0.1592E+04	0.4236E+01
23	0.2831E+02	0.5775E+03	0.4236E+02	0.1592E+04	0.4236E+01
24	0.2831E+02	0.5775E+03	0.4236E+02	0.1592E+04	0.4236E+01
25	0.2831E+02	0.7580E+03	0.4236E+02	0.1992E+04	0.4236E+01
26	0.2831E+02	0.7580E+03	0.4236E+02	0.1992E+04	0.4236E+01
27	0.2831E+02	0.7580E+03	0.4236E+02	0.1992E+04	0.4236E+01
28	0.2831E+02	0.7580E+03	0.4236E+02	0.1992E+04	0.4236E+01

OUTPUT 22

********** TRANSVERSE BEAM PROPERTIES **********

NO.	STIFFNESS (VERTICAL)	STIFFNESS (TORSIONAL)	ARM LENGTH
1	0.34504E+01	0.43472E+04	-0.25019E+03
2	0.34504E+01	0.43472E+04	0.25019E+03
3	0.34504E+01	0.43472E+04	-0.25019E+03
4	0.34504E+01	0.43472E+04	0.25019E+03
5	0.34504E+01	0.43472E+04	-0.25019E+03
6	0.34504E+01	0.43472E+04	0.25019E+03
7	0.34504E+01	0.43472E+04	-0.25019E+03
8	0.34504E+01	0.43472E+04	0.25019E+03
9	0.34504E+01	0.43472E+04	-0.25019E+03
10	0.34504E+01	0.43472E+04	0.25019E+03
11	0.34504E+01	0.43472E+04	-0.25019E+03
12	0.34504E+01	0.43472E+04	0.25019E+03
13	0.34504E+01	0.43472E+04	-0.25019E+03
14	0.34504E+01	0.43472E+04	0.25019E+03
15	0.00000E+00	0.43472E+04	0.00000E+00
16	0.00000E+00	0.43472E+04	0.00000E+00
17	0.00000E+00	0.43472E+04	0.00000E+00
18	0.00000E+00	0.43472E+04	0.00000E+00
19	0.00000E+00	0.43472E+04	0.00000E+00
20	0.00000E+00	0.43472E+04	0.00000E+00
21	0.00000E+00	0.43472E+04	0.00000E+00
22	0.00000E+00	0.43472E+04	0.00000E+00
23	0.00000E+00	0.43472E+04	0.00000E+00
24	0.00000E+00	0.43472E+04	0.00000E+00
25	0.00000E+00	0.43472E+04	0.00000E+00
26	0.00000E+00	0.43472E+04	0.00000E+00
27	0.00000E+00	0.43472E+04	0.00000E+00
28	0.00000E+00	0.43472E+04	0.00000E+00

OUTPUT 23

** D Y N A M I C   A N A L Y S I S **

INPUT DATA:

********** DETAILS OF INPUT BASE MOTION **********

MAX SCALED VALUE OF HORIZONTAL COMPONENT (g):	0.357
MAX SCALED VALUE OF VERTICAL COMPONENT (g):	0.000
TIME INTERVAL OF ANALYSIS (SEC):	0.0050
TOTAL DURATION OF RESPONSE ANALYSIS (SEC):	25.000
DAMPING COEFFICIENT (% OF CRITICAL):	2.000

VERTICAL COMPONENT OF BASE MOTION: 0

(=0, NOT INCLUDED; =1, INCLUDED)

WAVE NAME: TOCKACHI OKI 0.357g

NO. OF POINTS IN INPUT BASE MOTION:	1700
TIME INTERVAL OF INPUT WAVE (SEC):	0.020

OUTPUT 24

********** OUTPUT CONTROL DATA **********

NO. OF STORIES FOR WHICH OUTPUT IS REQUIRED: 2

OUTPUT TIME INTERVAL (SEC): 0.020

NO.	STORY NUMBER	OUTPUT TYPE
1	1	3
2	7	1

NOTATION FOR OUTPUT TYPE:

1 = DISPLACEMENT TIME HISTORY
2 = STORY DRIFT
3 = STORY SHEAR
4 = ALL OF ABOVE

OUTPUT 25

********** PROPERTIES FOR HYSTERETIC RULE **********

NO. OF TYPES OF HYSTERETIC RULES: 3

RULE NO.	DEGRADING COEFFICIENT	SLIPPAGE COEFFICIENT	DETERIORATING COEFFICIENT	POST-YIELD STIFFNESS RATIO
1	2.000	1000.000	0.000	0.015
2	2.000	1000.000	0.000	0.015
3	0.010	0.010	0.000	0.015

