STUDY OF THE BEHAVIOUR OF A HANGING BUILDING UNDER THE EFFECT OF AN EARTHQUAKE.

Carlos José Oto Larios.- Ingeniero Civil U.C.
Luis Castro Salas.- Ingeniero Civil U.C.
Gerdy Droppelmann Bittner.- Ingeniero Civil U.C.
Raúl Ebensperger Silva.- Ingeniero Civil U.C.

"STUDY OF THE BEHAVIOUR OF A HANGING BUILDING UNDER THE EFFECT OF AN EARTHQUAKE".

SUMMARY

The analysis has been made submiting a building, in which all the stories hang one basic structural element, to disturbing action at their basis and studyng directly the vibration of the structural system, through numerical integration methods.

This design makes that the dissipation of energy is carried out in a longer period of time, than in the conventional buildings. The favorable effect may be increased providing between the floors and the basic structure, elements specially designed.

The results obtained indicated the interest of this type of structure, in relation with conventional solutions, to resist seismic actions, under certain conditions.

INTRODUCTION

The present work analyses the seismic behaviour of a new type of structure for buildings, based in hanging all the floor assemblies from a basic structural element. This idea was put forward by Ing. César Barros L. and Ing. Hernán Bertling H. in the First Journeys of Seismology and Antiseismic Engeneering of Chile (Santiago, July, 1963).

HANGING BUILDINGS

In Hanging Buildings we can distinguish four fundamental elements.

a) Basic Structure. It is the supporting element from wich the floors hang, and that transmits all the efforts to the foundations; it can also have a functional charactere by including in its interior the elements of vertical transport and the service ducts.

b) Floors. It is the living-quarters part of the building; it is formed by slabs that hang from the Basic Structure.

c) Vertical Conections. These are the elements by means of wich the group of floors are hanged.

d) Horizontal Connections. These are the elements that can be installed inbetween floors and the Basic Structure to control horizontal movements.

With this structural disposition its possible to have in relation to conventional buildings, somre architectonic and design advantages.

There is more flexibility in the interior distribution due to the lower interference with the structural elements. The lack of front supporting walls, permits a larger freedom in the exterior design, and improves the posibilities of natural ventilation and ilumination. Therefore we obtain a better circulation disposition at ground level, facilities in services and apretiable disminution from street noices and vibrations.

The fact of having hanging floors, allows to use its behaviours like a pendulum under seismic action, with the possibility of placing a horizontal connection to absorve energy and graduate elasticity of this pendulum.

The calculus of the structure presents also advantages due to the simplicity of structuration. The slabs are all equal, and with lower secundary tensions on account of the lower horizontal rigidity of the vertical connections. These in turn are element submitted to tensile stress in wich can be used to the best advantage the maximun of the resistence of the material by avoiding the problem of buckling common to conventional buildings.

DESCRIPTION OF THE ANALYSED BUILDING

To make this study, a type-building was selected, formed by a structural element that holds a superior beam, from wich ten floors hang; the shape and the general dimentions of the building can be seen in appendix 1.

The columns and superior beam are reinforced concrete and the hangers of the floors are cables with no horizontal rigidity.

Between the floors and the columns there are elements intended to control the displacements of the hanging floors and dissipate part of the total energy that the building receives during an earthquake.

THEORYCAL ANALYSIS

For two basic reasons, the analysis of this building by means of some conventional dynamic method, like through the vibration modes of the structure, is not possible in this case. First, it is necessary to introduce the influence of intermediate viscous damper elements as horizontal connections, and second, the assembly of hanging floors and the basic structure have independently, completely different vibration modes, wich prevents the uncoupling of vibration modes of all the system.

For these reasons the problem was resolved by means of a direct analysis of the movements differential equations, solutiones by a numerical integration method, step by step. (Method of Constant Velocity).

For the analysis, the following hypothesis have been stated:

- There is no soil-foundation interaction.
- Homogeneus and isotropic materials in the elastic range.

- Self damping of structure is not considered.
- Only bending and shear deformations are included.
- Lineal characteristic of dampers and springs.

