EARTHQUAKE RESISTANT ANALYSIS OF SINGLE STORY INDUSTRIAL BUILDING WITH THE CONSIDERATION OF THE SPACE BEHAVIOR

by

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SYNOPSIS

The earthquake resistant analysis of single story industrial building with precast ribbed-slabs roof system is studied in this parper by using the analytic method of the discrete variables. In calculation, considering the whole roof system as a precast folded plate system, taking the displacement of connection of the ribbed-slabs to the roof truss as the unknown and using the Lagrangian equation, the vibration equation in space of industrial building is derived and the solution of the free vibration is given.

PREFACE

The aim of this paper is to analysis the single industrial building with pracast ribbed-slab roof system under earthquake. The ribbed-slabs are put on the upper chords of the truss and are welded of the slabs at three corner points. The brick wall is enclosed around the building.

It is demonstrated from the tests and calculation that the industrial building acts as a space structure under loading and the roof system plays an important role. Every ribbed-slab is assumed as a thin-walled member with channel section and the three welded points connected on the truss are assumed as hinges. Then, the whole structure of the industrial building can be considered as a space folded plate system which is elastically supported by the trusses, columns, walls and the braces between columns.

BASIC EQUATION

The connections of the ribbed-slab in the roof system are marked as shown in Fig.1. The mass concentrated at connection (x,y) is called m(x,y), and the deflection components in the longitudinal and transversal direction are taken as the unknowns.

If the deflection components are expressed as follwing:

$$\left.\begin{aligned} u(x,y) &= \sum_j \varphi_j(y)\, U_j(x) \qquad (j = 1.2 \cdots\cdots) \\ v(x,y) &= \sum_s \psi_s(y)\, V_s(x) \qquad (s = 1.2 \cdots\cdots) \end{aligned}\right\} \quad (1)$$

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in which, $\varphi_i(y)$ and $\psi_s(y)$ that chosen from some determined functions are represented the distributions of $U(x.y)$ and $V(x.y)$ along Y drection, $U_j(x)$ and $V_s(x)$ are the general longitudinal and transversal deflections and are unknown functions that must be solved.

Having calculated the kinetic energy and deformation energy of the whole system and replaced into Lagrangian Equation, the basic space vibration equations represented by the general deflection components $U_j(x)$ and $V_s(x)$ can be obtained as following:

$$\sum_j m_{u.ij}\ddot{U}_j(x) + \sum_j [a_{ij}(2-E_x-E_x^{-1}) + b_{ij}(E_x^{-1}-1) + C_{ij}(E_x-1) + d_{ij}]U_j(x)$$
$$+ \sum_s [e_{is}(2-E_x-E_x^{-1}) + f_{is}(E_x-1)]V_s(x) + \sum_j K_{ij}U_j(x) = Q_{x.i}$$
$$(i = 1.2.\cdots\cdots) \qquad (2)$$

$$\sum_s m_{v.rs}\ddot{V}_s(x) + \sum_j [e_{jr}(2-E_x-E_x^{-1}) + f_{jr}(E_x^{-1}-1)]U_j(x)$$
$$+ \sum_s t_{rs}(2-E_x-E_x^{-1})V_s(x) + \sum_s K'_{rs}V_s(x) + \sum_s K''_{rs}V_s(x) = Q_{y.r}$$
$$(r = 1.2.\cdots\cdots) \qquad (3)$$

Formulas (2) and (3) are the equations of the longitudinal and transversal vibration respectively. E_x and E_x^{-1} in equations (2) and (3) are difference operators, $m_{u.ij}$ and $m_{v.rs}$ are general masses, $Q_{x.i}$ and $Q_{y.r}$ are general forces and $a_{ij}\cdots\cdots$ are constants depended on stiffness of structural members.

SOLUTION OF FREE VIBRATION

If there are $(n+1)$ transversal frames in building and only takes $(n+1)$ values for every function of $u_i(x)$ and $v_s(x)$, then the linear and independent $(n+1)$ functions $f_0(x)\cdots\cdots f_n(x)$ are chosen to form functions $u_i(x)$ and $v_s(x)$ with linear composition.

Assume:

$$u_i(x) = [f_0(x).f_1(x)\cdots\cdots f_a(x)]\begin{Bmatrix} A_{i0} \\ A_{i1} \\ \vdots \\ A_{ia} \end{Bmatrix} = X_a A_i \qquad (a \leq n) \quad (4)$$

$$v_s(x) = [f'_0(x).f'_1(x)\cdots\cdots f'_b(x)]\begin{Bmatrix} B_{s0} \\ B_{s1} \\ \vdots \\ B_{sb} \end{Bmatrix} = X_b B_s \qquad (b \leq n) \quad (5)$$

in which A_i and B_s are column matrixes of constant.

Replacing equations (4) and (5) into equations (2) and (3), and summing along X direction, two groups of frequency equation are obtained.

If it is now assumed further that the transversal deflection (in Y direction) distributes as a straight line, the roof system is devided into some pieces with different heights. The trusses are assumed non-deformation and the slope of the roof is equal to each other, then the transversal deflection of every point at any frame of the same roof system must be equal as shown in Fig.2.

If

$$\left.\begin{aligned} X_a &= [\,1\ .\ x\,] \\ X_b &= [\,1\ ,\ x\ ,\ x^2\,] \end{aligned}\right\} \qquad (6)$$

and the industrial building is symmetrical in the longitudinal direction, the main vibration can be devided into symmetrical and anti-symmetrical two conditions.

