"ON THE STATIC AND SEISMIC BEHAVIOUR OF A STRUCTURAL MODEL OF AN INDUSTRIAL STORIED HALL"

by

C.MIHAI[II], D.DIACONU[I], M.MANOLOVICI[II], ST.MARINESCU[IV], ST.CIRLAN[III], M.ITICOVICI[II], D.AMARIEI[IV], I.SOROCEANU[IV]

ABSTRACT - INTRODUCTION

The paper belongs to a large program of researches on storied industrial halls initiated and coordinated by the Romanian Ministry of Industrial Construction through the Design Institute for Industrial Construction in collaboration with prof.dr.doc.Alex.Negoiţă from the Polytechnic Institute of Jassy.

One first model, tested statically and dynamically on the 14o tf shaking-table in Jassy. The aimed purpose in this first stage has been the determination of both the static and the dynamic behaviour of the model as well as the possibilities of using the lightweight concrete in some resistive members at industrial constructions.

DETAILS OF THE STRUCTURE

The prototype structure presents the following geometric and functionnal parameters:

- spans: 3 x 6.oo m; - bays 3 x 6.oo m; levels = 5;
- hights: 5 m for the grandfloor and 4.8o m for the I...IV floors;
- loadings (excepting the dead load): at every level 895 daN/m^2, at the roof 17o daN/m^2; 35 daN/m^2 perimetral surface from the walls;
- the degree of seismic intensity: 8 (MM scale).

From the constructive point of view the structure is partially prefabricated: monolith columns casted on the levels, and precast floors. The latter are composed of:•transversal beams of "overturned T" form, supported on the column cantilevers;•precast floor members, "TT", supported on the transversal beams. At current levels a reinforced concrete over-casting was achieved.•"T" shaped longitudinal beams that are completing the floors in front of the columns.

I. Asociated conf. main scientific researcher, chief of INCERC - Branch of Jassy.
II.Main scientific researcher - INCERC - Branch of Jassy.
III.Scientific researcher - INCERC - Branch of Jassy.
IV.Engineer, INCERC - Branch of Jassy - Rumania.

The static scheme: elastic frames with rigid joints in both directions.

Materials: • columns, beams, joints and concrete over-castings are made of reinforced concrete with river gravel;
• the "TT" floor members - of reinforced lightweight concrete;
• Rumanian reinforcement steel: OB 38, PC 52 and STM.

The analysed direction was the transversal one.

STRUCTURE MODELLING, TESTING METHODOLOGY AND MESUREMENTS

The similitude principles of Froud type have been applied where a supplimentary hypothesis has been introduced, viz. the model-prototype ratio of accelerations equals 1.

Imposed scales (model/prototype): lenghts = 1/3, accelerations = 1, elasticity modulli = 1, volumetric densities = 1.

Necessary deduced scales: specific elongations = 1/3, time = 1/3, unitary stresses (in concrete and reinforcement) = 1/3, strains = 1/9 and forces 1/27.

An assembly view of the executed model is shown in fig.1.

The actioning of the model in static range has been carried out in four different working stages: elastic;after the first crackings appeared; in the stage of developped crackings and in the hardly cracked stage with some local ruptures. A 2ooo daN horizontal static force has been gradually applied at the 5^{th} level -(fig.3).

The dynamic characteristics (in microseisms and small intensity impacts) have been determined in transversal and longitudinal direction as well as in torsion (table 1).

The seismic programme has been elaborated so that by increasing successively the actioning intensity the structure collapse to be achieved. In order to obtain the maximum response in an interval of frequences corresponding to the experimented model, several artificial earthquakes have been experimented C_1 (4 testings with 11 cycles), C_2 (6 testings with 28 cycles) and A_2 (5 testings with 22 cycles)according to [1] .

In the static testings, the force and general deformed shape of the model have been measured (the story horizontal displacements ,d_i).

For testings in seismic range the following data were recorded: the shaking-table acceleration (a_o), the shaking-table displacement (d_o), the story accelerations ($a_1 \ldots a_5$), the story horizontal displacement ($d_1 \ldots d_5$) the horizontal displacements of the transversal frames in the 1^{st} level (d_1^a , d_1^b , d_1^c and d_1^d), the angular displacements of the external and internal hinges - in marginal and central transversal frames - at the 1^{st} level ($d \measuredangle$ marginal and central) and the stresses (σ) in the reinforcement of columns-beams, in the concrete of the proper floor and of the over-casted concrete (tab.2).

RESULTS, CONCLUSIONS AND RECOMMENDATIONS

In the static testings (fig.3) the sideway stiffnesses degradation has varied from 1.7 times in the stage of cracking appearition up to 3.8 times in the precursory collapse stage, compared to the quasi-elastic stage. Accordingly, the remanents reached 14 % up to 25 %.

The static relative deformations of levels have been maximal until the crackings have developped in the 1^{st} and 2^{nd} level and finally in the 3^{rd}, 4^{th} and 5^{th} level.

