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DISCUSSION PRÉPARÉE / VORBEREITETE DISKUSSION / PREPARED DISCUSSION

Column-Free Box-Type Framing with and without Core

Bâtiments de grande hauteur sans poteaux intérieurs, avec ou sans noyau rigide

Hochhäuser ohne Innenstützen mit und ohne Kern

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§ 1 Introduction

To examine the possibility to represent by some parameters the elastic behavior of box-type framing(without core) subjected to lateral force,a numerical analysis is practiced with some amount of digital computation. The method of analysis used is the method mentioned in the APPENDIX in which the shear deformations of panel-zone,column and beam are ignored,that is,HD_K and $SD_{K,i}$ are put to zero,$CAS_{K,i}$ and $BAS_{K,i}$ are put to infinity,moreover,$G_{K,i}$ is omitted from the variables.

HITAC 5020E of the Computer Centre in Univ. of Tokyo is used at the digital computation.

§ 2 Table of symbols

I_c ----- moment inertia of column
I_B ----- moment inertia of beam
${}_cA_n$ ----- sectional area of column
K_0 ----- standard rigidity
K_c ----- rigidity ratio of column
K_B ----- rigidity ratio of beam
A ----- a half of replaced sectional area of column
d_c ----- depth of replaced section of column
λ ----- slenderness ratio of column
h ----- height of story
l ----- width of span
r ----- number of story of one block unit frame
n ----- number of bay of one block unit frame
δ_M ----- bending deformation of frame
δ_s ----- shearing deformation of frame
H ----- height of frame
P ----- lateral force at the top of frame
GA_F ----- shearing stiffness of frame
EI_F ----- bending stiffness of frame

§ 3 Assumptions, limitations, idealizations and parameters

1) Numerical analysis is carried out for the frame subjected to a lateral force at its top as shown in FIG 3-1 to know its fundamental behavior. Analyzed frames are of 5 and 10 story frames as one block unit, each have the same members as columns and the another same members as beams.

2) The column member section is replaced with a model as shown in FIG 3-2 so that it has the same moment inertia and the same sectional area with the actual section, as

$$I_c = A \cdot d_c^2/2 \qquad \text{----- (3-1)}$$

$$_cA_n = 2 \cdot A \qquad \text{----- (3-2)}$$

3) Defining parameter γ as $\gamma = I_c/h^2$, we have

$$I_c = \gamma \cdot h^2 \qquad \text{----- (3-3)}$$

$$_cA_n = 4 \cdot \gamma / q_c^2 \qquad \text{----- (3-4)}$$

where, q_c is introduced as $q_c = d_c/h$.
Considering that

$$q_c = \frac{2}{h}\sqrt{\frac{I_c}{_cA_n}} = \frac{2}{\lambda} \qquad \text{----- (3-5)}$$

and $\lambda = 20 \sim 25$ in recent frame design, the value of q_c is from 0.08 to 0.1. From this fact, 0.1 is adopted as the value of q_c in the analysis.

4) Letting $K_c = 1.0$, we have the value of K_0 as

$$K_0 = I_c/h = \gamma \cdot h \qquad \text{----- (3-6)}$$

Now, defining parameter α as $\alpha = I_B \cdot h/(I_c \cdot l)$, we have $K_B = \alpha$ and

$$I_B = \alpha \cdot \gamma \cdot h \cdot l \qquad \text{----- (3-7)}$$

5) The value of parameter γ is put to 1.0 in the analysis. Viewing Eqs. (3-3), (3-4), (3-6) and (3-7), we can know that this assumption influences only for the result concerning to the stiffness of frame which is to be corrected by being multiplied $1/\gamma$ to the direct result.

6) Parameter β is considered as $\beta = r/n$ to represent the slenderness of frame.

§ 4 Results of numerical analysis

1) To replace the F-frame* to a equivalent single chord member

From the corner column area $A_{eff.}$ equivalent to the F-frame calculated from the numerical $_RS^*$, efficiency of inner column $r_A = (A_{eff.} - A_{con.})/A_{in.}$ is obtained, using the symbols of FIG 4-1. Efficiency r_A is represented as shown in FIG 4-2 by the parameters α, β and h/l. The numerical results obtained here are not enough to represent r_A by an approximate equation, however, we can know from FIG 4-2 that the value of r_A is influenced mainly by α and h/l.

If we can know the efficiency r_A of a frame, the equivalent corner column area is obtained as

$$A_{eff.} = A_{con.} + r_A \cdot A_{in.}$$

2) Vertical resistant forces between F-frame and W-frame*

Distribution of vertical resistant forces between F-frame and W-frame (this corresponds to the distribution of shearing stress of box-beam at its corner) got from the numerical analysis is shown typically in FIG 4-3. Now, the value of F_{mean}/P is shown in FIG 4-4-a, -b using the parameters α, β and h/l. From these figures, we can know that the value of F_{mean}/P is influenced mainly by β and h/l. F_{mean}/P is shown again using the parameters β and h/l in FIG 4-4-c.

3) Bending deformation of frame

The bending deformation δ_M and the shearing deformation δ_S of a cantilever as shown in FIG 3-1 the section of which is shown in FIG 4-1, are as follows by beam theory.

$\delta_M = P \cdot H^3/(3 \cdot EI_F)$, $\delta_S = P \cdot H/(GA_F)$ ----- (4-1)

Now the bending deformation and the shearing deformation obtained in the numerical analysis are δ_M' and δ_S' respectively.

a) Efficiency of moment inertia

The actually efficient moment inertia being I_F', the ratio δ_M/δ_M' defines the efficiency of moment inertia $k'=I_F'/I_F$. The value of this efficiency k' is shown in FIG 4-5-a,-b using the parameters α,β and h/l. The value of k' being influenced mainly by β, h/l and r, this is again shown in FIG 4-5-c using β, h/l and r.

b) Ratio of the bending deformation to the shearing deformation

From Eq.(4-1) we have Eq.(4-2).

$\delta_M/\delta_S/H^2 = (GA_F)/(3 \cdot EI_F)$ ----- (4-2)

Because the right-side term of Eq.(4-2) is a specific quality of a section having the dimension of L^{-2}, the ratio $\delta_M'/\delta_S'/H^2$ obtained in the numerical analysis represent a dimensional ratio of the bending deformation to the shearing deformation. So the value $\delta_M'/\delta_S'/H^2$ is shown using the parameters α,β and h/l in FIG 4-6-a, -b.

4) Axial strain ratio of column

Axial strain ratios of the columns of the frame at the top of it(shown as "T") and at the base of it(shown as "B") are shown in FIG 4-7 and FIG 4-8 as to the F-frame and the W-frame respectively, using the parameters α,β and h/l and total story number of the frame r. It is to be noticed that the ratio of the W-frame at the base seems to be indifferent to the value of α.

* See APPENDIX.