OUTPUT 26

********** HYSTERETIC RULE FOR COLUMNS **********

COLUMN NO.	HYSTERESIS RULE NO.
1	1
2	1
3	1
4	1
5	1
6	1
7	1
8	1
9	1
10	1
11	1
12	1
13	1
14	1
15	1
16	1
17	1
18	1
19	1
20	1
21	1
22	1
23	1
24	1
25	1
26	1
27	1
28	1
29	1
30	1
31	1
32	1
33	1
34	1
35	1
36	1
37	1
38	1
39	1
40	1
41	1
42	1

OUTPUT 26 (CONT'D)

********** HYSTERETIC RULE FOR BEAMS **********

BEAM NO.	HYSTERESIS RULE NO.
1	2
2	2
3	2
4	2
5	2
6	2
7	2
8	2
9	2
10	2
11	2
12	2
13	2
14	2
15	2
16	2
17	2
18	2
19	2
20	2
21	2
22	2
23	2
24	2
25	2
26	2
27	2
28	2
29	2
30	2
31	2
32	2
33	2
34	2
35	2

OUTPUT 26 (CONT'D)

********** HYSTERETIC RULE FOR SHEAR WALLS **********

WALL NO.	HYSTERESIS RULE (FLEXURE)	HYSTERESIS RULE (SHEAR)
1	1	3
2	1	3
3	1	3
4	1	3
5	1	3
6	1	3
7	1	3

OUTPUT 26 (CONT'D)

****

RESULTS OF SUBSTRUCTURE ANALYSIS
ARE WRITTEN SEPARATELY
TO FILE: SUB.OUT

**1

********** MAXIMUM RESPONSE **********

STORY NO.	STORY DRIFT	DISPLACEMENT	VELOCITY	ACCELERATION	STORY SHEAR
1	0.3016E+01	0.3016E+01	0.1906E+02	0.6056E+03	0.4744E+03
2	0.3583E+01	0.6568E+01	0.3388E+02	0.7173E+03	0.4287E+03
3	0.3704E+01	0.1021E+02	0.5148E+02	0.6780E+03	0.3813E+03
4	0.3812E+01	0.1385E+02	0.6929E+02	0.6143E+03	0.3600E+03
5	0.3894E+01	0.1745E+02	0.8600E+02	0.5818E+03	0.3206E+03
6	0.3922E+01	0.2108E+02	0.1042E+03	0.8063E+03	0.2648E+03
7	0.3811E+01	0.2460E+02	0.1246E+03	0.1042E+04	0.1679E+03

OUTPUT 27

******************** OUTPUT TIME HISTORY ********************

TIME HISTORY FOR STORY NO. 1

NO. OF POINTS: 1250   OUTPUT TIME INTERVAL: 0.0200

TIME	STORY SHEAR
0.020	-0.32333E+00
0.040	-0.12442E+01
0.060	-0.21012E+01
0.080	-0.21164E+01
0.100	-0.12504E+01
0.120	-0.21148E+01
0.140	-0.91973E+01
0.160	-0.24314E+02
0.180	-0.41820E+02
0.200	-0.55215E+02
0.220	-0.62454E+02
0.240	-0.64051E+02
0.260	-0.60799E+02
0.280	-0.60465E+02
0.300	-0.63492E+02
0.320	-0.64319E+02
0.340	-0.60872E+02
0.360	-0.50894E+02
0.380	-0.29722E+02
0.400	-0.10017E+01
0.420	0.19686E+02
0.440	0.25673E+02
0.460	0.22703E+02
0.480	0.17064E+02
0.500	0.12450E+02
0.520	0.16519E+02
0.540	0.10817E+02
0.560	-0.14868E+02
0.580	-0.54963E+02
0.600	-0.92029E+02
0.620	-0.11187E+03
0.640	-0.10945E+03

OUTPUT 28

24.640	0.77347E+02
24.660	0.97727E+02
24.680	0.13768E+03
24.700	0.16939E+03
24.720	0.15854E+03
24.740	0.12554E+03
24.760	0.71974E+02
24.780	0.44952E+02
24.800	0.20574E+02
24.820	-0.51379E+01
24.840	-0.34787E+01
24.860	0.24834E+02
24.880	0.39596E+02
24.900	0.33774E+02
24.920	0.18668E+02
24.940	0.15788E+01
24.960	-0.23034E+02
24.980	-0.81683E+02
25.000	-0.13117E+03

OUTPUT 28 (CONT'D)

