525,2 Computer Progs Papers 531

ΒΙΒΛΙΟΘΗΚΗ
ΠΑΝΑΓΙΩΤΗ ΓΡ. ΚΑΡΥΔΗ
α. α.

BULGARIAN ACADEMY OF SCIENCES
EARTHQUAKE ENGINEERING
PROCEEDINGS OF THE THIRD EUROPEAN SYMPOSIUM ON EARTHQUAKE ENGINEERING
Sofia, September 14—17, 1970

# TABLES FOR THE DIRECT DYNAMIC ASEISMIC DESIGN OF MULTI-STOREY STRUCTURES

*F. E. Kokinopoulos, A. S. Ikonomou, P. G. Carydis et al.*[1]

## §1. INTRODUCTION

With the assumptions of: (I) masses $m_i$ lumped at storey-levels $i$; (II) elastic behavior; (III) validity of the "shear building" hypothesis; (IV) disregard of damping, the horizontal vibration of mass $m_i$ ($i=1\div n$) of an $n$-storey structure under the action of a given ground acceleration $\ddot{x}_{0t}$, is governed by the 2nd-order differential equation:

$$\ddot{v}_{it}+\ddot{x}_{0t}=+\frac{K_i}{m_i}v_{i-1,t}-\frac{K_i+K_{i+1}}{m_i}v_{it}+\frac{K_{i+1}}{m_i}v_{i+1,t}, \tag{1}$$

where $v_{it}$ denotes the horizontal genuine deflection at level $i$ with respect to the structure's base 0 at time instant $t$, and

$$K_i=12EJ_i/h_i^3 \tag{2}$$

is the stiffness coefficient of storey $i$, equal to the shear force required to produce unit displacement of top to foot of storey $i$, under the "shear building" assumption. In eq. (2) $E$, $h_i$, $J_i$ denote respectively: the elasticity modulus, the storey's height, and the sum of the sectional inertia moments of all vertical elements of storey $i$, with respect to their centrobaric axes perpendicular to the direction of motion.

In the simple case of a harmonic ground motion $x_{0t}=\alpha\sin\beta t$, $\ddot{x}_{0t}=-\alpha\beta^2\sin\beta t$, eq. (1) becomes:

$$\ddot{v}_{it}-\alpha\beta^2\sin\beta t=+\frac{K_i}{m_i}v_{i-1,t}-\frac{K_i+K_{i+1}}{m_i}v_{it}+\frac{K_{i+1}}{m_i}v_{i+1,t} \tag{3}$$

and the system of $n$ simultaneous defferential equations (3), $i=1\div n$ may be readily solved under the initial conditions $v_{i0}=\dot{v}_{i0}=0$ (at $t=0$), by means of a suitable computer, namely an analogue computer, yielding, on the instru-

[1] Scientific communication by the Institute of Structural Analysis. Aseismic Research of the National Technical University of Athens.

ment's automatic plotter, the $v_{it}$ displacement — graphs, or preferably the graphs of relative displacements $\delta_{it}=(v_{it}-v_{i-1,t})$ of top to foot of storey $i$, as a function of time $t$. The maximal value $\max \delta_{it}$ measured on these graphs, corresponds to the maximal solicitation of the vertical members of storey $i$ under the action of the given ground motion; these vertical members may be therefore designed to withstand such maximal solicitation.

In view of establishing Tables for the direct aseismic design of "usual" multi-storey structures of the shear building type, the relevant investigation consists in formulating the correlation prevailing between the given structure $S'$ (masses $m'$, stiffness coefficients $K'$) submitted to the given ground motion $x'_{0t}=\alpha' \sin \beta' t$, and a "model" structure $S$ (masses $m$, stiffness coefficients $K$), geometrically "similar" to $S'$, but already solved and tabulated for a large variety of harmonic ground motions $x_{0t}=\alpha \sin \beta t$; from the model curves $\max \delta_{it}$ as functions of frequency $\beta$ the values $\max \delta'_{it}$ of the actual structure $S'$, submitted to the ground motion $x'_{0t}$, may then be evaluated.

## § 2. THE PRINCIPLE OF THE METHOD

Two structures $S'$ (actual) and $S$ (model) of the same degree of freedom (same number of storeys $n$), both belonging to the "shear building" type and identified respectively by the stiffness coefficients $K'_i$, $K_i$ and the masses $m'_i$, $m_i$ $(i=1 \div n)$, are qualified as "similar", when the following relations are valid:

$$(4\alpha, \beta) \qquad k'_i=\vartheta_1 K_i, \quad m'_i=\vartheta_2 m_i;$$

$\vartheta_1$, $\vartheta_2$ representing constants. The two structures are excited to forced vibrations by means of harmonic ground motions of amplitudes and circular frequencies respectively equal to $\alpha'$, $\beta'$ and $\alpha$, $\beta$, where

$$(5\alpha, \beta) \qquad \alpha'=\vartheta_3 \alpha, \quad \beta'=\vartheta_4 \beta;$$