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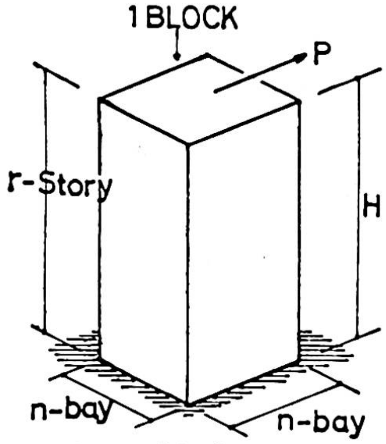


FIG 3-1

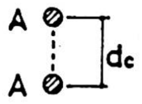


FIG 3-2

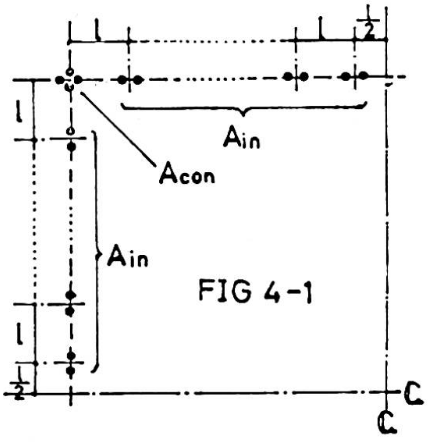


FIG 4-1

FIG 4-2 EFFICIENCY OF INNER COLUMN

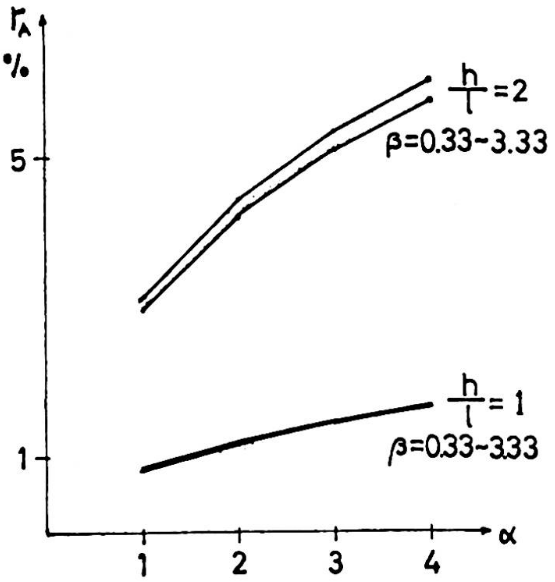


FIG 4-3

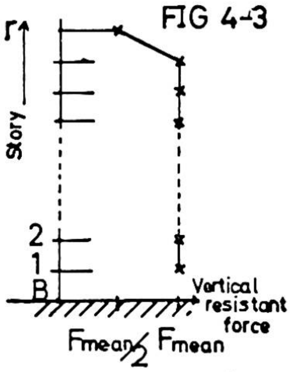


FIG 4-4-a

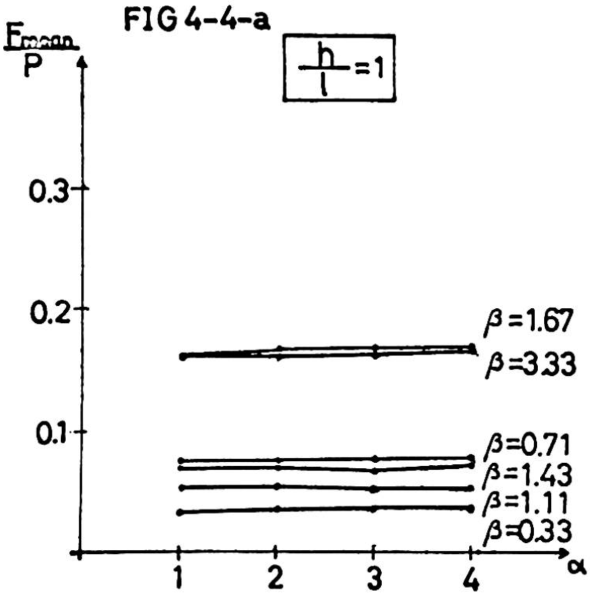


FIG 4-4-b

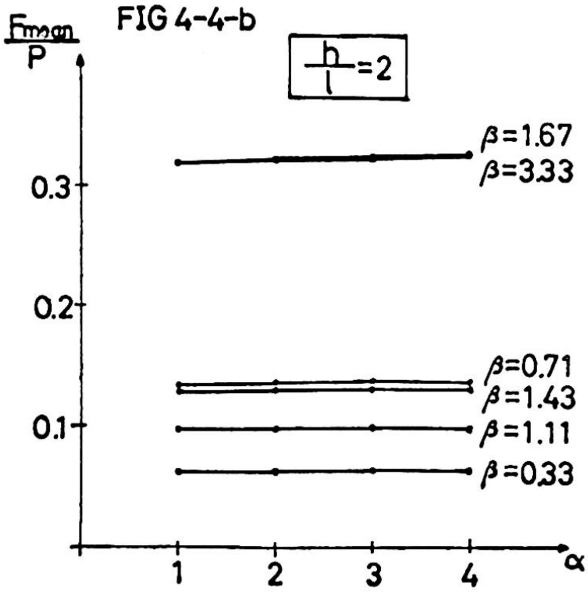


FIG 4-4-c

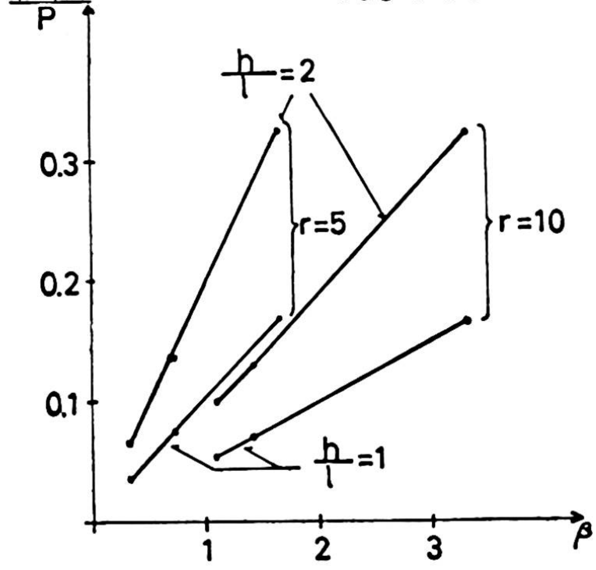


FIG 4-5-c

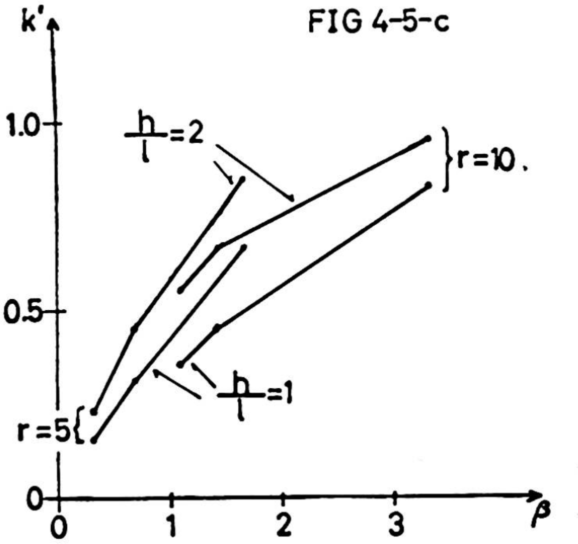


FIG 4-5-a

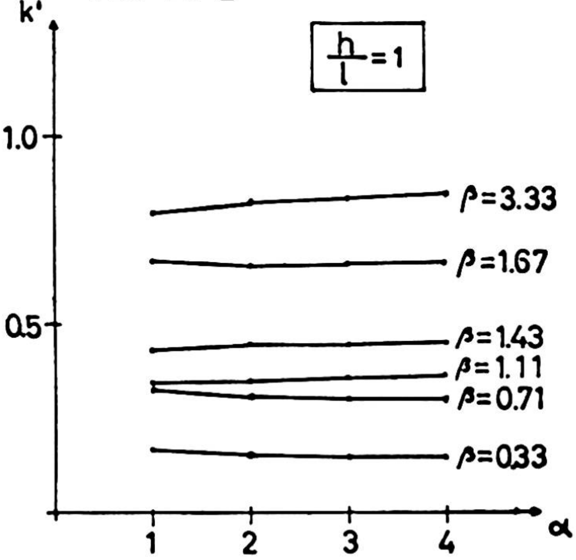


FIG 4-5-b

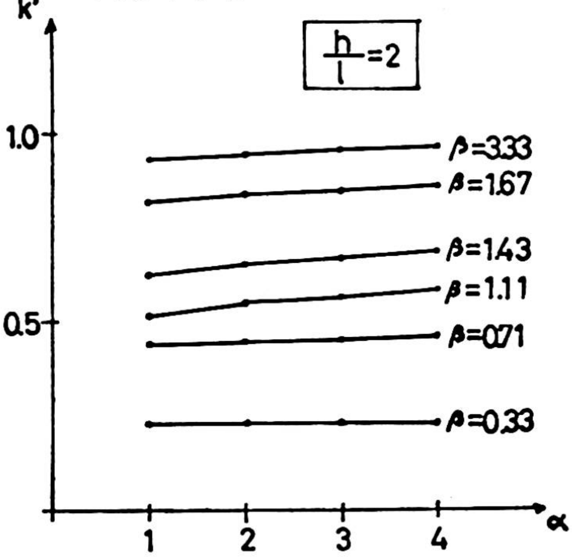


FIG 4-6-a

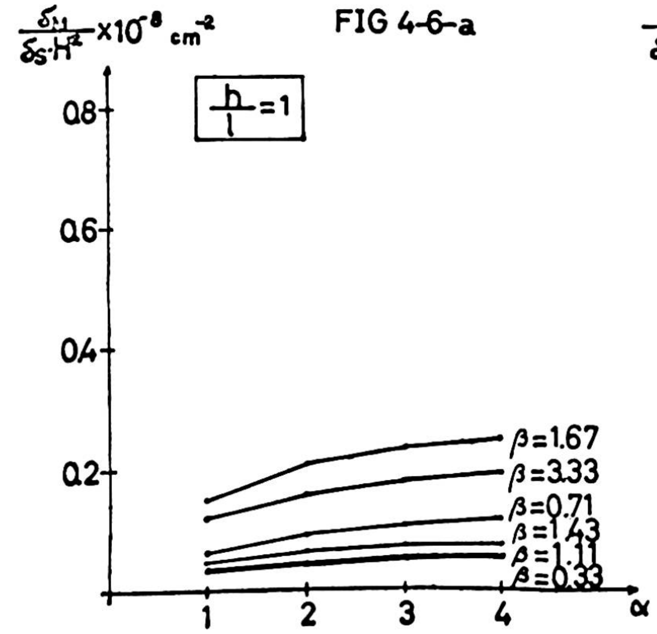


FIG 4-6-b

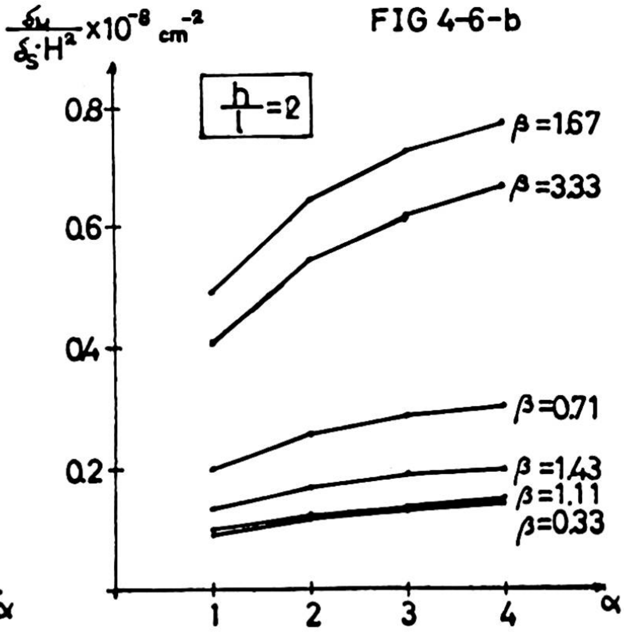


FIG 4-7 COLUMN AXIAL STRAIN RATIO OF W-FRAME

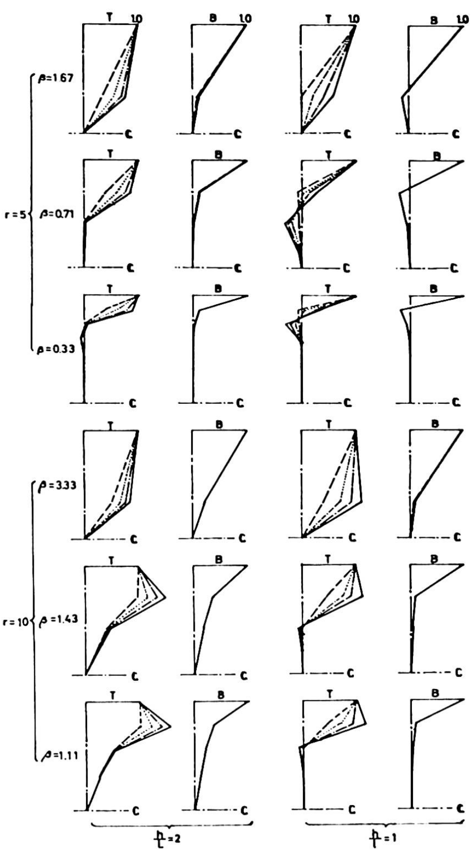
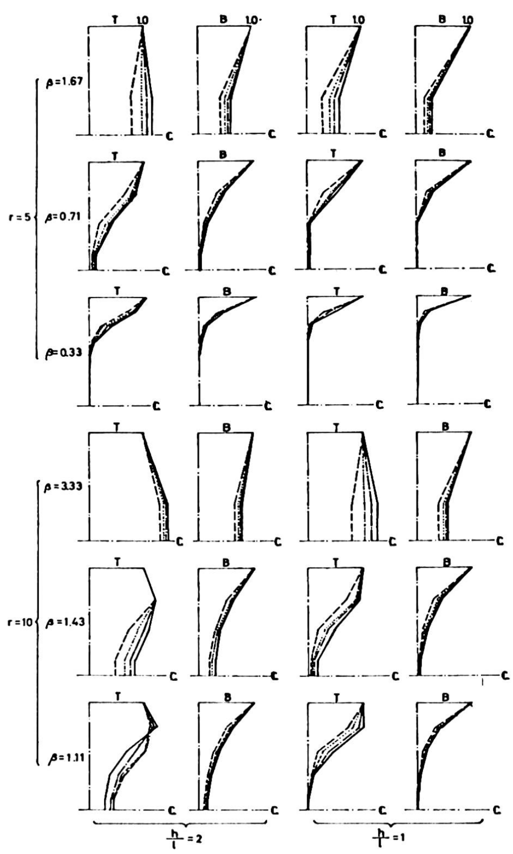


FIG 4-8 COLUMN AXIAL STRAIN RATIO OF F-FRAME



APPENDIX --- Method of Analysis ---

A-1 Introduction

The method of analysis mentioned hereafter is to analyze a box-type framing subjected to lateral force as shown in FIG A-1 that has its load carring members for lateral load at its outside only.

Assumptions are as follows.

(1) Consider the axial deformation of column and do not consider the axial deformation of beam.
(2) Do not consider the out-of-plane rigidity of the frame placed perpendicular to the lateral force(called "F-frame" hereafter).
(3) F-frame is to act upon the frame parallel to the lateral force(called "W-frame" hereafter) as a vertical spring complex connected to the W-frame at each story node.