TIME HISTORY FOR STORY NO. 7

NO. OF POINTS: 1250 OUTPUT TIME INTERVAL: 0.0200

TIME	DISPLACEMENT
0.020	-0.18625E-03
0.040	-0.12826E-02
0.060	-0.37957E-02
0.080	-0.77964E-02
0.100	-0.12223E-01
0.120	-0.16495E-01
0.140	-0.24295E-01
0.160	-0.45367E-01
0.180	-0.92214E-01
0.200	-0.17322E+00
0.220	-0.28668E+00
0.240	-0.41630E+00
0.260	-0.53368E+00
0.280	-0.61231E+00
0.300	-0.63432E+00
0.320	-0.59419E+00
0.340	-0.50327E+00
0.360	-0.37605E+00
0.380	-0.22592E+00
0.400	-0.60089E-01
0.420	0.11128E+00
0.440	0.27104E+00
0.460	0.39606E+00
0.480	0.45564E+00
0.500	0.43253E+00
0.520	0.33137E+00
0.540	0.17045E+00
24.740	0.36825E+01
24.760	0.31909E+01
24.780	0.26995E+01
24.800	0.21607E+01
24.820	0.15819E+01
24.840	0.99798E+00
24.860	0.43108E+00
24.880	-0.10436E+00
24.900	-0.59215E+00
24.920	-0.99580E+00
24.940	-0.13137E+01
24.960	-0.15944E+01
24.980	-0.18803E+01
25.000	-0.22073E+01

OUTPUT 28 (CONT'D)

```
******************** D A M A G E D   S T A T E   O F   F R A M E S ********************
```

FINAL STATE OF FRAME NO. 1

```
+Y---------Y+Y---------C+Y---------Y+
CI          Y           Y           YI
!I          !           !           !I
!E          !           !           !E
!I          !           !           !I
CI          C           Y           CI
+Y---------Y+Y---------Y+Y---------Y+
EI          C           C           CI
!I          !           !           !I
!E          !           !           !E
!I          !           !           !I
CI          C           C           CI
+Y---------Y+Y---------Y+Y---------Y+
CI          C           C           CI
!I          !           !           !I
!E          !           !           !E
!I          !           !           !I
CI          C           C           EI
+Y---------Y+Y---------Y+Y---------Y+
CI          C           C           EI
!I          !           !           !I
!E          !           !           !E
!I          !           !           !I
CI          C           C           EI
+Y---------Y+Y---------Y+Y---------Y+
EI          C           C           EI
!I          !           !           !I
!E          !           !           !E
!I          !           !           !I
CI          C           C           CI
+Y---------Y+Y---------Y+Y---------Y+
EI          C           C           EI
!I          !           !           !I
!E          !           !           !E
!I          !           !           !I
CI          C           C           CI
+Y---------Y+Y---------Y+Y---------Y+
EI          E           C           EI
!I          !           !           !I
!E          !           !           !E
!I          !           !           !I
YI          Y           Y           YI
```

NOTATION:

```
- = BEAM               E = ELASTIC
! = COLUMN             C = CRACK
W = SHEAR WALL         Y = YIELD
I = EDGE COLUMN
```

OUTPUT 29

FINAL STATE OF FRAME NO. 2

```
+Y---------Y+Y---------Y+
YI         E           YI
!I         W           !I
!C         E           !C
!I         W           !I
CI         E           CI
+Y---------Y+Y---------Y+
CI         C           CI
!I         W           !I
!C         E           !C
!I         W           !I
CI         E           CI
+Y---------Y+Y---------Y+
CI         E           CI
!I         W           !I
!C         E           !C
!I         W           !I
CI         C           CI
+Y---------Y+Y---------Y+
EI         C           CI
!I         W           !I
!E         E           !C
!I         W           !I
CI         C           CI
+Y---------Y+Y---------Y+
CI         C           CI
!I         W           !I
!E         E           !C
!I         W           !I
CI         C           CI
+Y---------Y+Y---------Y+
EI         C           CI
!I         W           !I
!E         C           !C
!I         W           !I
CI         Y           YI
+Y---------Y+Y---------Y+
CI         C           CI
!I         W           !I
!E         Y           !C
!I         W           !I
YI         Y           YI
```

NOTATION:

```
- = BEAM           E = ELASTIC
! = COLUMN         C = CRACK
W = SHEAR WALL     Y = YIELD
I = EDGE COLUMN
```

OUTPUT 29 (CONT'D)

********** PARAMETERS FOR DAMAGE INDEX COMPUTATIONS **********

NOTATION	DESCRIPTION	UNITS
DELTA-M	MAX DEFORMATION	CMS OR INS
DELTA-U	ULT DEFORMATION	CMS OR INS
BETA	STRENGTH PARAMETER	NONDIMENSIONAL
ENERGY	FORCE X DISPL	CM-TON OR IN-KIP
QY	YIELD STRENGTH	TONNES OR KIPS

