Performance of framed-tube structures under vertical forces

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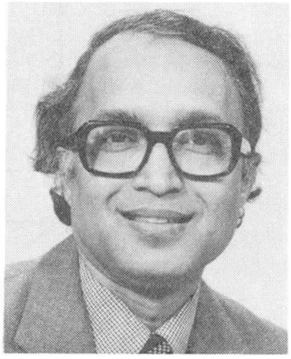

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Summary

This paper reports the summary of a simplified analysis of framed-tube structures subjected to vertical forces.

1. Introduction

The framed-tube structure consists of a closely spaced exterior columns tied at each floor level by spandrel beams to produce a system of four orthogonal rigidly jointed frame panels forming a rectangular tube system (see fig 1(a)). The most significant framed-tube structure are the 110-storey twin towers for the World Trade Centre in New York, USA. The analysis of framed-tube structures supported on rigid and elastic bases and subjected to lateral wind load were considered in two papers[1,2]. By replacing the discrete structure by an equivalent orthotropic tube (see fig 1(b)), and making simplifying assumptions regarding the stress distribution in the substitute structure simple closed solutions were obtained. In addition to the lateral load, the framed-tube structure is subjected to vertical forces due to the dead load of the structure and the imposed load acting on the floor areas.

2. Method of analysis

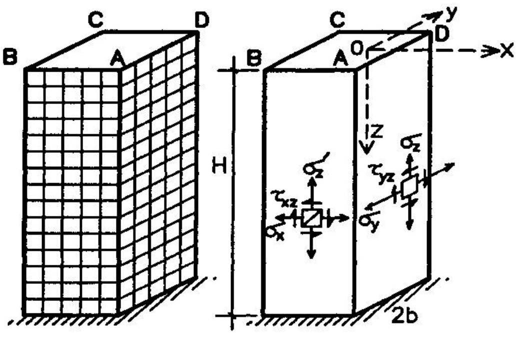
Detailed analysis of a framed-tube structure of rectangular cross-section, subjected to vertical forces, is given in Reference 3. In this paper a framed-tube of square section, of side 2b, is considered (see fig 2). The vertical force caused due to the weight of the structure itself may be considered as a uniform force ρ_s per unit volume of the equivalent tube structure. The weight of the floor system and the imposed load acting on the floor areas are transferred equally to the four panels at every floor level, which for the panel AD may be expressed as

$$\rho = \rho_f \left[1 - \left(\frac{y}{b} \right)^2 \right] \qquad (1)$$

where ρ_f is a constant term independent of the height coordinate z.

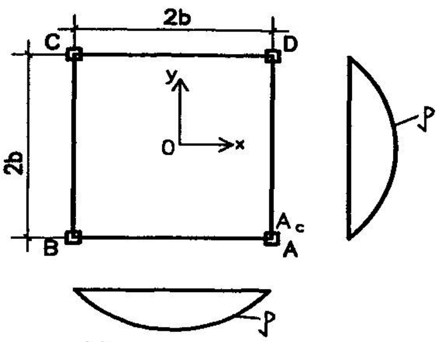
The simplest approximation which may be made for the symmetrical distribution of vertical stress σ_z in the panel AD may be expressed as

$$\sigma_z = f_1 + \left(\frac{y}{b} \right)^2 f_2 \qquad (2)$$



(a) (b)

Fig 1 Framed tube (a) real and (b) substitute structure



(c)

Fig 2 Vertical forces due to floor load

in which f_1 and f_2 are functions of the height coordinate z only.

By considering the condition of vertical force equilibrium at any level z the function f_1 is given as

$$f_1 = -\frac{W}{A} - \frac{3n+2}{3(n+2)} f_2 \qquad (3)$$

in which W is the total vertical force at that level, given by

$$W = 4tz\left[\frac{4}{3} b\rho_f + \left(2b + \frac{Ac}{t}\right)\rho_s\right] \qquad (4)$$

$n=A_c/bt$, A is the area of the equivalent tube section, given by $A=8bt+4\ A_c$, t is the thickness of the equivalent tube and A_c is the area of the corner column.

By applying the laws of equilibrium and the principle of least work the function f_2 is determined as

$$f_2 = \frac{\rho_f \sinh m_2 H\xi}{m_2 \cosh m_2 H} \qquad (5)$$

in which m_2 is constant and $\xi = z/H$.

The distribution of vertical stress in each panel may be expressed as

$$\sigma_z = -\frac{W}{A} - \left[\frac{3n+2}{3(n+2)} - \left(\frac{y}{b}\right)^2\right] f_2 \qquad (6)$$

The normal stress σ_y ($=\sigma_x$) and shear stress τ_{yz} ($= \tau_{xz}$) may also be found. The results from the substitute continuum system must then be transferred into the real discrete structure to give shears, and thus moments, and axial forces in beams and columns.

References

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