SIMPLIFIED ANALYSIS OF SHEAR WALLS IN TALL BUILDINGS TO EARTHQUAKE ACTION

by

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SYNOPSIS

Starting from the unanimously acknowledged hypotheses the paper proposes a simplified device for the design of tall building with shear walls, utilizing the drift between adjacent stories.

INTRODUCTION

The design methods of shear walls in tall buildings has been developed in a remarkable degree in the last decade. Speciality literature contains various numeric methods of approaching this problem, based upon different simplified hypotheses of investigation. Because of the complexity of behaviour of these structural types to lateral loads when those so-called exact methods represent an approximative analysis of stress and deformation state.

At these types of structural elements, the main lateral actions are constituted by wind or by earthquake. The researches made up to the present aprioristically admit as already known the intensity of the lateral forces which, at it is commonly known depend on the self characteristics of vibration of the analysed structures. From these, the natural periods of vibration have a decisive part in what the determination of the lateral forces produced by the seismic motion as concerned.

The authors of this paper suggest a method of calculus for the fundamental period of vibration using the drift between adjacent stories. Direct formulas for calculation which are satisfactouly from the practical point of view in the approximate analysis of the seismic shear walls were established in order to determine the rigidities between two adjacent stories. Through these rigidities the seismic forces can be distributed together with their effects upon vertical elements of resistence.

We are going to present breafly only the final results of the study accomplished as well as the conditions under which they were obtained.

The main hypotheses which have been taken into consideration are the following: the geometry of the diaphragm

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is the same to the height of the building, all the hallows have the same dimensions and are situated along the same vertical; the height between the floors is constant, the number of levels is big enough, the points of inflexions of the horizontal beams are at the middle of the spans, the structure of the floors is rigid in horizontal plan, the seismic forces are considered to act at the level of the floor we take into consideration only the horizontal components of the seismic forces; the material is considered to be homogenius and izotropic and the calculation is made in the elastic domain. The geometrical characteristics of all structural elements and the notations used are shown in fig.1.

THE DESIGN RELATIONS

The effect of the deformations of bending and shearing have been taken into consideration at the determination of the expression of calculation of the relative rigidities between the two adjacent stories, minding the rotation of the sections of vertical walls at the level of the floors.

For calculation of the drift between adjacent stories which corresponds to only one element of the wall, taking into consideration the contribution of the beams included within their points of inflexion, the following formula was determined:

$$K_{STORY} = \frac{12\,EI_c}{h_c^3}\,\eta_{STORY} \qquad (1)$$

where the coefficient of relative rigidity η_{STORY} is obtained with the relation

$$\eta_{STORY} = \frac{1}{4+6(1-\alpha)\frac{d}{h_c} - 12\alpha\left(\frac{d}{h_c}\right)^2 + \frac{35}{h_c^2}\left(\frac{I_c}{A_c}\right)} \qquad (2)$$

The coefficient α which appears in the second formula have the expression:

- for the exterior walls (fig.2)

$$\alpha = \frac{1}{\frac{1}{12}\frac{b^3}{dh_c^2}\left(\frac{I_c}{I_b}\right) + \frac{2d}{h_c}} \qquad (3)$$

- for interior walls (fig.3)

$$\alpha = \frac{1}{\frac{1}{24}\frac{b^3}{dh_c^2}\left(\frac{I_c}{I_b}\right) + \frac{2d}{h_c}}\ , \quad d = \frac{d_1+d_2}{2} \qquad (4)$$

For the whole structure, the total rigidity between the two adjacent stories will be

$$K_{\substack{TOTAL\\STORY}} = \sum_1^m K_{STORY} \qquad (5)$$

If the building is uniformily loaded in such a way that the resultant of the gravitational loads at each floor is the same $Q_{\substack{TOTAL\\STORY}} = m_{\substack{TOTAL\\STORY}}\, g$, the following formula was deduced for the calculation of the fundamental period of vibration:

$$T_1 = 0.15n\sqrt{\frac{Q_{\substack{TOTAL\\STORY}}}{K_{\substack{TOTAL\\STORY}}}} \qquad (6)$$

in which n represents the number of floors.

If there are slight variations of the geometric dimensions and of the loads the fallowing relation are to be used:

$$Q_{\substack{TOTAL\\STORY}} = \frac{1}{n}\sum_{1}^{n} Q_{\substack{TOTAL\\STORY}}, \text{ in tons.} \quad K_{\substack{TOTAL\\STORY}} = \frac{1}{n}\sum_{1}^{n} K_{\substack{TOTAL\\STORY}}, \text{ in tons/cm.}$$

The periods of supperior degree can be expressed as it follows:

$$T_2 = \frac{1}{3}T_1, \qquad T_3 = \frac{1}{5}T_1$$

In the above expressed analysis the horizontal force is assumed to act separately in the longitudinal and transvers direction. When eccentricity exists between the center of shear and center of rigidity, the resulting torsion must be taken into account.

As the shear walls are elements of rigid resistance, the influence of the deformability of ground of foundation on the fundamental period is important enough. In this sense the value of the period calculated by the formula (6) can adequately be corrected. Generally a rouse of the period With about 10 - 30% results.

The methods proposed in recent years for the evaluation of the stress in tall buildings with shear walls are: iterative methods, continuous medium methods, energy methods, stiffness matrix method, flexibility matrix method, equivalent column method, finite elements method.

The above method briefly described offers satisfactory results in planning. A more accurate calculation of the elements presented here is extremely laborious and sometimes even impossible to be carried out. The authors intend to improve this method in the future, considering it at the present moment only in an incipient stage.