COLUMN PARAMETERS:

	DELTA-M	DELTA-U	BETA	ENERGY	QY
1	1.19529	27.35472	0.03154	34.28740	15.67509
2	1.19803	19.15194	0.06063	41.17363	21.51629
3	1.28612	19.16577	0.06063	39.15351	21.51629
4	1.00321	27.46299	0.03154	36.02055	15.67509
5	1.54467	28.36082	0.03004	36.94744	15.35754
6	1.34997	28.51890	0.03004	38.67820	15.35754
7	0.33038	18.57047	0.02742	2.75301	19.28998
8	0.53354	12.87989	0.05176	12.94349	25.88427
9	0.45614	12.87931	0.05176	11.23633	25.88427
10	0.13028	18.52365	0.02742	1.28616	19.28998
11	0.52505	19.11557	0.02620	4.94977	18.94492
12	0.59977	19.15974	0.02620	7.01947	18.94492
13	0.15849	19.68812	0.02460	-0.12820	18.20384
14	0.47339	13.68936	0.04619	9.88154	23.72629
15	0.62708	13.65730	0.04619	5.23699	23.72629
16	0.12952	19.71501	0.02460	-0.32929	18.20384
17	0.46186	20.32103	0.02353	-0.41453	17.91832
18	0.36054	20.32478	0.02353	1.49144	17.91832
19	0.17546	20.64953	0.02318	0.07461	17.22764
20	0.70171	16.69471	0.01797	23.68733	33.14376
21	1.03199	15.78365	0.03650	20.21758	21.75356
22	0.10406	20.81884	0.02318	0.00632	17.22764
23	0.40971	20.81997	0.02318	-0.15437	16.99760
24	0.35086	20.81007	0.02318	0.83065	16.99760
25	0.22602	20.83377	0.02328	0.87748	16.20071
26	0.89832	16.71947	0.01797	38.20566	32.68791
27	0.80932	18.36406	0.02842	26.93697	19.63689
28	0.18494	20.69946	0.02328	-0.08058	16.20071
29	0.86002	20.67515	0.02328	3.82290	16.02971
30	0.63023	20.68614	0.02328	4.06270	16.02971
31	0.10066	19.25336	0.01871	0.10933	14.69885
32	0.63994	14.72826	0.03144	12.85918	16.76215
33	0.59294	14.74805	0.03144	15.04346	16.76215
34	0.10498	19.19680	0.01871	0.16786	14.69885
35	0.66791	19.25161	0.01871	0.89560	14.59868
36	0.32008	18.94989	0.01871	1.01739	14.59868
37	0.71265	19.42922	0.02047	22.87927	13.85078
38	1.65590	19.80890	0.02047	52.60929	14.90125
39	2.02279	19.85933	0.02047	78.54578	14.90125
40	1.86424	19.62377	0.02047	9.26907	13.85078
41	2.02933	19.57908	0.02047	26.91298	13.80530
42	2.54915	19.63742	0.02047	30.56018	13.80530

OUTPUT 30

BEAM PARAMETERS:

	DELTA-M	DELTA-U	BETA	ENERGY	QY
1	6.44533	53.97139	0.01184	67.16213	7.55999
2	4.97098	36.71430	0.01184	73.54615	9.23999
3	6.45360	53.97139	0.01184	88.30550	7.55999
4	8.22772	50.47910	0.01218	155.56708	8.93505
5	8.77660	50.47910	0.01218	113.53308	8.93505
6	7.11300	54.03272	0.01185	88.26371	7.54478
7	5.40010	36.75602	0.01185	88.51675	9.22140
8	6.98656	54.03272	0.01185	109.12424	7.54478
9	10.49029	50.53648	0.01219	171.80231	8.91499
10	9.74324	50.53648	0.01219	158.96074	8.91499
11	7.46817	53.65588	0.01178	92.11738	7.48902
12	6.02119	36.49967	0.01178	106.06502	9.15325
13	7.91501	53.65588	0.01178	111.66444	7.48902
14	10.98164	50.18401	0.01214	150.06256	8.80071
15	10.10492	50.18401	0.01214	197.93779	8.80071
16	7.23801	52.23535	0.01118	148.99013	9.26870
17	6.31686	52.23535	0.01118	135.39153	9.26870
18	7.41681	53.99189	0.01184	128.56755	7.55479
19	10.81910	50.49829	0.01218	150.95670	8.92817
20	10.73886	50.49829	0.01218	175.87724	8.92817
21	6.92475	54.09351	0.01186	98.43887	7.59264
22	6.26421	36.79737	0.01186	78.94589	9.27989
23	8.86080	54.09351	0.01186	92.55157	7.59264
24	10.13574	50.59333	0.01219	208.15793	8.99426
25	11.11648	50.59333	0.01219	167.79050	8.99426
26	8.11993	49.99017	0.02289	81.63750	6.56725
27	5.67344	34.00606	0.02289	99.72311	8.02664
28	7.85676	49.99017	0.02289	95.25063	6.56725
29	11.42827	46.75550	0.05243	184.25491	6.83555
30	10.79199	46.75550	0.05243	148.88634	6.83555
31	3.92116	51.50811	0.01131	41.18100	7.04874
32	1.74587	35.03864	0.01131	8.72902	8.61512
33	7.64266	51.50811	0.01131	12.24905	7.04874
34	8.87562	48.17521	0.02174	103.71481	7.87518
35	11.62608	48.17521	0.02174	74.78041	7.87518