$\vartheta_3$ and $\vartheta_4$ representing again constants. Now, it has been proved by Dr. A. S. Iconomou in his doctoral thesis (Ntl Techn. University, Athens, April 1965) that under aforementioned assumptions the genuine dynamic deflections $v'_{it}$ of structure $S'$ at time instant $t$, are identical to the genuine dynamic deflections $v_{it}$ of structure $S$ at time instant $\tau=t\sqrt{\vartheta_1/\vartheta_2}$, when this model structure $S$ is submitted to the harmonic ground motion of characteristics:

$$(6\alpha, \beta) \qquad \alpha'=\vartheta_3 \alpha, \quad \beta''=\vartheta_4 \beta \sqrt{\vartheta_2/\vartheta_1}=\beta' \sqrt{\vartheta_2/\vartheta_1}.$$

The aseismic investigation being restricted to the determination of the maximal values $\max \delta'_{it}=\max(v'_{it}-v'_{i-1,t})$, the time difference between $t$ and $\tau$ is obviously irrelevant and does not interfere any further in the design procedure. Therefore, if a model $n$-storey structure $S$ is chosen with its model values $K_1$, $m_i$ following a certain law of distribution as function of $i$ and also a model harmonic vibration $x_{0t}=\alpha \sin \beta t$ is chosen with a fixed amplitude $\alpha$ and a wide variation of frequency $\beta$, then for each value of $\beta$ the model system of $n$ differential equations (3) may be established and its

solution accomplished in an analogue computer, yielding on the automatic plotter the $n$ curves $\delta_{it}$, and hence the $n$ values $\max\delta_{it}$. These standard or model values $\max\delta_{it}$ may be drawn as ordinates at the corresponding value of abscissa $\beta$ and thus, by establishing a graph in the form of

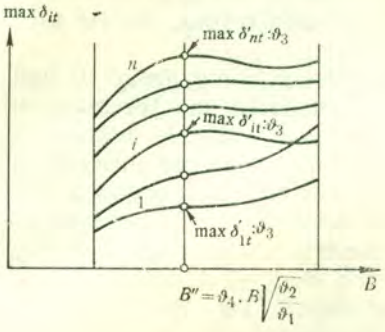



Fig. 1

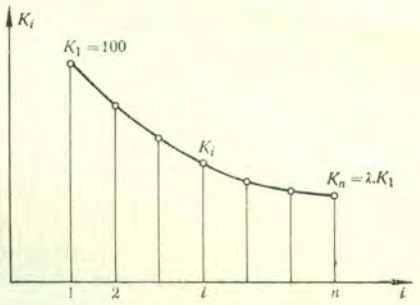



Fig.

Fig. 1, $n$ curves are obtained yielding, at each abscissa value $\beta$, the ordinates $\max\delta_{it} \div \max\delta_{nt}$ of the model structure in question. The actual structure $S'$, "similar" by assumption to $S$, with its actual values $K'_i$, $m'_i$ related to the model values by eqs. (4) and submitted to the harmonic ground motion $x'_{0t} = \alpha' \sin \beta' t$ related to the model ground motion $x_{0t} = \alpha \sin \beta t$ by eqs. (5) may then be analysed by evaluating the constants $\vartheta_1$ to $\vartheta_4$ and determining the "reduced" frequency $\beta''$ from eq. ($6\beta$), which latter is taken as abscissa in the graph of Fig. 1. The ordinates of the model curves at abscissa $\beta''$ yield the $\frac{1}{\vartheta_3} \max\delta'_{it}$-values, namely the required $\max\delta'_{it}$-values of the actual structure $s'$, divided by constant $\vartheta_3$.

## § 3. DESCRIPTION OF THE TABLES

The Tables cover the cases $n=1$ to $n=7$ but may be easily expanded to $n>7$, provided an adequately powerful computer is used. The authors used their Institute's analogue electronic computer type PACE, TR-48-3 of Electronic Associates Inc., New Jersey, U. S., with a capacity not exceeding substantially the solution of a system of 7, 2nd order differential equations. In view that, for usual multi-storey structures (appartment buildings), the standard floor plan prevails above the ground storey, all model masses lumped at levels $i=1$ to $n-1$ have been taken equal, namely $m_1 \div m_{n-1} = 1$ (t.sec$^2$. m$^{-1}$), while for the top mass $m_n$ a reasonably inferior standard value $m_n = 0.75$ (t. sec$^2$ . $m^{-1}$) has been accepted. For the model coefficients $K_i$ a gradual decrease from ground to top storey has been assumed, starting with $K_1 = 100$ (t/m) and ending at the top with $K_n = \lambda K$ (t/m), where parameter $\lambda$ varies between 0.10 and unity, at equidistance of 0.10. Intermediately, between $K_1$ and $K_n$, the variation of $K_i$ is assumed to follow the line of a parabola, as shown in Fig. 2, in accordance to the relation $K_i = K_n + (K_1 - K_n)(n-1)^2/(n-1)^2$, or with $K_1 = 100$, and $K_n = \lambda K_1$:

(7) $$K_i = 100\,\lambda + 100(1-\lambda)\left(\frac{n-i}{n-1}\right)^2 .$$

The model ground motion has been assumed harmonic with the standard amplitude $\alpha = 1.62 \cdot 10^{-3}$ (m), while the circular frequency extends to the range of integer values $\beta = 1 \div 31$ (sec$^{-1}$). All quantities involved in the tabulation procedure are expressed in meters (m) or its subdivisions, metric tons weight (t), and seconds.

For each specific number of storeyes $n$ the corresponding group of 2nd order model differential systems (3) has been formulated and the solution performed on the analogue computer, which proved a very valuable instrument especially in the present case, where the transition from one differential system to another of the same group was readily feasible by turning a few potentiometer knobs. In view that the excitation term of eq. (3) acquires 31 different values ($\beta = 1 \div 31$) and moreover parameter $\lambda$ extends over a variety of 10 values ($\lambda = 0.10 \div 1$), it follows that for each $n = 2 \div 7$ a total of $31 \times 10 = 310$ model differential systems had to be solved, the grand total of the required analogue solutions (includinque 31 solutions for $n = 1$) amounting thus to $6 \times 310 + 31 = 1891$. From these solutions the values $\max \delta_{it}$ were found and the $n$ curves $\max \delta_{it}$ drawn, corresponding to each specific number of storeyes $n$ and extending over a frequency range of $\beta = 1 \div 31$ (sec$^{-1}$).

Actually a number of analogue solutions, well exceeding the 2000, has proved necessary because of the occasional interposition of decimal values of $\beta$ between the integers $1 \div 31$, so that the curves $\max \delta_{it}$ could be accurately drawn, especially in the resonance regions, where the excitation frequency $\beta$ approaches the natural freguency $\omega_i$ of the model structure. Moreover, to improve the accuracy, the $n$ eigenvalues $\omega_i$ of each model structure have been precisely calculated on a digital computer and used for drawing the resonance peaks of the $\max \delta_{it}$-curves. It is apparent that values of $\beta'' = \beta' \sqrt{\vartheta_2 / \vartheta_1}$, see eq. (6$\beta$), corresponding to the resonance areas and therefore leading to inadmissibly large values of $\max \delta_{it}$, must be regarded as prohibited, which brought to the necessity of exhibiting these areas clearly and exactly on the Tables, so that they might be avoided by suitably altering the dimensions of the vertical elements of the actual structure and consequently adjusting the similarity coefficient $\vartheta_1$ and/or the parameter $\lambda$. To determine the width and the top level of these prohibited resonance areas, a fully cast-in concrete column (quality B160 of German Standards) 3.5 m high, reinforced with the maximal steel reinforcement (St I of German Standards) and of the least admissible cross-section $20 \times 20$ cm, has been considered and the maximal relative deflection $\max \delta_i$ of top to foot of the column precisely evaluated, so that the maximal admissible stresses are just attained. This maximal relative deflection was found practically equal to $\max \delta_i = 2.5$ cm and therefore the top level of all resonance peaks of the Tables was fixed at 2.5 cm, while the width of these peaks varies from case to case.

Each Table refers to the $\max \delta_{it}$ of a specific storey $i$ of the $n$-degree model structure with the frequency $\beta$ and the parameter $\lambda$ varying respectively in the prescribed ranges $\beta = 1 \div 31$ (sec$^{-1}$) and $\lambda = 0.10 \div 1.0$. For a given degree $n$ of the model structure the equal number $n$ of Tables has been established, the total number of Tables amounting thus to $1 + 2 + 3 + \cdots + 7 = 28$, which number was finally increased to $28 + 13 = 41$, in view that for $n = 6$