Figures or equations are shown for the case that the F-frame and the W-frame either has a vertical line of symmetry for simplicity,however,the same method can be used with a slight change in the application of equations when no such line is exist.

A-2 Analysis of F-frame

F-frame is as shown in FIG A-2. The method to analyze the F-frame subjected to vertical force as shown in the same figure is explained in this section.

(a) Expression of end-moments

Using subscripts "k" and "i" to represent story-level and column-row respectively,dimensions around the k-story i-column node(called "node (k,i)" hereafter) are shown in FIG A-4. End-moments named as shown in FIG A-5 are expressed by the Eq.(A-1) using the simplifications of Eq.(A-2),where the sign of $G_{k,i}$ is fixed as shown in FIG A-6.

(b) Equation of moment equilibrium

Considering the equilibrium of moment around the center of (k,i) panel-zone,Eq.(A-3) is obtained.

(c) Equation of equilibrium of vertical force

Considering the equilibrium of vertical force at node (k,i), Eq.(A-4) is obtained.

(d) Deformation equation of panel-zone

From the condition of deformation of (k,i) panel-zone,next equation is derived.

$$\left\{\frac{1}{\alpha_{k,i}}\cdot\frac{E}{2\cdot(1+\nu)}\cdot TP_{k,i}\cdot HD_k\cdot SD_{k,i}\right\}\cdot G_{k,i} = M1_{k,i} + M3_{k,i} + RS2_{k,i}\cdot(M2_{k,i} + M4_{k,i-1}) + RS1_{k,i+1}\cdot(M2_{k,i+1} + M4_{k,i})$$

where, $\alpha_{k,i}$ is a constant about the deformation of panel-zone and is put to unity when the beams and the columns around it have H-section.

Using Eqs.(A-3),(A-4) and (A-5),F-frame can be sufficiently analyzed.

To replace F-frame with a vertical spring complex,following two steps are taken.