OUTPUT 31

SHEAR WALL PARAMETERS:

	DELTA-M	DELTA-U	BETA	ENERGY	QY
1	3.01607	7.67575	0.03364	2843.80713	351.02170
2	0.52064	5.97600	0.02982	333.24146	450.71936
3	0.29493	5.17571	0.02757	114.77982	624.86829
4	0.22873	4.63399	0.02777	28.19049	721.45300
5	0.09170	6.25540	0.02783	16.20378	452.95624
6	0.11149	6.03664	0.02456	21.10688	285.97101
7	0.04952	6.46281	0.02600	18.13270	228.35669

OUTPUT 32

********** DAMAGE ANALYSIS **********

DAMAGE INDEX FOR COLUMNS:

NO.	DAMAGE INDEX	ENERGY RATIO
1	0.046	0.020
2	0.069	0.026
3	0.073	0.025
4	0.039	0.020
5	0.057	0.011
6	0.050	0.012
7	0.018	0.020
8	0.043	0.070
9	0.037	0.062
10	0.007	0.007
11	0.028	0.018
12	0.032	0.025
13	0.008	0.008
14	0.036	0.128
15	0.047	0.113
16	0.007	0.004
17	0.023	0.018
18	0.018	0.020
19	0.009	0.012
20	0.043	0.309
21	0.068	0.317
22	0.005	0.005
23	0.020	0.013
24	0.017	0.020
25	0.011	0.023
26	0.055	0.432
27	0.046	0.310
28	0.009	0.011
29	0.042	0.056
30	0.031	0.046
31	0.005	0.007
32	0.045	0.299
33	0.042	0.325
34	0.005	0.009
35	0.035	0.042
36	0.017	0.025
37	0.038	0.096
38	0.087	0.239
39	0.107	0.346
40	0.096	0.100
41	0.106	0.085
42	0.132	0.100

OUTPUT 33

DAMAGE INDEX FOR BEAMS:

NO.	DAMAGE INDEX	ENERGY RATIO
1	0.121	0.192
2	0.138	0.202
3	0.122	0.234
4	0.167	0.205
5	0.177	0.167
6	0.134	0.199
7	0.150	0.195
8	0.132	0.234
9	0.212	0.189
10	0.197	0.182
11	0.142	0.194
12	0.169	0.210
13	0.151	0.225
14	0.223	0.169
15	0.207	0.202
16	0.142	0.248
17	0.124	0.222
18	0.141	0.219
19	0.218	0.147
20	0.217	0.163
21	0.131	0.212
22	0.173	0.172
23	0.166	0.207
24	0.206	0.219
25	0.224	0.191
26	0.168	0.191
27	0.175	0.212
28	0.154	0.217
29	0.275	0.205
30	0.255	0.174
31	0.077	0.215
32	0.050	0.061
33	0.149	0.119
34	0.190	0.304
35	0.246	0.301

OUTPUT 34

DAMAGE INDEX FOR SHEAR WALLS:

NO.	DAMAGE INDEX	ENERGY RATIO
1	0.428	0.886
2	0.091	0.797
3	0.058	0.709
4	0.050	0.326
5	0.015	0.121
6	0.019	0.295
7	0.008	0.035