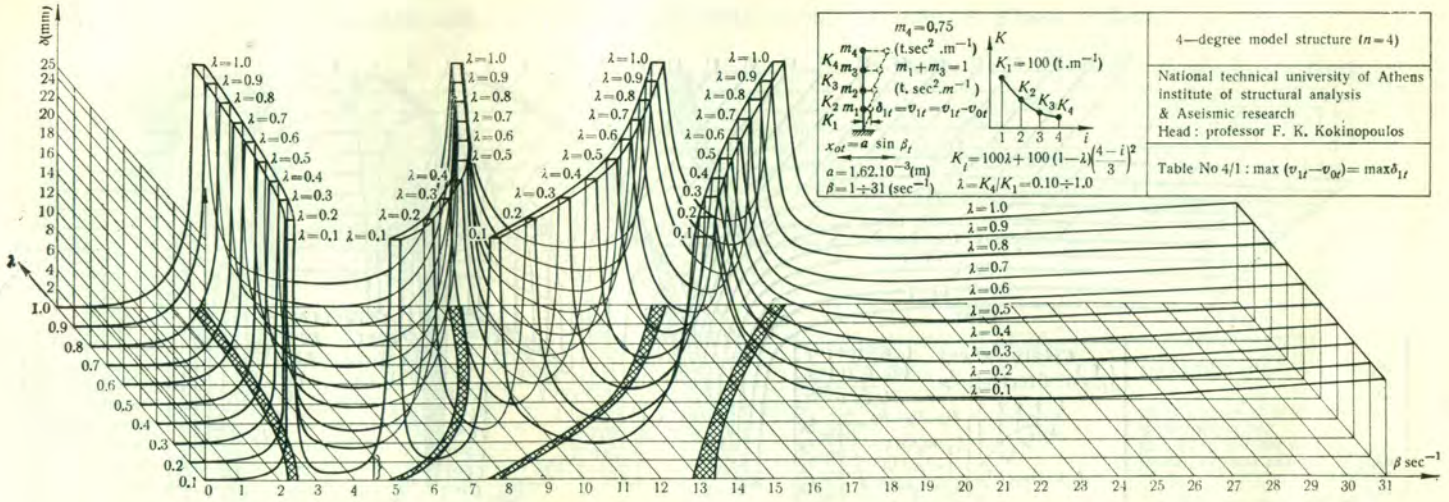
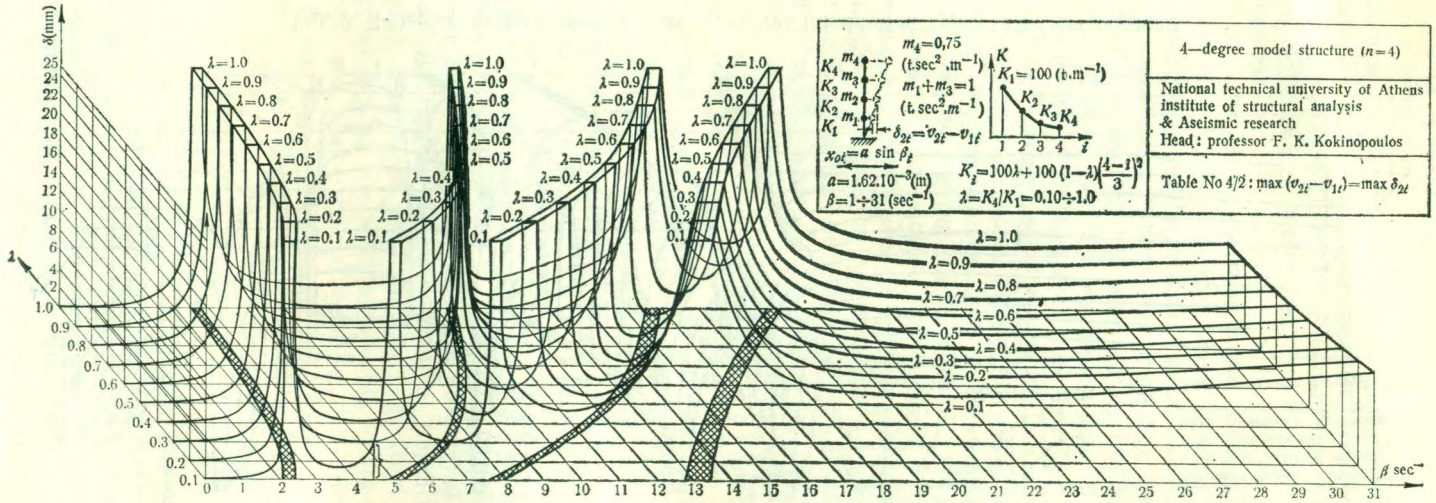
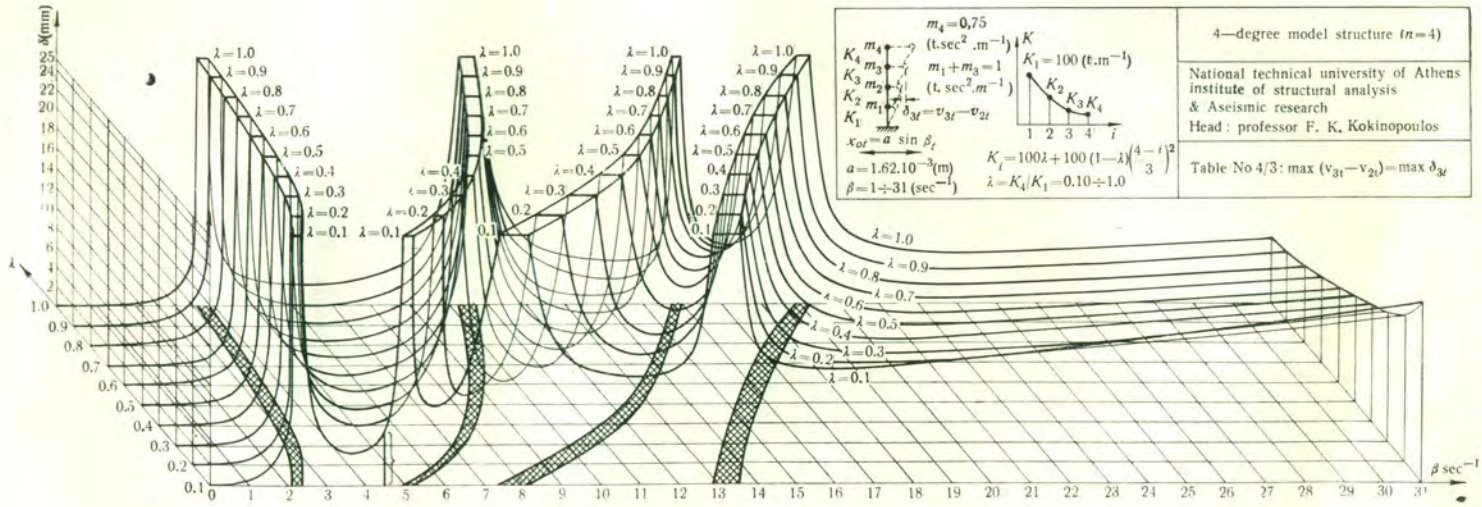