1) Calculate the flexibility matrix ${}_R\mathbb{F}$ about the vertical force and displacement at the edge of F-frame,as

$${}^T\{D_1, D_2, \ldots\ldots, D_r\} = {}_R\mathbb{F}\cdot{}^T\{F_1, F_2, \ldots\ldots, F_r\}$$

2) Then,calculate the stiffness matrix ${}_R\mathbb{S}$ that represent the vertical spring complex,by inverting ${}_R\mathbb{F}$, as

$${}_R\mathbb{S} = ({}_R\mathbb{F})^{-1}$$

A-3 Analysis of total frame

The method to analyze the total frame as the W-frame subjected to the lateral force and resisted by the vertical spring complex as shown in FIG A-3 is explained in this section.

Using the matrix ${}_{R}S$, vertical resistant force F_K is represented by Eq.(A-6).

$$F_K = \sum_{j=1}^{r} {}_{R}S_{K,j} \cdot D_j \qquad \text{----- (A-6)}$$

(a) Expression of end-moments

Eq.(A-1) is used.

(b) Equation of moment equilibrium

Eq.(A-3) is used.

(c) Equation of equilibrium of vertical force

Eq.(A-4) is used generally. For i=1, Eq.(A-7) is used in place of Eq.(A-4), considering Eq.(A-6).

$$(-3 \cdot BK_{K,i+1} \cdot h_0/S_{i+1}) \cdot T_{K,i} + (-3 \cdot BK_{K,i+1} \cdot h_0/S_{i+1}) \cdot T_{K,i+1} + \{6 \cdot BK_{K,i+1} \cdot (h_0/S_{i+1})^2 + 0.5 \cdot h_0^2 \cdot {}_{R}S_{K,K}/E/K_0\} \cdot Y_{K,i} - 6 \cdot BK_{K,i+1} \cdot (h_0/S_{i+1})^2 \cdot Y_{K,i+1} + \sum_{j \neq K} (0.5 \cdot h_0^2 \cdot {}_{R}S_{K,j}/E/K_0) \cdot Y_{j,i} = 0 \qquad \text{----- (A-7)}$$

(d) Deformation equation of panel-zone

Eq.(A-5) is used.

(e) Equation of equilibrium of lateral force

Considering the equilibrium of lateral force at story k, Eq.(A-8) is obtained.

Using Eqs.(A-3),(A-4),(A-5),(A-7) and (A-8), total frame can be fully analyzed.