The sideway deformation pattern is similar to framed strctures and the variation of the deformed shape curve emphasizes the modification of sideway stiffnesses of the strctural members, especially in the 3^{rd} - 5^{th} levels, in the collapse vicinity.

In measuring the dynamic characteristics (tab.1) it was found that, up to the micro-cracking stage, the transversal period increases with 2o % and the critical damping with 44 %. These characteristics are increasing, in the stage of developped crackings, with 5o % and 24o % respectively and in the collapse vicinity with 65 % and 35o % respectively.

The longitudinal and torsional periods have increased in the three working-phases with 25 %, 4o % and 7o % when compared to the elastic stage.

In the seismic regime testings (tab.2), (fig.4.5):The working stages have been established during the testings as the following levels of base accelerations of the shaking-table: 2.8 m/s^2, 4.75 m/s^2 and 6.5 m/s^2.

In quasi-elastic range the strcture has oscillated according to the natural mode and large elastic deformations have been exhibited into the floors. In the stages of evolution and development of crackings the structure oscillates according to the I^{st} and II^{nd} mode. In the stage precursory to the collapse, the oscillations have been obtained according to a combination of modes: some marked degradations have appeared in zones where the column cross-sections presented some variations while the floor above the groundfloor presented rathes large deformations and marked crackings especially along the boundary. The angular displacements indicated an unfavourable working-manner of the marginal joints and especially the corner ones.

The stresses measured on the floor have shown a good co-operation of the precast members with the over-casted concrete.

Generally, the cracking has occured around the beam-column connections, beginning with the groundfloor (fig.6 and 7). Some tendencies of dislocation in the frontons and more marked ones in the corner columns were observed. The panel zones of the joints maintained noncracked. In the final stages of structure working, the crackings have become more conspicuous between the levels 1 - 2 and 3 - 4.

For improving the structural behaviour at strong seismic actions it has been recommended, when estimating the stiffnesses, to take into account the concrete over-casting when evaluating the structure rigidities, to decrease the variation of column stiffnesses and to improve the fronton connections and particularly the connections of the corner columns to the rest of structure.

The use of TT members in lightweight concrete has been found to be reasonable.

R E F E R E N C E S

1. P.C. Jennings, G.W.Housner, M.C.Isai: "Simulated Earthquake Motions" Pasadena, California, April 1968.

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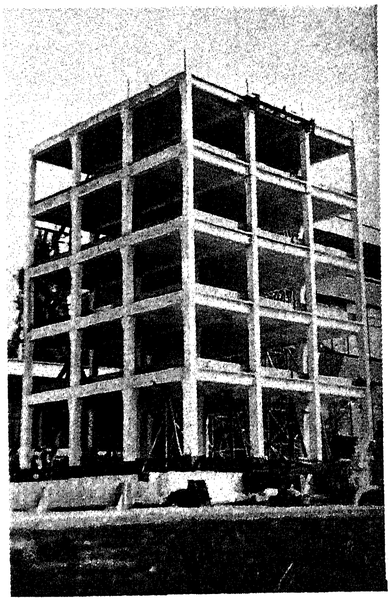

Fig.1 - Ensemble view

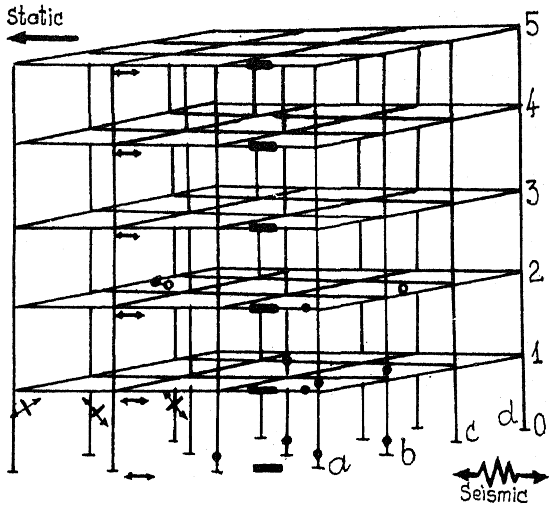

Fig.2- Measure points - notations:
- • Resistive transducers on steel
- o Resistive transducers on concrete
- ↔ inductive transducers - horizontal displacement
- ↔+ inductive transducers - angle - displacement
- ▬ accelerometer