Fig. 3. 4-Degree model structure, max $\delta_{1t}$-curves (diminution appr. 1 : 3 from original)




. . 4-degree model structure, max $\delta_{2t}$-curves (diminution appr. 1 : 3 from o rigina




Frg. 5. 4-degree model structure, max $\delta_{3t}$-curves (diminution appr. 1 : 3 from original)

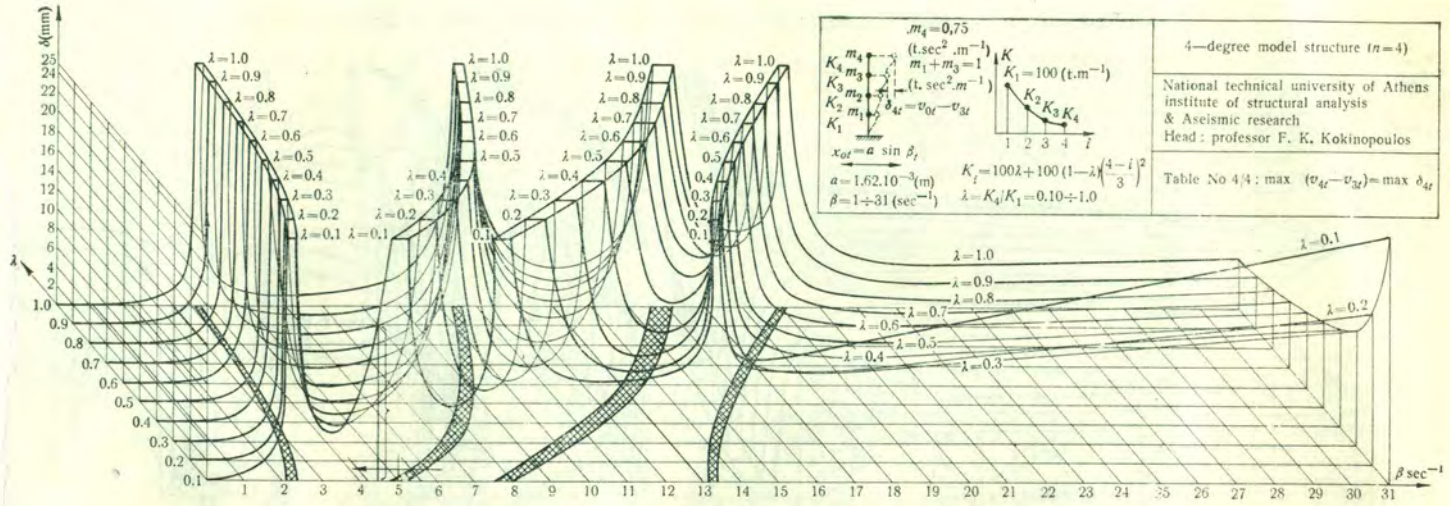
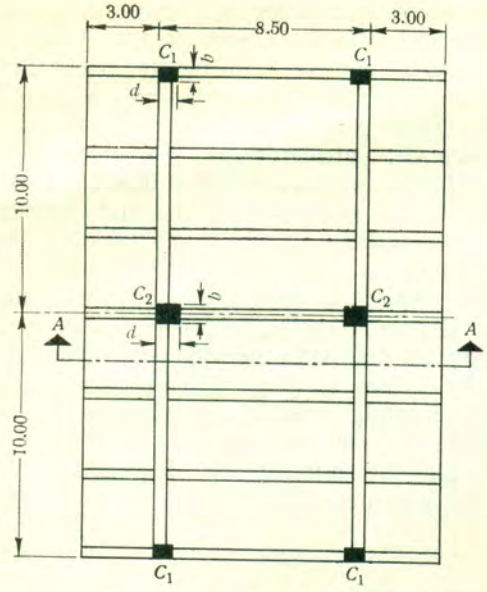