****

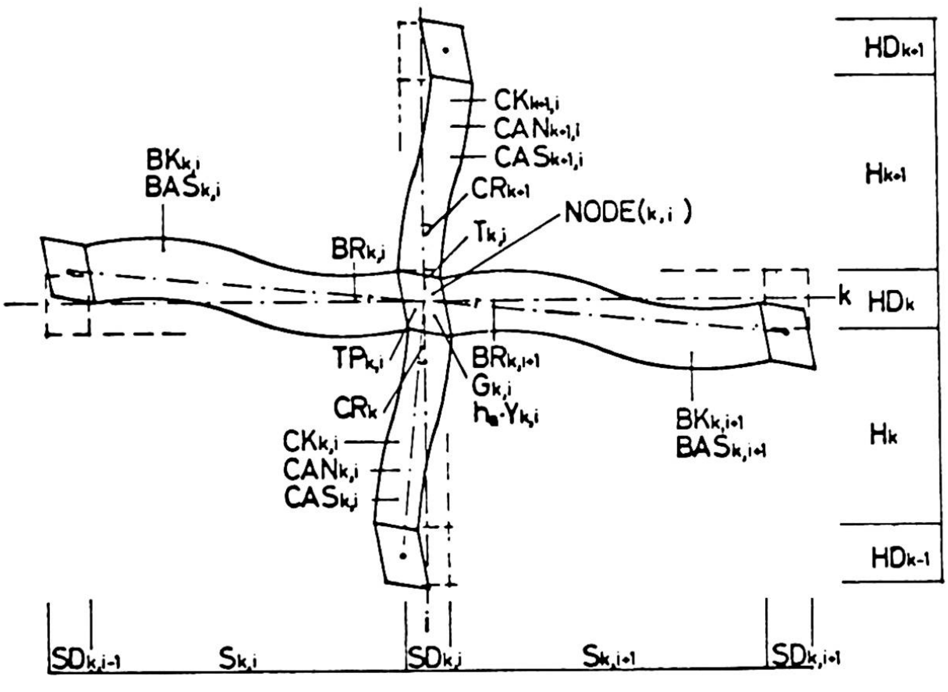


FIG A-4

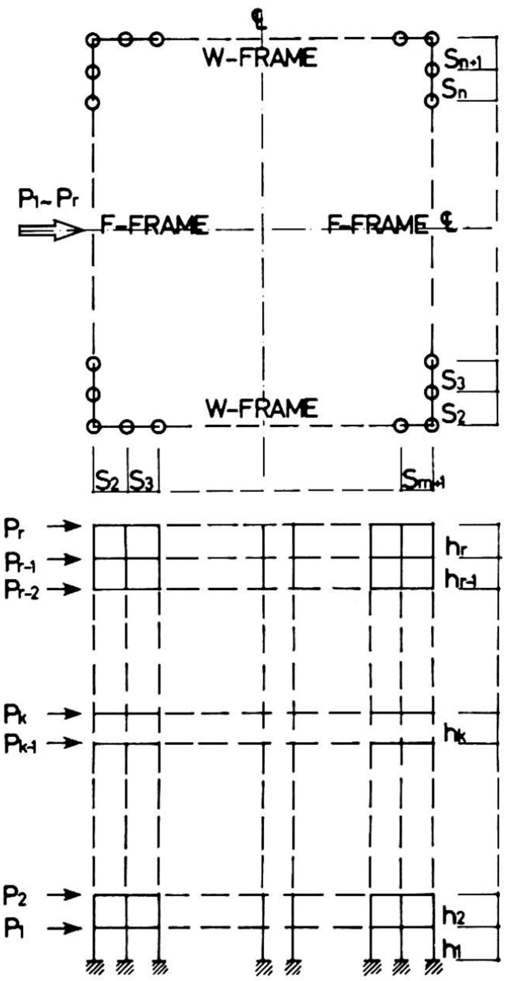


FIG.A-1

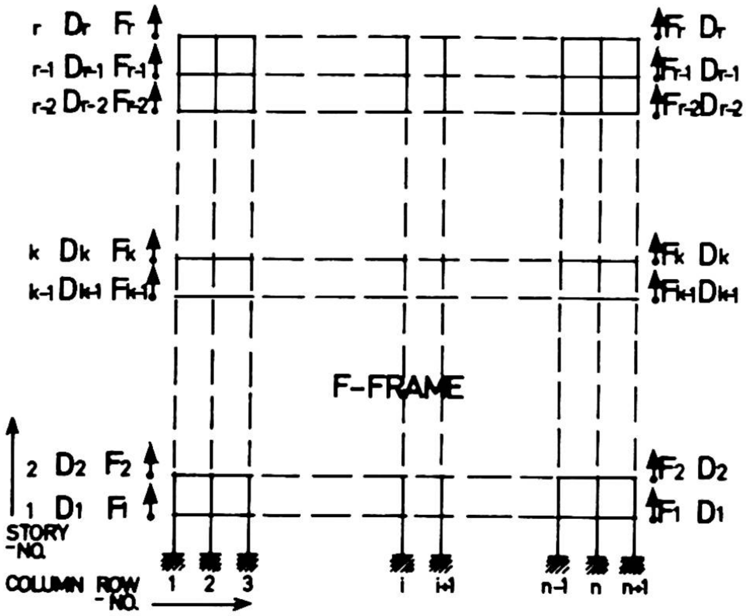


FIG.A-2

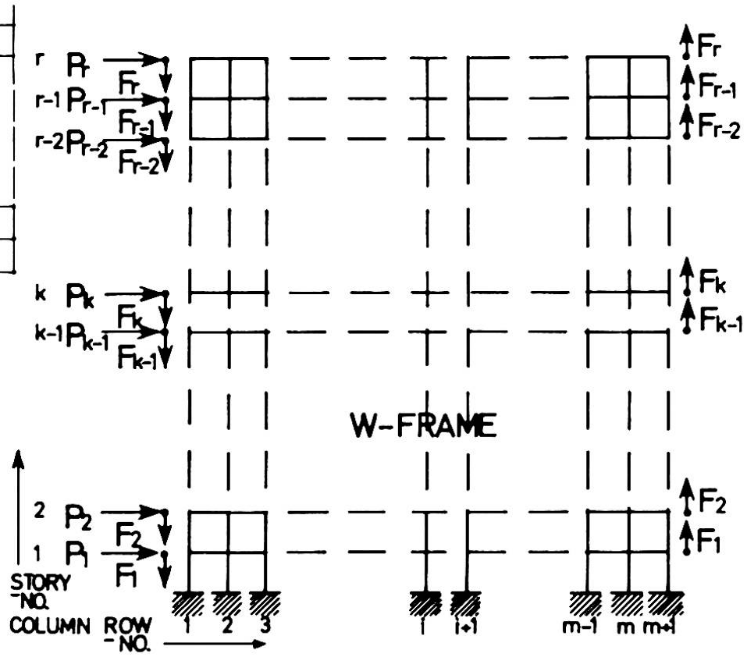


FIG.A-3

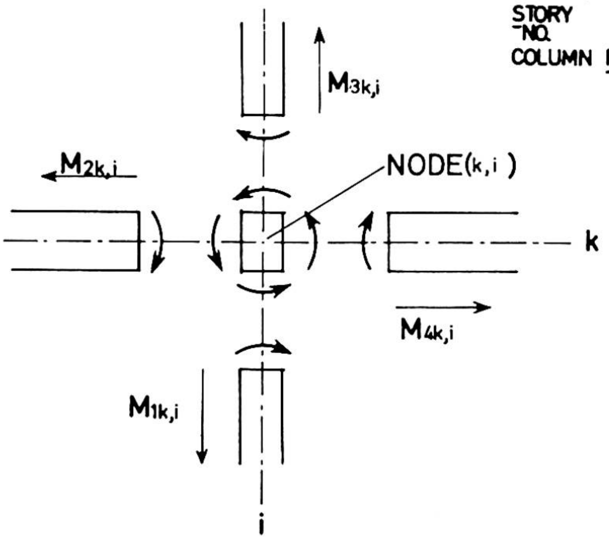


FIG.A-5

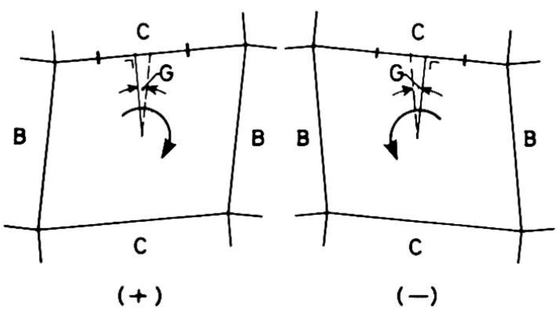


FIG.A-6

$$
\left[\frac{M1_{k,i}}{CK_{k,i}} \;\middle|\; \frac{M2_{k,i}}{BK_{k,i}} \;\middle|\; \frac{M3_{k,i}}{CK_{k+1,i}} \;\middle|\; \frac{M4_{k,i}}{BK_{k,i+1}}\right]^T
$$

$$
=2\cdot E\cdot K_0\cdot
\left[\begin{array}{ccccc|ccccc|ccc|cc}
\begin{smallmatrix}CA_{k,i}\\+CC_{k,i}\\ \times RH2_k\end{smallmatrix} & \begin{smallmatrix}CB_{k,i}\\+CC_{k,i}\\ \times RH1_k\end{smallmatrix} & 0 & 0 & 0 & \begin{smallmatrix}CC_{k,i}\\ \times RH2_k\end{smallmatrix} & \begin{smallmatrix}CC_{k,i}\\ \times RH1_k\end{smallmatrix} & 0 & 0 & 0 & 0 & 0 & 0 & \begin{smallmatrix}-CC_{k,i}\\ \times(1+RH1_k+RH2_k)\end{smallmatrix} & 0 \\
\hline
\begin{smallmatrix}BA_{k,i}\\+BC_{k,i}\\ \times RS2_{k,i}\end{smallmatrix} & 0 & \begin{smallmatrix}BB_{k,i}\\+BC_{k,i}\\ \times RS1_{k,i}\end{smallmatrix} & 0 & 0 & BA_{k,i} & 0 & BB_{k,i} & 0 & 0 & \begin{smallmatrix}BC_{k,i}\\ \times h_0/S_{k,i}\end{smallmatrix} & \begin{smallmatrix}-BC_{k,i}\\ \times h_0/S_{k,i}\end{smallmatrix} & 0 & 0 & 0 \\
\hline