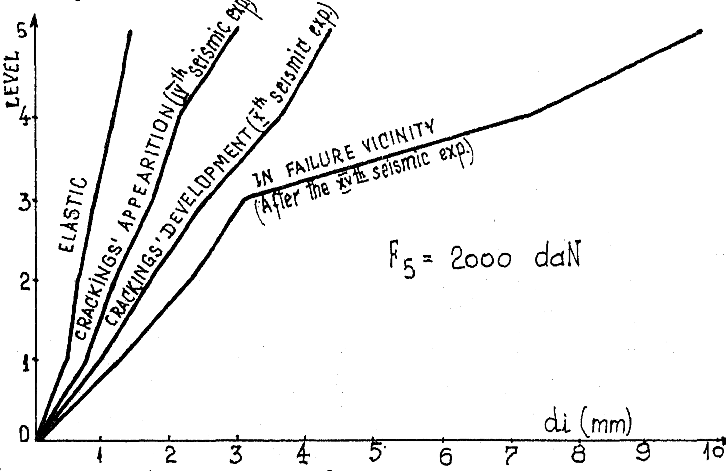

Fig.3 - Static deformed - shape - model -

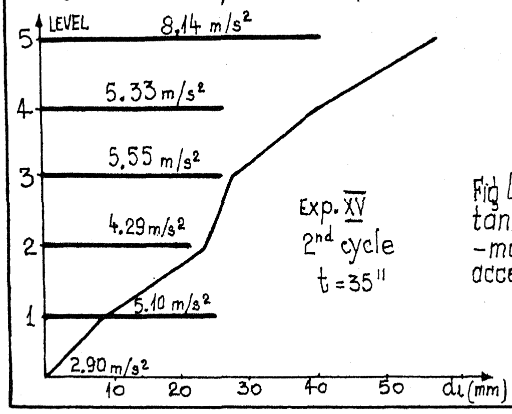

Fig 4.-Dynamic instantaneous deformed-shape -model- and level of accelerations

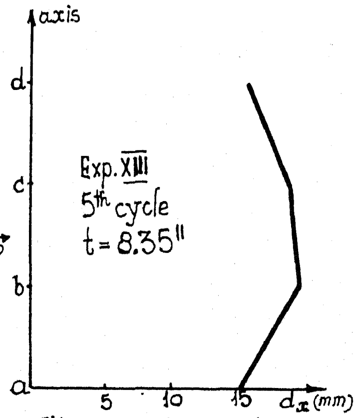

Fig. 5 -Dynamic instantaneous deformed - shape - model - and level of accelerations

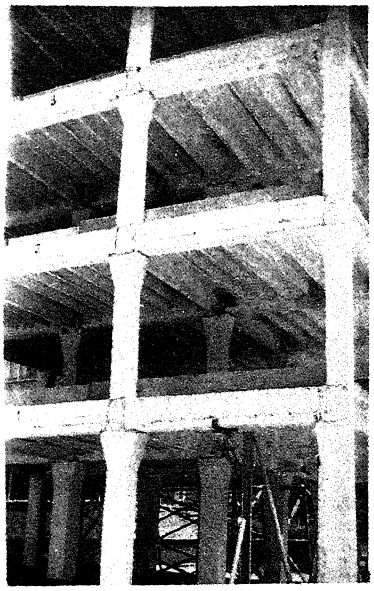

Fig.6 -Ensembly cracking

Fig 7- Detail of joint cracking

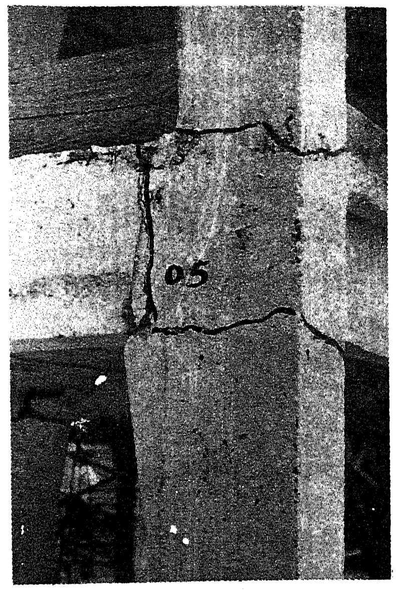

Table 1 - Dynamic characteristics - model-

Stage		Transversal		Longitudinal		Torsion	
		T (sec)	ν (%)	T (sec)	ν (%)	T (sec)	ν (%)
Non-loaded		0.22	1.18	0.31	-	0.31	2.36
Loading	Non cracked	0.30	0.98	0.39	0.89	0.40	2.63
	Apearition of crackings	0.36	1.37	0.43	1.22	0.42	3.13
	Development of crackings	0.47	2.00	0.50	-	-	-
	in vicinity of failure	0.49	2.90	0.54	2.64	0.55	3.55

Table 2 - Synthesis of results of seismic testings

Stage / Max. results	Quasi-elastic	Appearition and development of crackings	In vicinity of failure
a_o (m/s^2)	2.81	4.75	6.50
a_5 (m/s^2)	5.72	10.06	12.10
d_5 (mm)	29.80	50.66	63.30
$d_{\measuredangle\,marg.}$ (mm)	1.84	3.60	4.77
$d_{\measuredangle\,central}$ (mm)	2.11	2.91	3.00
$\sigma^{col.+beams}_{steel}$ (daN/cm^2)	Bottom of marginal columns at the 1st floor	Marginal beams are added to the 1st floor - in creep -	bottom column and floor beams are added at the 1st floor
$\sigma^{floor}_{concrete}$ (daN/cm^2)	2.2	11.4	14.20
$\sigma^{over\text{-}cast}_{concrete}$ (daN/cm^2)	1.7	10.1	12.80