OUTPUT 35

```
********** RESULTS OF DAMAGE ANALYSIS **********



DAMAGE INDEX STATISTICS OF FRAME NO.  1


      +-----------+-----------+-----------+
      !   0.07    !   0.05    !   0.14    !
      !  (0.21)   !  (0.06)   !  (0.11)   !
      !0.03       !0.08       !0.10       !0.09
      !(.09)      !(.23)      !(.34)      !(.09)
      !           !           !           !
      +-----------+-----------+-----------+
      !   0.16    !   0.17    !   0.16    !
      !  (0.19)   !  (0.21)   !  (0.21)   !
      !0.00       !0.04       !0.04       !0.00
      !(.00)      !(.29)      !(.32)      !(.00)
      !           !           !           !
      +-----------+-----------+-----------+
      !   0.13    !   0.17    !   0.16    !
      !  (0.21)   !  (0.17)   !  (0.20)   !
      !0.01       !0.05       !0.04       !0.00
      !(.02)      !(.43)      !(.31)      !(.01)
      !           !           !           !
      +-----------+-----------+-----------+
      !   0.14    !   0.12    !   0.14    !
      !  (0.24)   !  (0.22)   !  (0.21)   !
      !0.00       !0.04       !0.06       !0.00
      !(.01)      !(.30)      !(.31)      !(.00)
      !           !           !           !
      +-----------+-----------+-----------+
      !   0.14    !   0.16    !   0.15    !
      !  (0.19)   !  (0.21)   !  (0.22)   !
      !0.00       !0.03       !0.04       !0.00
      !(.00)      !(.12)      !(.11)      !(.00)
      !           !           !           !
      +-----------+-----------+-----------+
      !   0.13    !   0.15    !   0.13    !
      !  (0.19)   !  (0.19)   !  (0.23)   !
      !0.01       !0.04       !0.03       !0.00
      !(.01)      !(.07)      !(.06)      !(.00)
      !           !           !           !        VALUES IN PARANTHESIS INDICATE ENERGY RATIOS
      +-----------+-----------+-----------+
      !   0.12    !   0.13    !   0.12    !
      !  (0.19)   !  (0.20)   !  (0.23)   !
      !0.04       !0.06       !0.07       !0.03
      !(.02)      !(.02)      !(.02)      !(.02)
      !           !           !           !
```

OUTPUT 36

DAMAGE INDEX STATISTICS OF FRAME NO. 2

```
+-----------+-----------+
!   0.19    W    0.24   !
!  (0.30)   W   (0.30)  !
!0.10       W0.00       !0.13
!(.08)      W(.03)      !(.10)
!           W           !
+-----------+-----------+
!   0.27    W    0.25   !
!  (0.20)   W   (0.17)  !
!0.03       W0.01       !0.01
!(.04)      W(.29)      !(.02)
!           W           !
+-----------+-----------+
!   0.20    W    0.22   !
!  (0.21)   W   (0.19)  !
!0.04       W0.01       !0.03
!(.05)      W(.12)      !(.04)
!           W           !
+-----------+-----------+
!   0.21    W    0.21   !
!  (0.14)   W   (0.16)  !
!0.01       W0.04       !0.01
!(.01)      W(.32)      !(.01)
!           W           !
+-----------+-----------+
!   0.22    W    0.20   !
!  (0.16)   W   (0.20)  !
!0.02       W0.05       !0.01
!(.01)      W(.70)      !(.02)
!           W           !
+-----------+-----------+
!   0.21    W    0.19   !
!  (0.18)   W   (0.18)  !
!0.02       W0.09       !0.03
!(.01)      W(.79)      !(.02)
!           W           !
+-----------+-----------+
!   0.16    W    0.17   !
!  (0.20)   W   (0.16)  !
!0.05       W0.42       !0.04
!(.01)      W(.88)      !(.01)
!           W           !
```

VALUES IN PARANTHESIS INDICATE ENERGY RATIOS

OUTPUT 36 (CONT'D)

********** STORY LEVEL DAMAGE INDICES **********

STORY NO.	VERTICAL COMPONENTS DAMAGE INDEX	VERTICAL COMPONENTS ENERGY RATIO	HORIZONTAL COMPONENTS DAMAGE INDEX	HORIZONTAL COMPONENTS ENERGY RATIO
1	0.386	0.287	0.144	0.073
2	0.079	0.038	0.163	0.089
3	0.052	0.017	0.176	0.095
4	0.051	0.014	0.161	0.109
5	0.044	0.016	0.180	0.091
6	0.035	0.008	0.206	0.085
7	0.094	0.041	0.169	0.037

++
+ DAMAGE INDEX FOR TOTAL STRUCTURE : 0.220 +
++

OUTPUT 37

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*************** S U B S T R U C T U R E   A N A L Y S I S ***************

CONTROL DATA:

FRAME NUMBER OF SUBSTRUCTURE........ 1

COLUMN LOCATION (J-COORDINATE)...... 3

(=0, ENTIRE FRAME IS CONSIDERED
AS SUBSTRUCTURE)

BOTTOM STORY NUMBER TO BE CUT....... 4

POSITION OF LOWER BOUNDARY.......... 0.50

(AS RATIO OF STORY HEIGHT)