\begin{smallmatrix}CA_{k+1,i}\\+CC_{k+1,i}\\ \times RH1_{k+1}\end{smallmatrix} & 0 & 0 & \begin{smallmatrix}CB_{k+1,i}\\+CC_{k+1,i}\\ \times RH2_{k+1}\end{smallmatrix} & 0 & \begin{smallmatrix}CC_{k+1,i}\\ \times RH1_{k+1}\end{smallmatrix} & 0 & 0 & \begin{smallmatrix}CC_{k+1,i}\\ \times RH2_{k+1}\end{smallmatrix} & 0 & 0 & 0 & 0 & 0 & \begin{smallmatrix}-CC_{k+1,i}\\ \times(1+RH1_{k+1}+RH2_{k+1})\end{smallmatrix} \\
\hline
\begin{smallmatrix}BA_{k,i+1}\\+BC_{k,i+1}\\ \times RS1_{k,i+1}\end{smallmatrix} & 0 & 0 & 0 & \begin{smallmatrix}BB_{k,i+1}\\+BC_{k,i+1}\\ \times RS2_{k,i+1}\end{smallmatrix} & BA_{k,i+1} & 0 & 0 & 0 & BB_{k,i+1} & \begin{smallmatrix}-BC_{k,i+1}\\ \times h_0/S_{k,i+1}\end{smallmatrix} & 0 & \begin{smallmatrix}BC_{k,i+1}\\ \times h_0/S_{k,i+1}\end{smallmatrix} & 0 & 0
\end{array}\right]
$$

$$
\times\left[T_{k,i}\;\; T_{k-1,i}\;\; T_{k,i-1}\;\; T_{k+1,i}\;\; T_{k,i+1} \;\middle|\; G_{k,i}\;\; G_{k-1,i}\;\; G_{k,i-1}\;\; G_{k+1,i}\;\; G_{k,i+1} \;\middle|\; Y_{k,i}\;\; Y_{k,i-1}\;\; Y_{k,i+1} \;\middle|\; CR_k\;\; CR_{k+1}\right]^T
$$

------- (A-1)

$$
\left.\begin{array}{lll}
RH1_k=\dfrac{HD_{k-1}}{2\cdot H_k} & CA_{k,i}=CY_{k,i}+0.5 & BA_{k,i}=BY_{k,i}+0.5 \\
RH2_k=\dfrac{HD_k}{2\cdot H_k} & CB_{k,i}=CY_{k,i}-0.5 & BB_{k,i}=BY_{k,i}-0.5 \\
RS1_{k,i}=\dfrac{SD_{k,i-1}}{2\cdot S_{k,i}} & CC_{k,i}=2\cdot CY_{k,i} & BC_{k,i}=2\cdot BY_{k,i} \\
RS2_{k,i}=\dfrac{SD_{k,i}}{2\cdot S_{k,i}} & CY_{k,i}=\dfrac{1.5}{1+\dfrac{24(1+\nu)\cdot K_0\cdot CK_{k,i}}{CAS_{k,i}\cdot H_k}} & BY_{k,i}=\dfrac{1.5}{1+\dfrac{24(1+\nu)\cdot K_0\cdot BK_{k,i}}{BAS_{k,i}\cdot S_{k,i}}}
\end{array}\right\} \cdots (A-2)
$$

EQUILIBRIUM OF MOMENT AT NODE (k, i)