EARTHQUAKE LOAD AND INTERNAL FORCE OF STRUCTURE

It is not difficult to calculate the frequency and corresponding vibration mode from frequency equation. The earthquake load can be obtained from response spectrum of earthquake.

EXAMPLE

According to the above method the natural frequency and the vibration mode of the industrial building (I) can be obtained. The plan of the industrial building is shown in Fig. 3.1 and the transverse section is shown in Fig.3.2. The modulus of elasticity of columns and ribbed-slabs are $E = 3.0 \times 10^5\ kg/cm^2$.

The results of calculation of the anti-symmetrical vibration modes are shown in Fig.3.3.and the results of the natural frequencies (with measured frequencies) are shown in Table 1. The results of the natural frequencies (with the measured frequencies) are shown in table 2.

Table 1.

No. of Vibration Mode	1	2	3	4	5	6		
Calculated Natural Frequency (HZ)	1.62	4.62	6.38	7.53	9.36	26.84		
Measured Natural Frequency (HZ)	2.49	4.10						

Table 2.

No. of Vibration Mode	1	2	3	4	5	6	7	8
Calculated Natural Frequency (HZ)	1.68	4.40	6.30	6.90	8.30	9.20	11.70	33.00
Measured Natural Frequency (HZ)	3.37	4.49	6.78	8.34				

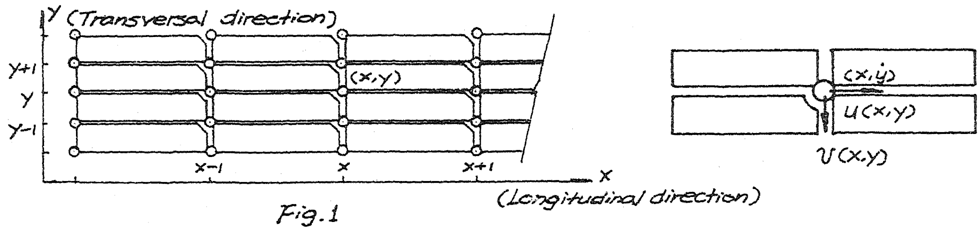

Fig.1

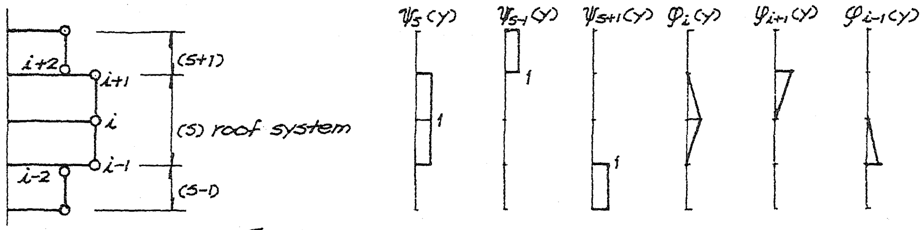

Fig.2

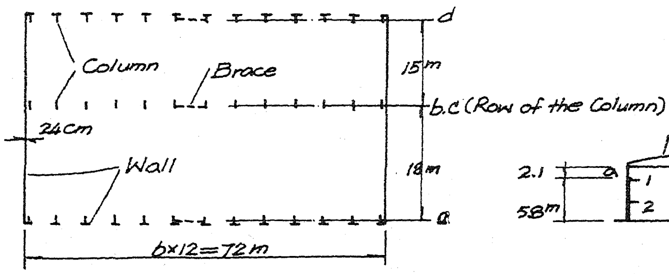

Fig.3.1.

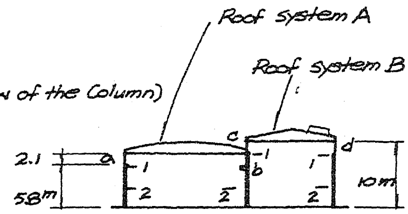

Fig.3.2

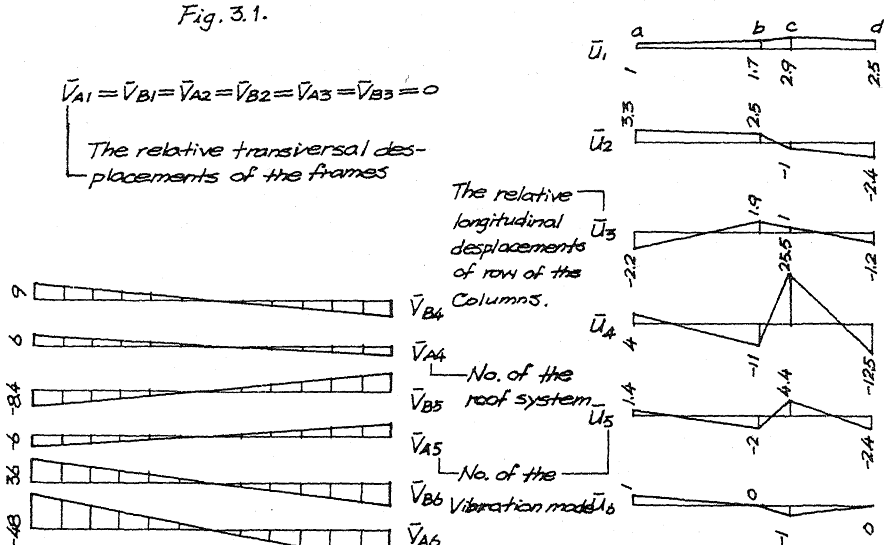

Fig. 3.3.