NUMERICAL APLICATIONS

I. We consider a building with 15 floors made out of shear walls and having a cross-section as in fig.4. The load to each floors is $Q_{\substack{TOTAL\\STORY}} = 90$tons. Using the relations from this paper results that $T_1 = 0,51$ sec.

II. In fig. 5 another type of shear walls is presented to which $Q_{\substack{TOTAL\\STORY}} = 115$ tons, resulting that $T_1 = 0,42$ sec.

BIBLIOGRAPHY

IFRIM,MIHAIL. Earthquake Modal Analysis of Multistory Structures. Relative Stiffness, Eigenvalues and Eigenvectors. Proc.of the Conf.Earthq.Anal.of Str., Jassy, Romania, Sept. 1970.

IFRIM,MIHAIL and DOBRESCU ALEXANDRU. Un metodo para la determination de los periodos naturales y los modos normales de vibracion de las estructuras de edificios.Rev.Soc.Mexicana Seismolog.Nr.2/1966.

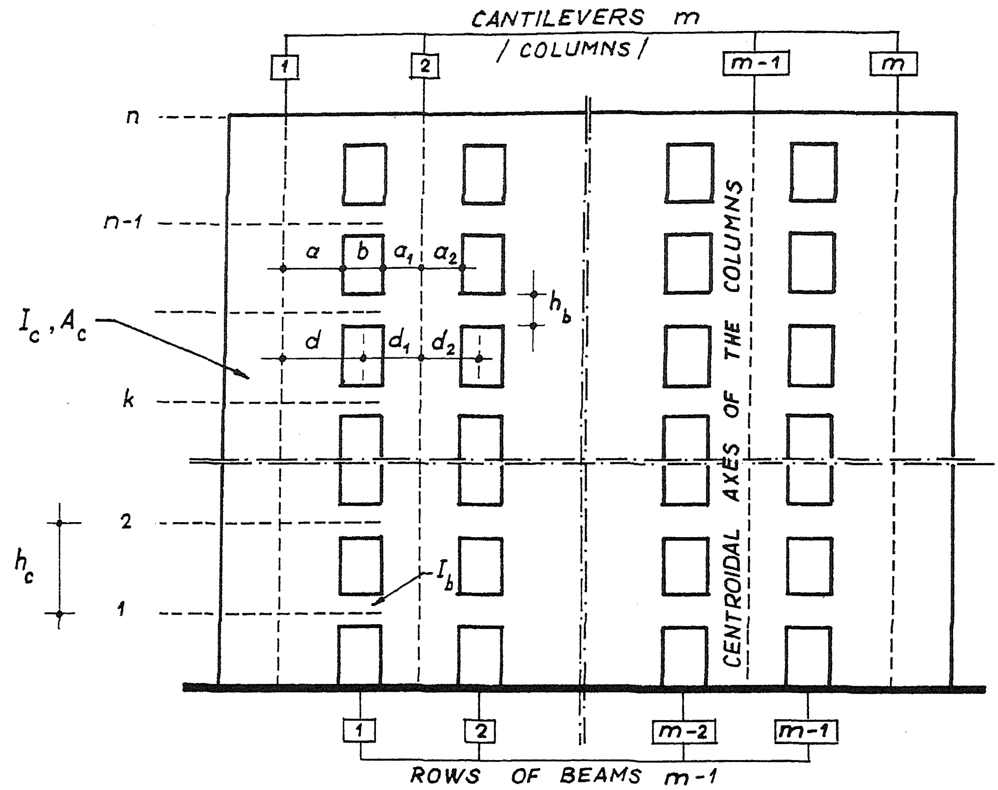


FIG. 1

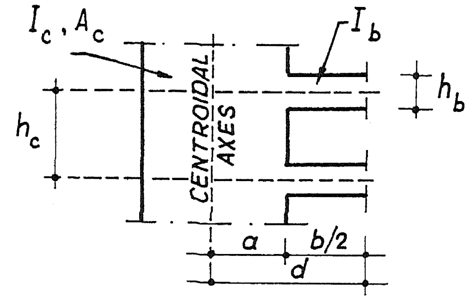


FIG. 2

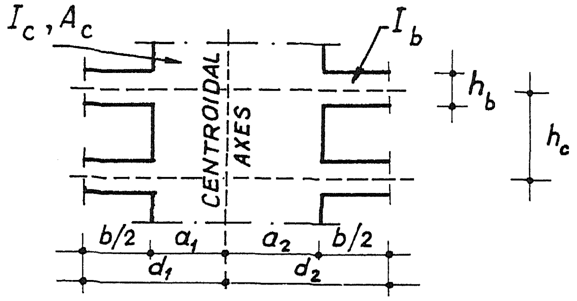
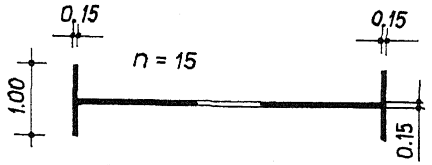


FIG. 3

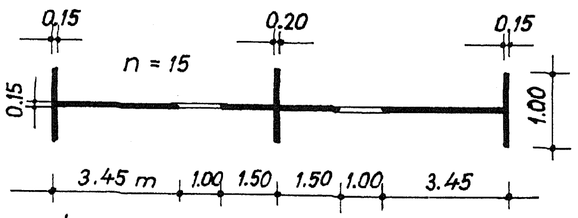


$h_b = 0.80\,m$, $h_c = 3.00\,m$

$E = 2.5 \times 10^6$ tons/m^2

$K_{\substack{TOTAL\\STORY}} = 1793$ tons/cm

FIG. 4



$h_b = 0.80\,m$, $h_c = 3.00\,m$

$E = 2.5 \times 10^6$ tons/m^2

$K_{\substack{TOTAL\\STORY}} = 3370$ tons/cm

FIG. 5