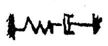
In reference to the mechanical sketch, show in appendix 2, and to these hypothesis, the movement equations of the system would be:

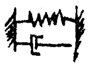
$$m_i(\ddot{x}_0+\ddot{y}_i)+\sum_{j=1}^{11}k_{ij}x_j+k_{i,\beta}\beta-F_i=0 \qquad i=1,11$$

$$I_\beta\ddot{\beta}+\sum_{j=1}^{11}k_{\beta j}x_j+k_{\beta\beta}\beta=0$$

$$m_i'(\ddot{x}_0+\ddot{x}_{11}+\ddot{x}_i')+F_i+F_i'=0$$

NOTES:

 $$F_i=k_i e^{-\frac{k_i}{c_i}t}\int_0^t e^{\frac{k_i}{c_i}\beta}\left\{\dot{x}_{11}(\beta)+\dot{x}_i'-\dot{x}_i(\beta)\right\}d\beta \qquad i=1,10$$

 $$F_i=k_i(x_{11}+x_i'-x_i)+c_i(\dot{x}_{11}+\dot{x}_i'-\dot{x}_i) \qquad i=1,10$$

$$F_{11}=T_{10}\frac{x_{10}'}{h_{10}}$$

$$F_i'=T_i\frac{x_i'-x_{i+1}'}{h_i}-T_{i-1}\frac{x_{i-1}'-x_i}{h_{i-1}}$$

$$T_i=ig\sum_{j=1}^{i}m_j'$$

The solution of these equations as was shown previously, was realysed through the "Method of Constant Velocity" (I).

The time interval required for the step by step calculus, to eliminate the problems of inestability and divergency, resulted between 0.0015 and 0.0025 seconds.

The processing of the data was made by a IBM 1620 computer at the Catholic University of Chile.

(I) Method developed in the M.I.T. It is asumed that the area under the acceleration curve can be replaced by a series of equivalent pulses acting in time intervals.

BEHAVIOUR OF THE TYPE-BUILDING

To study the behaviour of type-building, it was submitted to basic perturbations taken from an earthquake registered (TAFT, USA- 1952), and also to ideal vibrations.

a) Influence of the horizontal connection.

It is required the existence of an intermediate element to control the oscilation of the hanging floors, because otherwise not recomanded deformations are obtained. This element can be used at the same time, to absorbe energy.

The type-building was then submitted to the TAFT earthquake (USA-1952), and was analysed the case of an intermediate element composed by a spring and a damper in series, taking different values for each case; the results are shown in appendix 3.

In it, we can see it is possible to find in the basic structure elements that allow minimize the answer.

Also, it is appreciated that the efforts diminish in a outstanding way (in the range of 70%) between the rigid case and the ideal (that is, minimun answer).

It may also be seen that for a certain value of the spring, the minimun basal shear is obtained with the larger damper, and that for the higher spring values, less basal shear is obtained with damper of lower magnitude,

It is convenient to note that the distribution of values of the dampers as well as those of the springs in the different floors, was of trapeeze type in the relation 1: 10 between the first and the last, beeing the maximun in the lower floor.

b) Influence of the period of the basal perturbation.

To investigate the causes by which maximun effort states may originate in the building, it was submitted to a series of different period perturbations, until obtaining the maximun effort for different values of spring or of damper as an intermediate element.

The form of the uniform perturbation was of the type:

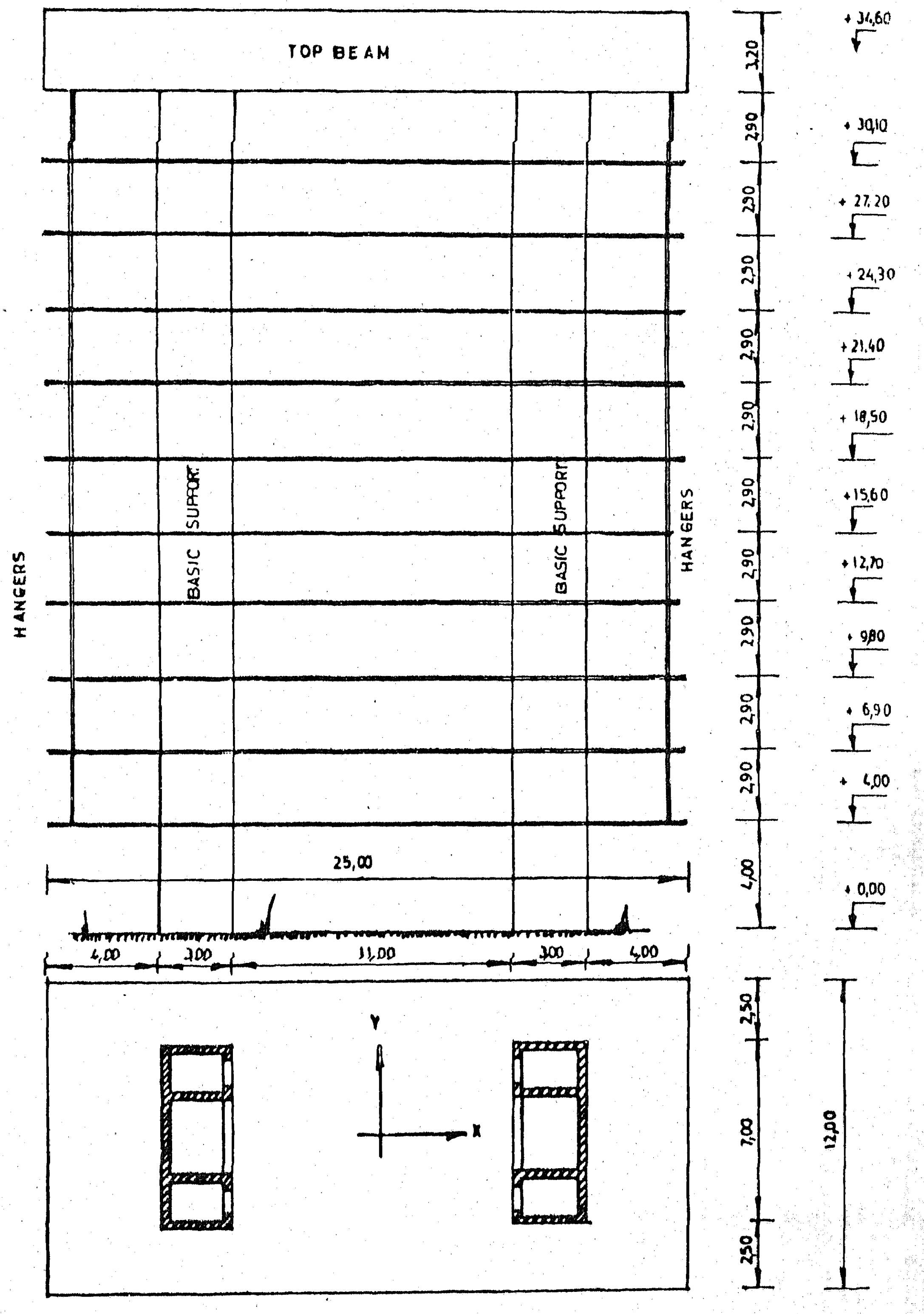
$$\ddot{y}(t) = A \sin \omega t$$

The amplitude A was supposed equal to 0.20 g, and periods were chosen between 0.05 and 0.20 seconds.

In appendix 4 the maximun basal shear resulting for different values of spring or damper, are detailed.