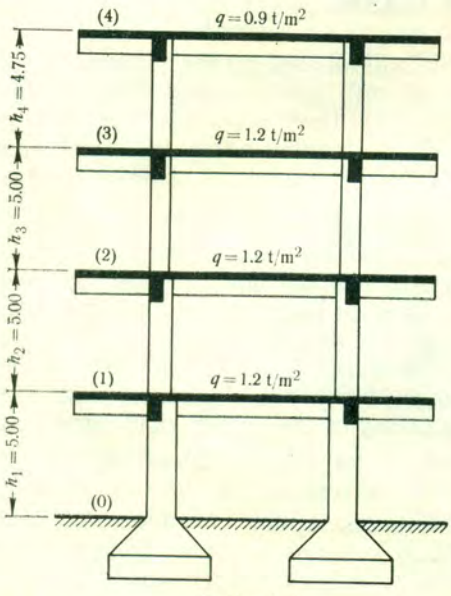

Fig. 6. 4-dgeree model structure, max $\delta_{4t}$-curves (diminution appr. 1 : 3 from original)

and 7 each Table was split in 2 for the sake of convenience. Figures 3 to 6 in the Appendix, under enumeration No. 4/1 to No 4/4, refer to the 4-degree model structure and contain the curves max $\delta_{1t}$ to max $\delta_{4t}$. The frequency axis $\beta$ is taken horizontal, while the axis of parameter $\lambda$ is directed under a certain angle, in the case of $n=4$ under about 135°, to axis $\beta$, so that for each value of $\lambda$ the corresponding max $\delta_{it}$-curves are transposed above and to the left, with respect to the curves of the lower $\lambda$-value. The figures attain thus the shape of solids in space, with their successive peaks and depressions, the section of these solids by the vertical planes $\beta - \delta$ yielding the specific max $\delta_{it}$-curves of the case under consideration. The peaks, all lying at top level max $\delta_i = 2.5$ cm, correspond to the resonance zones and are equal in number to the structure's degree, namely, in present case, equal to 4. The width of the resonance zones is distinctly defined and its projection on plane $\beta - \lambda$ is marked on the Tables by shading. Such collective presentation of the Tables in the form of solids greatly contributed to the localization and correction of inaccuracies of the max $\delta_{it}$-curves; moreover it provided the possibility of reducing the number of the Tables and of choosing intermediate values of parameter $\lambda$, between the decimal $\lambda = 0.10 \div 1.0$.

## § 4. ILLUSTRATIVE EXAMPLE

Tables No 4/1 to No 4/4 in the Appendix will be used for the dynamic aseismic design of a 4-storey warehouse building, with its structural frame of reinforced concrete (elasticity modulus $E = 2.10 \times 10^6$ t/m$^2$) shown in Fig. 7, supported by 4 columns $C_1$ and 2 columns $C_2$ and submitted in the transverse direction to a harmonic ground motion $x'_{0t} = \alpha' \sin \beta' t$, where $\alpha' = 1.862 \times 10^{-3}$ m, $\beta' = 17.95$ sec$^{-1}$. These seismic data (maximal acceleration $\ddot{x}'_{0t} = \alpha' \beta'^2 \cong$ $\cong 0.6$ m. sec$^{-2}$, vibration period $T_0 = 2\pi/\beta' \cong 0.35$ sec) approximately correspond to the general characteristics of an Athenian earthquake under adverse soil conditions. The total load (dead plus live) for floor levels $1 \div 3$ amounts to $q = 1.2$ t/m$^2$ including wall partitions, and for the top floor to $q = 0.9$ t/m$^2$. From these loads, suitably increased to include the frame's dead weight, the loads carried by columns $C_1$ and $C_2$ in each storey are evaluated and the dimensions of the columns defined, as tabulated in the upper right-hand part of Fig. 7, together with the lumped masses $m'_i$ and the stiffness cofficients $K'_i = 12 E J_i / h_i^3$ (see eq. (2)), which coefficients correspond to the — in present case — unreservedly acceptable shear building assumption. $J_i$ equals the sum of the sectional inertia moments of all 6 columns in storey $i$. The ratio $K'_4 : K'_1 = 5.14 : 49.59 \cong 0.105$ almost coincides to the parameter value $\lambda = 0.10$ and it is readily verified that with this parameter value the $K'_i$ values very satisfactorily approach the parabolic law of eq. (7). Moreover, masses $m'_1$ to $m'_3$ are all equal to 35.83 while $m'_4 = 26.70$ (t.sec$^2$.m$^{-1}$), thus yielding the ratio $m'_4 : m'_1 = 0.745$, very close to the required 0.75 of the Tables. The constants $\vartheta_1$, $\vartheta_2$ of eq. (4) become: $\vartheta_1 = K'_1 / K_1 = 49.59 \times 10^3 / 100 = 495.9$ and $\vartheta_2 = 35.83/1 =$ $= 35.83$, while constant $\vartheta_3$ attains the value $\vartheta_3 = \alpha'/\alpha = 1.862/1.62 = 1.15$. By