TOP STORY TO BE CUT................. 5

POSITION OF UPPER BOUNDARY.......... 0.50

(AS RATIO OF STORY HEIGHT)

HORIZONTAL COMPONENT 1
VERTICAL COMPONENT 0
ROTATIONAL COMPONENT 0

(NOTATION: = 0, NOT INCLUDED; = 1, INCLUDED)

NUMBER OF BOUNDARY BEAMS: 2

NO.	BOUNDARY BEAM NO.
1	17
2	18

OUTPUT 38 SUBSTRUCTURE 1

******************** OUTPUT TIME HISTORY ********************

NO. OF OUTPUT POINTS ..... 1250 OUTPUT TIME INTERVAL 0.0200

********** TIME HISTORY OF HORIZONTAL COMPONENT **********

TIME	DISPLACEMENT	LOWER FORCE	UPPER FORCE
0.020	0.58957E-06	-0.53144E-04	0.20150E-04
0.040	-0.37581E-04	0.12242E-02	0.17885E-03
0.060	-0.40458E-03	0.15287E-01	-0.73972E-02
0.080	-0.11521E-02	0.38459E-01	-0.29546E-01
0.100	-0.20270E-02	0.59438E-01	-0.62679E-01
0.120	-0.25985E-02	0.66174E-01	-0.90750E-01
0.140	-0.29229E-02	0.75863E-01	-0.94590E-01
0.160	-0.47369E-02	0.15337E+00	-0.11360E+00
0.180	-0.11064E-01	0.38068E+00	-0.25426E+00
0.200	-0.23935E-01	0.76901E+00	-0.63701E+00
0.220	-0.42530E-01	0.12628E+01	-0.12638E+01
0.240	-0.64504E-01	0.18327E+01	-0.20240E+01
0.260	-0.85752E-01	0.24144E+01	-0.27367E+01
0.280	-0.99707E-01	0.27918E+01	-0.32075E+01
0.300	-0.10264E+00	0.28610E+01	-0.33087E+01
0.320	-0.95852E-01	0.26894E+01	-0.30708E+01
0.340	-0.80562E-01	0.22917E+01	-0.25426E+01
0.360	-0.59649E-01	0.17138E+01	-0.18613E+01
0.380	-0.35794E-01	0.10241E+01	-0.11188E+01
0.400	-0.10557E-01	0.29219E+00	-0.35014E+00
0.420	0.17209E-01	-0.53106E+00	0.49339E+00
0.440	0.45013E-01	-0.12996E+01	0.14117E+01
24.840	0.32654E+00	0.39715E+01	-0.40071E+00
24.860	0.22492E+00	0.46675E+01	-0.93589E+00
24.880	0.13026E+00	0.53527E+01	-0.14950E+01
24.900	0.58026E-01	0.58594E+01	-0.19563E+01
24.920	-0.13115E-02	0.63876E+01	-0.22921E+01
24.940	-0.45461E-01	0.67768E+01	-0.24532E+01
24.960	-0.71950E-01	0.70451E+01	-0.25730E+01
24.980	-0.91282E-01	0.72384E+01	-0.26053E+01
25.000	-0.11312E+00	0.74441E+01	-0.26327E+01

OUTPUT 38 SUBSTRUCTURE 1 (CONT'D)

********** TIME HISTORY OF BOUNDARY FORCES **********

NO.	TIME	BOUNDARY FORCE
1	0.0200	0.28068E-04
2	0.0400	-0.76685E-03
3	0.0600	-0.11419E-01
4	0.0800	-0.33503E-01
5	0.1000	-0.59713E-01
6	0.1200	-0.76745E-01
7	0.1400	-0.84631E-01
8	0.1600	-0.13429E+00
9	0.1800	-0.31660E+00
10	0.2000	-0.69446E+00
11	0.2200	-0.12428E+01
12	0.2400	-0.18926E+01
13	0.2600	-0.25230E+01
14	0.2800	-0.29364E+01
15	0.3000	-0.30212E+01
16	0.3200	-0.28209E+01
17	0.3400	-0.23686E+01
18	0.3600	-0.17524E+01
19	0.3800	-0.10509E+01
20	0.4000	-0.31294E+00
21	0.4200	0.50332E+00
1229	24.5800	-0.70864E+00
1230	24.6000	-0.65254E+00
1231	24.6200	-0.67329E+00
1232	24.6400	-0.78766E+00
1233	24.6600	-0.97694E+00
1234	24.6800	-0.12270E+01
1235	24.7000	-0.15009E+01
1236	24.7200	-0.19351E+01
1237	24.7400	-0.23047E+01
1238	24.7600	-0.27083E+01
1239	24.7800	-0.31337E+01
1240	24.8000	-0.35548E+01
1241	24.8200	-0.40251E+01
1242	24.8400	-0.45917E+01
1243	24.8600	-0.52466E+01
1244	24.8800	-0.59371E+01
1245	24.9000	-0.64645E+01
1246	24.9200	-0.69151E+01
1247	24.9400	-0.72439E+01
1248	24.9600	-0.74522E+01
1249	24.9800	-0.75910E+01
1250	25.0000	-0.77400E+01