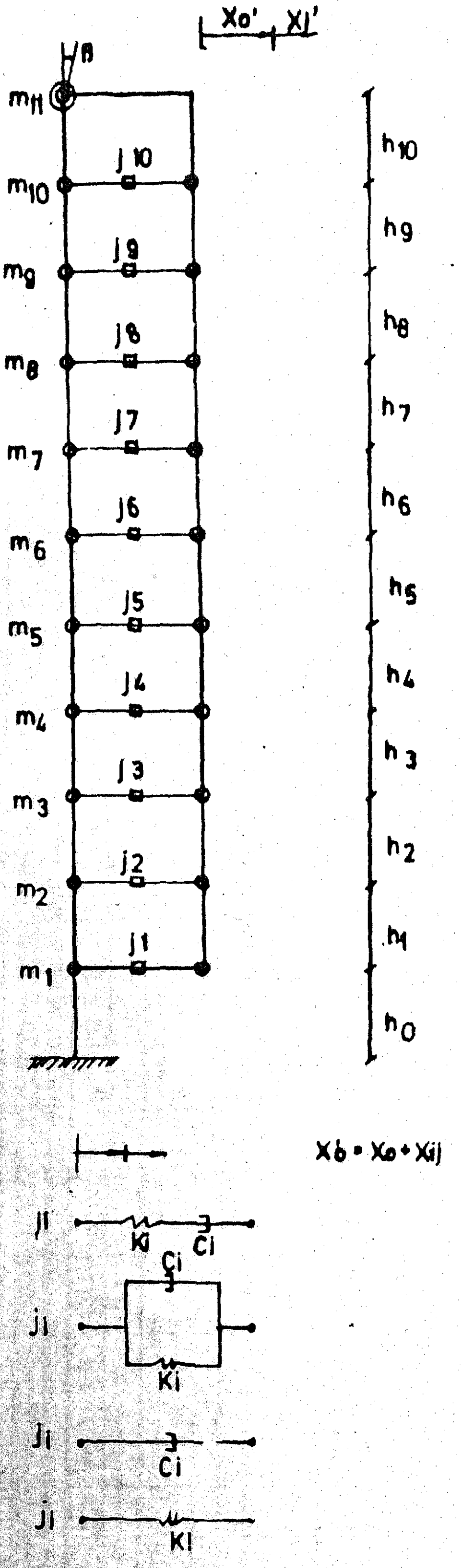
In general, it can be said that the maximun efforts increase when the period of basic perturbation is increased, but a discontinuity exists when the period of basic perturbation is close to the period of the second vibration mode of the structure, in which the efforts increase notoriously; this increase of efforts is lower when the value of the spring increases, and practically vanishes when the value of the intermediate damper increases, which demostrate and adventage of this last element as horizontal connection.

APPENDIX N°1 TIPE BUILDING ELEVATION AND PLANT



B-3

APPENDIX N°2



$m_1 = \frac{70.3 \text{ ton.}}{g}$ $T_1 = 88$ ton

$m_2 = \frac{59.4 \text{ ton.}}{g}$ $T_2 = 176$ "

$m_3 = \frac{5,65 \text{ ton.}}{g}$ $T3 = 264$ "

$m_4 = \frac{53.3 \text{ ton.}}{g}$ $T4 = 352$ "

$m_5 = \frac{53.3 \text{ ton.}}{g}$ $T5 = 440$ "

$m_6 = \frac{50.4 \text{ ton.}}{g}$ $T6 = 528$ "

$m_7 = \frac{47.3 \text{ ton.}}{g}$ $T7 = 616$ "

$m_8 = \frac{47.3 \text{ ton}}{g}$ $T8 = 704$ "

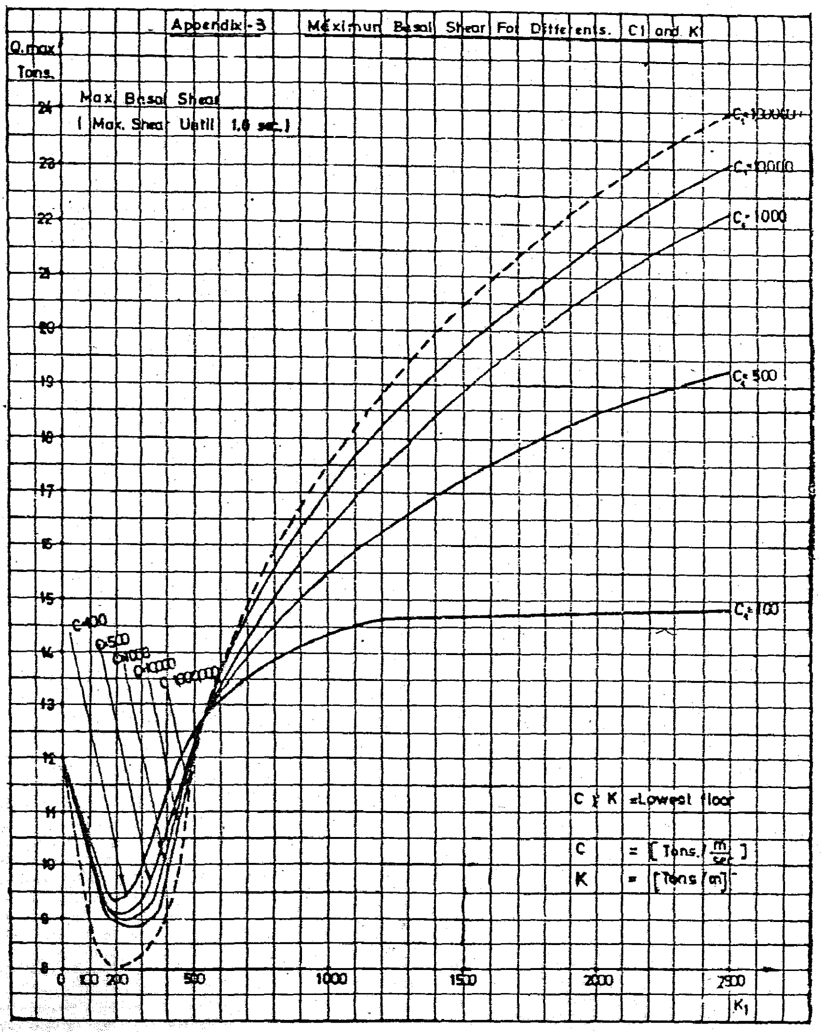
$m_9 = \frac{44.5 \text{ ton.}}{g}$ $T9 = 792$ "