Section *A-A*

$X'_{ot} = a' \sin \beta'_t$

($a' = 1.862.10^{-3}$ m, $\beta' = 17{,}95$ sec$^{-1}$)

Initial data of columns

| Storey No | Column | $b$ (cm) | $d$ (cm) | $h_i$ (m) | $m'_i$ (t sec$^2$ $\times$m$^{-1}$) | $K'_i$ (t/m) |
|---|---|---|---|---|---|---|
| (1) | (2) | (3) | (4) | (5) | (6) | (7) |
| 1 | $C_1$ | 60 | 60 | 5.00 | 35.83 | $49.59.10^3$ |
| | $C_2$ | 80 | 115 | | | |
| 2 | $C_1$ | 50 | 55 | 5.00 | 35.83 | $25.76.10^3$ |
| | $C_2$ | 70 | 95 | | | |
| 3 | $C_1$ | 40 | 45 | 5.00 | 35.83 | $10.24.10^3$ |
| | $C_2$ | 55 | 75 | | | |
| 4 | $C_1$ | 30 | 35 | 4.75 | 26.70 | $5.14.10^3$ |
| | $C_2$ | 25 | 75 | | | |

$E = 2.1.10^6$ (t/m$^2$)

Final data of columns

| Storey No | Column | $b$ (cm) | $d$ (cm) | $h_i$ (m) | $m'_i$ (t sec$^2$ $\times$m$^{-1}$) | $K'_i$ (t/m) |
|---|---|---|---|---|---|---|
| (1) | (2) | (3) | (4) | (5) | (6) | (7) |
| 1 | $C_1$ | 50 | 75 | 5.0 | 35.83 | $57.69.10^3$ |
| | $C_2$ | 75 | 120 | | | |
| 2 | $C_1$ | 45 | 60 | 5.0 | 35.83 | $28.37.10^3$ |
| | $C_2$ | 65 | 100 | | | |
| 3 | $C_1$ | 40 | 45 | 5.0 | 35.83 | $10.24.10^3$ |
| | $C_2$ | 55 | 75 | | | |
| 4 | $C_1$ | 30 | 35 | 4.75 | 26.70 | $5.14.10^3$ |
| | $C_2$ | 25 | 75 | | | |

Fig. 7

applying eq. (6$\beta$) the frequency $\beta''$, "reduced" to the model structures of the Tables, is evaluated, namely:

$$\beta''=\beta'\sqrt{\vartheta_2/\vartheta_1}=17.95\sqrt{35.83/495.9}\cong 4.81 \text{ sec}^{-1} \tag{8}$$

and entered as abscissa into Tables No 4/1 to 4/4 under parameter $\lambda=0.10$. It is seen, at first glance, that value $\beta''=4.81$ sec$^{-1}$ falls almost at the border of the resonance zone and leads to undesirably large dynamic deflections. Moreover a value of $\beta''$ in the magnitude of 4.50 sec$^{-1}$ under invariable parameter $\lambda=0.10$ would be much preferable, which means that $\vartheta_1$ should then resume a new increased value, namely:

$$\vartheta_1=\vartheta_2\beta'^2/\beta''^2=35.83\left(\frac{17.95}{4.5}\right)^2\cong 570. \tag{9}$$

An increase of $\vartheta_1=K_1'/K_i$, see eq. (4$\alpha$), corresponds to an increase of the actual structure's rigidity, which will be attained by slightly altering the dimensions of columns $C_1$, $C_2$. This alteration is shown on the lower right-hand part of Fig. 7 and extends only to the 2 lower storeys, because it is readily confirmed that such alteration does not compel to a substantial change of parameter $\lambda$. From the altered column-data the new ratio $K_4':K_1'=5.14:57.69=0.089$ is found, diverging only a little from parameter $\lambda=0.10$, which may therefore be maintained. Moreover, the new $K_i'$ values satisfactorily disclose the parabolic distribution of eq. (7), under parameter $\lambda=0.10$. Thus, the new constant $\vartheta_1=K_1'/K_1=57.69\times 10^3/100=576.9$ is determined, leading to the new "reduced" frequency $\beta''=17.95\sqrt{35.83/576.9}\cong$ $\cong 4.47$ sec$^{-1}$, which yields, on the $\lambda=0.10$-curves of Tables No 4/1 to 4/4, the ordinates $\max\delta_1$ to $\max\delta_4$, equal respectively to 2.85, 4.00, 5.35 and 16.00 mm. These ordinates, multiplied by constant $\vartheta_3=1.15$ (see above), furnish the maximal relative deflections $\max\delta_1'$ to $\max\delta_4'$, equal respectively to 3.28, 4.60, 6.15 and 18.40 mm, and the columns of the structure may then be designed to withstand these maximal deflections.

