STATIC AND SEISMIC MODEL BEHAVIOUR OF A NEW TYPE OF MIXED STRUCTURE FOR REINFORCED CONCRETE INDUSTRIAL STORIED BUILDINGS

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ABSTRACT - INTRODUCTION

The paper belongs to a large program of researches on storied industrial halls coordinated by the Design Institute for Standard Type Structures, in collaboration with pro.dr. doc. Alexandru Negoita from the Polytechnic Institute of Iassy.

The researches regarding the behaviour of a new model of mixed structure tested both statically and dynamically on the 140 tf shaking-table in Iassy, are briefly presented.

DESCRIPTION OF STRUCTURE

The prototype structure presents the following geometric and functional parameters: -spans: 2 x 12.00 m; bays:3 x 6.00 m; -levels: 3; -hights: 4.20 m for the groundfloor and the second level; 3.20 m for the third level; -livel:, -live and dead loadings: 1150 kgf/m^2 at current levels and 200 kgf/m^2 at the roof; -degree of design seismic intensity = 8 (scale M.M.).

From the constructive viewpoint,the structure is partiall prefabricated (current floor with longitudinal beams of "overturned T" type supported on cantilevers provided at columns and of π_t members with longitudinal beams and π members with tympanums); -the joints of the wet type members as well as the continuity of the longitudinal beams at the joints and that of the π_t members over the beams was achieved by means supplimentary reinforcing bars located into the overcasting and by overlapping the books extended from the prefabricated members. Weldings have been provided only at the support in front of the columns, at the π_t members and at the main beams as well as when joining the supplementary bars at the floor borders, in order to assure a high productivity.

Materials: concrete of B 300 quality and indigenous steels: OB 37, PC 52 and STMB.

Static scheme: - frames in both directions of the hall, the roof members being pin-ended on columns; continuity on the transversal direction and "unidirectional embeding" on the longitudinal direction at the other levels; - the floors realize a stiff slab for the vertical carying members.

The analysed direction was the transversal one, "Fig.1".

STRUCTURE MODELLING. TESTING METHODOLOGY. MEASUREMENTS.

The similitude principles of Froud type have been applied where a supplimentary hypothesis has been introduced, viz. the acceleration scale equal to 1.

Imposed scales: (model/prototype): lenghts $= \frac{3}{10}$, accelerations = 1, elasticity modulli = 1, volumetrie densities = 1.

Necessary deduced scales: specific elongations $= \frac{3}{10}$, time $= \frac{3}{10}$, unitary stresses $= \frac{3}{10}$ (on concrete and reinforcement), forces $= \frac{27}{1000}$ (both inertial and and gravitational ones).

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The action of the model in static range has been carried out in four different working stages: elastic, after crackings, iniation and development crackings and large cracking stage - in failure vicinity-For static testings a horizontal static force of 500 kgf has been gradually applied at the third level "Fig.2". The dynamic characteristics for microseisms and low-intensity shocks have been measured on transversal and longitudinal directions and in torsion "Tab.1". The seismic programme has been elaborated so that by increasing successively the intensity, the structure collapse has been achieved. In order to obtain the maximum response into an interval of frequences that corresponded to the tested model, several artificial earthquakes have been employed, D_2, B_2 and A_2 according to [1] as well as the record of natural earthquake occured in Romania 1977.

During the tests the horizontal dispalecements of levels, the accelerations as well as the angular variations beam-column at the central and marginal joints, and the specific elongations on reinforcement and concrete have been measured.

RESULTS, CONCLUSIONS AND RECOMMENDATIONS.

For static tests: (Fig.2") the sideway stiffness degradation has varied from 18% in the stage of cracking a-pearition up to 104 % in the stage preceeding the collapse, compared to the quasi-elastic stage. To theese degradations the corresponding remanences of displacements were 6 % and 20 % respectively. The static relative displacements between the levels haue been maximum in the stage preceeding the collapse at the groudfloor and at the second floor. The pattern of the static lateral deformed shapes has been specific to a framed structure and the curvature variation in theese deformed shapes have emphasized the modifications of the sideway stiffnesses of the structural members especially at the levels 1 and 3, in failure vicinity.