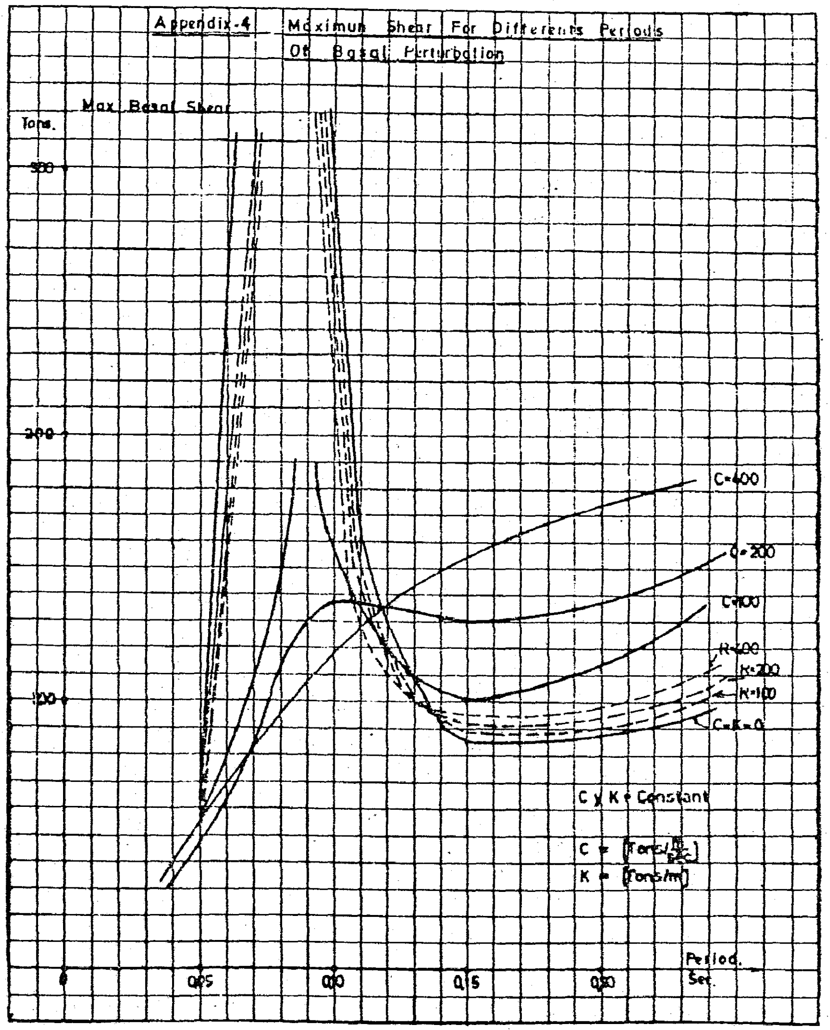
$m_{10} = \frac{41.1 \text{ ton.}}{g}$ $T10 = 880$ "

$m_{11} = \frac{387,5 \text{ ton.}}{g}$ $g = 9.806 \text{ m/seg}^2$

$m_1' = m_2' ---- m_{10}' = \frac{88 \text{ ton}}{g}$

$I_{\theta x} = \frac{4220 \text{ ton/m}^2}{g}$


Appendix-3 Maximun Basal Shear For Differents. C1 and K1


Appendix-4 Maximun Shear For Differents Periods Of Basal Perturbation