V.	C.
$T_{k,i}$	$0.5\cdot CK_{k,i}\cdot\{1+(1+2\cdot RH2_k)^2\cdot CC_{k,i}\} + 0.5\cdot CK_{k+1,i}\cdot\{1+(1+2\cdot RH1_{k+1})^2\cdot CC_{k+1,i}\}$ $+0.5\cdot BK_{k,i}\cdot\{1+(1+2\cdot RS2_{k,i})^2\cdot BC_{k,i}\} + 0.5\cdot BK_{k,i+1}\cdot\{1+(1+2\cdot RS1_{k,i+1})^2\cdot BC_{k,i+1}\}$
$T_{k-1,i}$	$0.5\cdot CK_{k,i}\cdot\{(1+2\cdot RH2_k)\cdot(1+2\cdot RH1_k)\cdot CC_{k,i}-1\}$
$T_{k,i-1}$	$0.5\cdot BK_{k,i}\cdot\{(1+2\cdot RS2_{k,i})\cdot(1+2\cdot RS1_{k,i})\cdot BC_{k,i}-1\}$
$T_{k+1,i}$	$0.5\cdot CK_{k+1,i}\cdot\{(1+2\cdot RH1_{k+1})\cdot(1+2\cdot RH2_{k+1})\cdot CC_{k+1,i}-1\}$
$T_{k,i+1}$	$0.5\cdot BK_{k,i+1}\cdot\{(1+2\cdot RS1_{k,i+1})\cdot(1+2\cdot RS2_{k,i+1})\cdot BC_{k,i+1}-1\}$
$G_{k,i}$	$CK_{k,i}\cdot(1+2\cdot RH2_k)\cdot RH2_k\cdot CC_{k,i} + CK_{k+1,i}\cdot(1+2\cdot RH1_{k+1})\cdot RH1_{k+1}\cdot CC_{k+1,i}$ $+0.5\cdot BK_{k,i}\cdot\{(1+2\cdot RS2_{k,i})\cdot BC_{k,i}+1\} + 0.5\cdot BK_{k,i+1}\cdot\{(1+2\cdot RS1_{k,i+1})\cdot BC_{k,i+1}+1\}$
$G_{k-1,i}$	$CK_{k,i}\cdot(1+2\cdot RH2_k)\cdot RH1_k\cdot CC_{k,i}$
$G_{k,i-1}$	$0.5\cdot BK_{k,i}\cdot\{(1+2\cdot RS2_{k,i})\cdot BC_{k,i}-1\}$
$G_{k+1,i}$	$CK_{k+1,i}\cdot(1+2\cdot RH1_{k+1})\cdot RH2_{k+1}\cdot CC_{k+1,i}$
$G_{k,i+1}$	$0.5\cdot BK_{k,i+1}\cdot\{(1+2\cdot RS1_{k,i+1})\cdot BC_{k,i+1}-1\}$
$Y_{k,i}$	$BK_{k,i}\cdot(1+2\cdot RS2_{k,i})\cdot BC_{k,i}\cdot h_0/S_{k,i} - BK_{k,i+1}\cdot(1+2\cdot RS1_{k,i+1})\cdot BC_{k,i+1}\cdot h_0/S_{k,i+1}$
$Y_{k,i-1}$	$-BK_{k,i}\cdot(1+2\cdot RS2_{k,i})\cdot BC_{k,i}\cdot h_0/S_{k,i}$
$Y_{k,i+1}$	$BK_{k,i+1}\cdot(1+2\cdot RS1_{k,i+1})\cdot BC_{k,i+1}\cdot h_0/S_{k,i+1}$
CR_k	$-CK_{k,i}\cdot(1+2\cdot RH2_k)\cdot(1+RH1_k+RH2_k)\cdot CC_{k,i}$
CR_{k+1}	$-CK_{k+1,i}\cdot(1+2\cdot RH1_{k+1})\cdot(1+RH1_{k+1}+RH2_{k+1})\cdot CC_{k+1,i}$

$$\Sigma(V.)\times(C.)=0 \qquad (A-3)$$

EQUILIBRIUM OF VERTICAL FORCE AT NODE(k, i)

V.	C.
$T_{k,i}$	$BK_{k,i} \cdot (1+2 \cdot RS2_{k,i}) \cdot BC_{k,i} \cdot h_0/S_{k,i} - BK_{k,i+1} \cdot (1+2 \cdot RS1_{k,i+1}) \cdot BC_{k,i+1} \cdot h_0/S_{k,i+1}$
$T_{k,i-1}$	$BK_{k,i} \cdot (1+2 \cdot RS1_{k,i}) \cdot BC_{k,i} \cdot h_0/S_{k,i}$
$T_{k,i+1}$	$-BK_{k,i+1} \cdot (1+2 \cdot RS2_{k,i+1}) \cdot BC_{k,i+1} \cdot h_0/S_{k,i+1}$
$G_{k,i}$	$BK_{k,i} \cdot BC_{k,i} \cdot h_0/S_{k,i} - BK_{k,i+1} \cdot BC_{k,i+1} \cdot h_0/S_{k,i+1}$
$G_{k,i-1}$	$BK_{k,i} \cdot BC_{k,i} \cdot h_0/S_{k,i}$
$G_{k,i+1}$	$-BK_{k,i+1} \cdot BC_{k,i+1} \cdot h_0/S_{k,i+1}$
$Y_{k,i}$	$0.5 \cdot CAN_{k,i} \cdot h_0^2/K_0/HC_k + 0.5 \cdot CAN_{k+1,i} \cdot h_0^2/K_0/HC_{k+1}$ $+2 \cdot BK_{k,i} \cdot BC_{k,i} \cdot (h_0/S_{k,i})^2 + 2 \cdot BK_{k,i+1} \cdot BC_{k,i+1} \cdot (h_0/S_{k,i+1})^2$
$Y_{k-1,i}$	$-0.5 \cdot CAN_{k,i} \cdot h_0^2/K_0/HC_k$
$Y_{k,i-1}$	$-2 \cdot BK_{k,i} \cdot BC_{k,i} \cdot (h_0/S_{k,i})^2$
$Y_{k+1,i}$	$-0.5 \cdot CAN_{k+1,i} \cdot h_0^2/K_0/HC_{k+1}$
$Y_{k,i+1}$	$-2 \cdot BK_{k,i+1} \cdot BC_{k,i+1} \cdot (h_0/S_{k,i+1})^2$

* $HC_k = 0.5 \cdot (HD_k + HD_{k-1}) + H_k$ *

$$\Sigma (V.) \times (C.) = \frac{h_0}{2 \cdot E \cdot K_0} F_{k,i} \quad \text{---------} (A-4)$$