If as usual the soil vibration $x_{0t}'=\alpha'\sin\beta' t$ extends under invariable amplitude $\alpha'$ over a range of frequencies $\beta'$ or periods $T_0$, the Tables are still readily applicable. Considering again the example of Fig. 7, let now the seismic period $T_0$ vary between 0.30 and 0.40 sec, which means that $\beta'$ fluctuates within the range of $\max\beta'=2\pi/0.30=20.90$ sec$^{-1}$ and $\min\beta'=2\pi/0.40=15.70$. sec$^{-1}$. With the initial dimensions of columns $C_1$, $C_2$ (upper part of Fig. 7) and $\lambda=0.10$, further with $\vartheta_1=495.9$, $\vartheta_2=35.83$, $\vartheta_3=1.15$ as previously, the range of the "reduced" frequency $\beta''$ covers the section between $\max\beta''=\max\beta'\sqrt{\vartheta_2/\vartheta_1}=$ 5.61 sec$^{-1}$ and $\min\beta''=\min\beta'\sqrt{\vartheta_2/\vartheta_1}=4.21$ sec$^{-1}$, which section fully corresponds ($\lambda=0.10$) to the prohibited resonance zone of Tables No 4/1 to 4/4. To avoid this zone, a new suitable $\max\beta''$ value is defined, say $\max\beta''=$ $=4.50$ sec$^{-1}$, and hence a new $\vartheta_1$-value evaluated, namely:

$$\vartheta_1=\vartheta_2\left(\frac{\max\beta''}{\max\beta'''}\right)^2=35.83\left(\frac{20.9}{4.5}\right)^2\cong 772, \tag{10}$$

while the new $\min\beta''$-value becomes:

$$\min\beta''=\min\beta'\sqrt{\vartheta_2/\vartheta_1}=15.70\sqrt{35.83/772}\cong 3.38 \text{ sec}^{-1}. \tag{11}$$

Instead of range $\beta''=4.21\div5.61$ sec$^{-1}$ ($\vartheta_1=495.9$), the new range $\beta''=3.38\div4.50$ sec$^{-1}$ ($\vartheta_1\cong772$) is chosen, corresponding, for $\lambda=0.10$, to a fully admissible zone. By increasing in Fig. 7 the dimensions of $C_1,C_2$ so that $K_1'\cong77.2\times10^3$ (t/m) and $K_1':K_1=\vartheta_1=\cong772$, while $K_2'$ to $K_4'$ maintain approximately the parabolic distribution law for parameter $\lambda=0.10$, the new precise $\vartheta_1$-value is evaluated and hence the final extention of the $\beta''$-range is found, now totally avoiding the resonance zone. The $\max\delta_1'\div\max\delta_4'$- values may then be defined as previously.

Instead of changing $\vartheta_1$ and maintaining parameter $\lambda$ to avoid the resonance zone the alternative procedure may be applied, namely by maintaining $\vartheta_1$ and altering parameter $\lambda$. It is seen f. i. from Table No 4/4 that while region $\beta''=4.21\div5.61$ sec$^{-1}$ is prohibitive for $\lambda=0.10$, it is not any more for $\lambda\cong0.165$ and even less so for $\lambda=0.20$. By maintaining thus the initial dimensions of columns $C_1,C_2$ in the ground storey ($\vartheta_1=495.9$) and by increasing their dimensions in the upper storeys, so that the parabolic distribution law of eq. (7) is approximately satisfied with $\lambda=0.20$, the $\max\delta_1'\div\max\delta_4'$-values will be again defined as previously outside the resonance zone, with the only difference that now the $\lambda=0.20$-curves will be used instead of the $\lambda=0.10$-curves of the previous case. It is also noted that now to avoid resonance effects the increase of the structure's rigidity is restricted to the upper storeys, while in the previous case it was more or less extended to the whole structure.

Note. Figs. 1 & 2 of present communication were taken from Dr. A. S. Iconomou's doctoral thesis at the Civil Engineering Department of the Athens Ntl Techn. University, April 1965. In the same thesis, dissertation adviser Prof. F. E. Kokinopoulos, the initial proposal for the establishment of Tables of Direct Aseismic Design has been formulated. The further development and elaboration of the Tables has been performed during the last 5 years in the Institute of Structural Analysis & Aseismic Research of the Ntl Techn. University of Athens, under Prof. F. E. Kokinopoulos' leadership.