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OUTPUT 38 SUBSTRUCTURE 2

*************** S U B S T R U C T U R E   A N A L Y S I S ***************

CONTROL DATA:

FRAME NUMBER OF SUBSTRUCTURE........ 1

COLUMN LOCATION (J-COORDINATE)...... 0

(=0, ENTIRE FRAME IS CONSIDERED
AS SUBSTRUCTURE)

BOTTOM STORY NUMBER TO BE CUT....... 1

POSITION OF LOWER BOUNDARY.......... 0.60

(AS RATIO OF STORY HEIGHT)

TOP STORY TO BE CUT................. 3

POSITION OF UPPER BOUNDARY.......... 0.40

(AS RATIO OF STORY HEIGHT)

HORIZONTAL COMPONENT 1
VERTICAL COMPONENT 0
ROTATIONAL COMPONENT 0

(NOTATION: = 0, NOT INCLUDED; = 1, INCLUDED)

******************** OUTPUT TIME HISTORY ********************

NO. OF OUTPUT POINTS 40   OUTPUT TIME INTERVAL 0.500

********** TIME HISTORY OF HORIZONTAL COMPONENT **********

TIME	DISPLACEMENT	LOWER FORCE	UPPER FORCE
0.500	0.48637E-01	-0.68708E+00	0.37291E+01
1.000	0.26946E+00	-0.97984E+01	0.16007E+02
1.500	0.45736E+00	-0.16668E+02	0.15870E+02
2.000	-0.86860E-01	0.49109E+01	-0.97837E+01
2.500	-0.42955E+00	-0.21071E+01	-0.28077E+00
3.000	0.99190E-01	0.92342E+01	-0.41950E+01
3.500	-0.11363E+01	0.37827E+01	-0.52143E+01
4.000	0.11758E+01	-0.20317E+02	0.12468E+02
4.500	-0.70750E+00	0.13442E+02	-0.65961E+01
5.000	0.83840E+00	-0.12853E+02	0.57340E+01
5.500	-0.10500E+01	0.21026E+02	-0.15207E+02
6.000	-0.23650E+00	0.59969E+01	-0.40755E+01
6.500	0.20291E+01	-0.16729E+02	0.16157E+02
7.000	-0.74801E+00	0.19304E+02	-0.10667E+02
7.500	0.16878E+01	-0.83148E+01	0.14744E+02
8.000	-0.19656E+01	0.25940E+02	-0.23033E+02
8.500	0.14528E+01	-0.11800E+02	0.12131E+02
9.000	0.41215E+00	0.17861E+01	0.31997E+00
9.500	0.63615E+00	0.91418E+00	0.22750E+01
10.000	0.15820E+00	0.68690E+01	-0.16027E+01
10.500	0.42156E-01	0.54302E+01	-0.22716E+01
11.000	0.81612E+00	-0.20156E+01	0.41016E+01
11.500	-0.38400E+00	0.94029E+01	-0.52443E+01
12.000	0.46912E+00	-0.38530E+00	0.20423E+01
12.500	0.43003E+00	0.20267E+01	0.18284E+01
13.000	0.11695E+00	0.70708E+01	-0.90643E+00
13.500	0.70626E+00	-0.63686E+00	0.43867E+01
14.000	-0.47742E+00	0.10464E+02	-0.59802E+01
14.500	0.42508E+00	0.30012E+01	0.21261E+01
15.000	0.31454E+00	0.27811E+01	0.88535E+00
15.500	0.41217E+00	0.73804E+00	0.24354E+01
16.000	-0.14407E+00	0.27234E+01	-0.17173E+01
16.500	0.28001E+00	-0.10115E+01	0.12098E+01
17.000	0.83365E-01	-0.87643E+00	0.43199E+00
17.500	0.24646E+00	-0.50683E+01	0.13597E+01
18.000	0.35130E+00	-0.52404E+01	0.25191E+01
18.500	0.42195E+00	-0.52192E+01	0.32124E+01
19.000	0.29453E+00	-0.12867E+01	0.20862E+01
19.500	-0.20139E+00	0.12155E+01	-0.20864E+01
20.000	0.73416E+00	-0.10353E+02	0.65087E+01

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