DEFORMATION EQUATION OF PANEL ZONE

V.	C.
$T_{k,i}$	$0.5 \cdot CK_{k,i} \cdot \{(1+2 \cdot RH2_k) \cdot CC_{k,i} + 1\} + 0.5 \cdot CK_{k+1,i} \cdot \{(1+2 \cdot RH1_{k+1}) \cdot CC_{k+1,i} + 1\}$ $+BK_{k,i} \cdot (1+2 \cdot RS2_{k,i}) \cdot RS2_{k,i} \cdot BC_{k,i} + BK_{k,i+1} \cdot (1+2 \cdot RS1_{k,i+1}) \cdot RS1_{k,i+1} \cdot BC_{k,i+1}$
$T_{k-1,i}$	$0.5 \cdot CK_{k,i} \cdot \{(1+2 \cdot RH1_k) \cdot CC_{k,i} - 1\}$
$T_{k,i-1}$	$BK_{k,i} \cdot (1+2 \cdot RS1_{k,i}) \cdot RS2_{k,i} \cdot BC_{k,i}$
$T_{k+1,i}$	$0.5 \cdot CK_{k+1,i} \cdot \{(1+2 \cdot RH2_{k+1}) \cdot CC_{k+1,i} - 1\}$
$T_{k,i+1}$	$BK_{k,i+1} \cdot (1+2 \cdot RS2_{k,i+1}) \cdot RS1_{k,i+1} \cdot BC_{k,i+1}$
$G_{k,i}$	$CK_{k,i} \cdot RH2_k \cdot CC_{k,i} + CK_{k+1,i} \cdot RH1_{k+1} \cdot CC_{k+1,i}$ $+BK_{k,i} \cdot RS2_{k,i} \cdot BC_{k,i} + BK_{k,i+1} \cdot RS1_{k,i+1} \cdot BC_{k,i+1} - 0.25 \cdot TP_{k,i} \cdot HD_k \cdot SD_{k,i}/(1+\nu)/K_0/\alpha_{k,i}$
$G_{k-1,i}$	$CK_{k,i} \cdot RH1_k \cdot CC_{k,i}$
$G_{k,i-1}$	$BK_{k,i} \cdot RS2_{k,i} \cdot BC_{k,i}$
$G_{k+1,i}$	$CK_{k+1,i} \cdot RH2_{k+1} \cdot CC_{k+1,i}$
$G_{k,i+1}$	$BK_{k,i+1} \cdot RS1_{k,i+1} \cdot BC_{k,i+1}$
$Y_{k,i}$	$2 \cdot BK_{k,i} \cdot RS2_{k,i} \cdot BC_{k,i} \cdot h_0/S_{k,i} - 2 \cdot BK_{k,i+1} \cdot RS1_{k,i+1} \cdot BC_{k,i+1} \cdot h_0/S_{k,i+1}$
$Y_{k,i-1}$	$-2 \cdot BK_{k,i} \cdot RS2_{k,i} \cdot BC_{k,i} \cdot h_0/S_{k,i}$
$Y_{k,i+1}$	$2 \cdot BK_{k,i+1} \cdot RS1_{k,i+1} \cdot BC_{k,i+1} \cdot h_0/S_{k,i+1}$
CR_k	$-CK_{k,i} \cdot (1+RH1_k+RH2_k) \cdot CC_{k,i}$
CR_{k+1}	$-CK_{k+1,i} \cdot (1+RH1_{k+1}+RH2_{k+1}) \cdot CC_{k+1,i}$

$$\Sigma (V.) \times (C.) = 0 \quad \text{---------} (A-5)$$

*** TABLE OF SYMBOLS ***

P_K	-----	lateral force
F_K	-----	vertical force at the edge of F,W-frame
D_K	-----	vertical displacement at the edge of F,W-frame
$M1_{K,i}$	-----	end-moment of column
$M2_{K,i}$	-----	end-moment of beam
$M3_{K,i}$	-----	end-moment of column
$M4_{K,i}$	-----	end-moment of beam
H_K	-----	length of column
HD_K	-----	depth of beam
HC_K	-----	height of story
$S_{K,i}$	-----	length of beam
$SD_{K,i}$	-----	depth of column
$CK_{K,i}$	-----	rigidity ratio of column
$BK_{K,i}$	-----	rigidity ratio of beam
$CAS_{K,i}$	-----	area efficient for shear deformation of column
$BAS_{K,i}$	-----	area efficient for shear deformation of beam
$CAN_{K,i}$	-----	sectional area of column
$TP_{K,i}$	-----	thickness of panel-zone
$T_{K,i}$	-----	rotation of panel-zone at column side
$G_{K,i}$	-----	shear strain of panel-zone
$Y_{K,i}$	-----	ratio of vertical displacement of node to h_0
CR_K	-----	chord rotation of story
$BR_{K,i}$	-----	chord rotation of beam
h_0	-----	standard height of story
K_0	-----	standard rigidity
E	-----	modulus of elasticity
ν	-----	Poisson's ratio
$\alpha_{K,i}$	-----	shear deformation constant of panel-zone

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EQUILIBRIUM OF LATERAL FORCE AT STORY k

V.	C
$T_{k,i}$	$CK_{k,i} \cdot (1+2 \cdot RH2_k) \cdot CC_{k,i}$
$T_{k-1,i}$	$CK_{k,i} \cdot (1+2 \cdot RH2_k) \cdot CC_{k,i}$
$G_{k,i}$	$2 \cdot CK_{k,i} \cdot RH2_k \cdot CC_{k,i}$
$G_{k-1,i}$	$2 \cdot CK_{k,i} \cdot RH1_k \cdot CC_{k,i}$
R_k	$-2 \cdot (1+RH1_k+RH2_k) \cdot \sum_i CK_{k,i} \cdot CC_{k,i}$

$$\sum (V.) \times (C.) = -\frac{H_k}{2EK_0} \sum_k^{\prime} P_k \text{ -----(A-8)}$$

SUMMARY

The possibility to represent by some parameters the elastic behavior of box-type framing subjected to lateral force is investigated. As parameters of this purpose, α, β, γ, h/l and r seem to be sufficient from the result of § 4.

The number and variety of sample frames taken in the numerical analysis are not sufficient to represent the elastic behavior by some approximate equations using these parameters, however, the orientation to do so is now clear and some criteria for preliminary design can be found in the figures of §4.

RÉSUMÉ

On a étudié la possibilité de représenter par quelques paramètres le comportement élastique de portiques en caisson soumis à des forces latérales. Comme le montre § 4, les paramètres α, β, γ, h/l et r sont suffisants pour ce propos.

Le nombre et la diversité restraints des exemples de portiques considérés dans l'analyse numérique ne permettent pas de représenter le comportement élastique par quelques équations approximatives entre ces paramètres, cependant on voit clairement le chemin à suivre pour ce faire, en outre les figures de § 4 faciliteront un dimensionnement préliminaire.

ZUSAMMENFASSUNG

Es wird die Möglichkeit untersucht, das elastische Verhalten kastenförmiger Rahmentragwerke mit einigen Beiwerten zu beschreiben, falls dieses seitlichen Kräften unterworfen ist. Es scheint, dass für dieses Unterfangen die Parameter α, β, γ, h/l und r den Ergebnissen von § 4 genügen. Die Zahl und die Veränderlichkeit der durch die numerische Rechnung geprüften Rahmen sind für die Darstellung des elastischen Verhaltens durch angenäherte, obige Beiwerte verwendende Gleichungen ungenügend; trotzdem ist die zu verfolgende Richtung bekannt und für die Vorbemessung können einige Charakteristiken aus den Figuren des § 4 entnommen werden.

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