Variation of dynamical characteristics ("Tab.1"). Up to the concrete micro-cracking, the transverse period has increased with 8 % and the percentage in the critical damping with 42 %. In the stage of large crackings theese characteristics increase with 12 % and 62 % respectivelly and in the failure vicinity with 41 % and 96 % respectivelly, when compared to the quasi-elastic stage. The longitudinal periods on the direction perpendicular the actioning direction have incresed within the three working stage with 2 %, 6 % and 23 % as compared to the elastic stage.

At seismic range testings ("Tab.2" and "Fig.3"). The working stages along the test sequences have been established at the following levels of bazic accelerations of the shaking-table. 4.24 m/s^2, 5.83 m/s^2 and 7.95 m/s^2. In the elastic stage the structure has oscillated in the fundamental mode, in the stage of initiation and development of the crackings it has oscillated in the mode I over which the mode II has superposed in some situations. The stiff slab effect in that energetic level of actioning has been weakened, the floor over the ground-level presenting some large relative-displacements. In the stage that preceeds the failure, the oscillation shapes show a combination of modes. Some marked degradations have appeared especially at the ground-floor and at first floor levels. In the first level floor slab the ground-floor some marked crackings of the ribs and beams have appeared, especially on the boundary. The angular variation of the beam-column joinings has emphasized the disadvantageous manner of working of the marginal joints and especially that of the corner ones.

The cracking manner: The first crackings have appeared in the upper part of the columns, at the ground-floor. Further on, the ribs of the π members have got crackings that have also extended to the first floor. Some tendencies of dislocating the concrete have been noticed to the frontons and to the corner columns ("Fig.4"). The pannel zones of the joinings have maintained uncracked and the overcasting has had a good cooperation with the floor-elements.

The experimental model has had a satisfactory behaviour in the seismic testings at a level corresponding to the 8^{th} degree of intensity.

Recommendations: Improving the connections of the fronton frames and especially of the corner columns to the floors. Improving the connections of π floor-elements to the transverse beams and providing a proper solution for over-casting rein-forcement in the supporting areas of the floors. Reducing the variation of the concrete cross-section areas of the columns along the vertical line. Increasing the side-way ductility of the corner columns. It is not advisable to use the structure in zones exceeding the 8^{th} degree of seismic intensity (scale M.M.).

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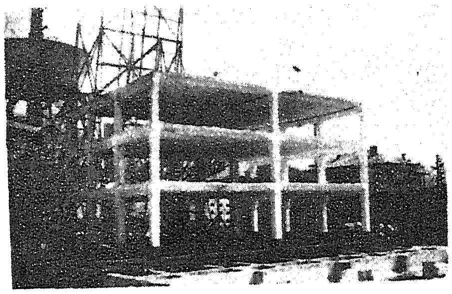

Fig. 1- Ensemble view.

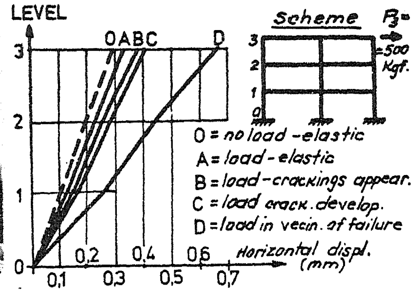

Fig. 2 - Static deformed shape - model -

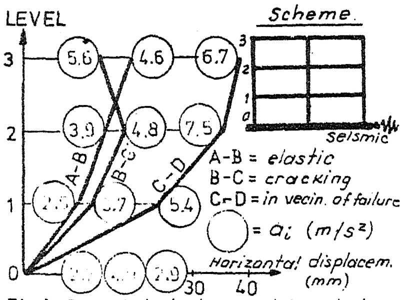

Fig.3 Dynamic instantaneau deformed shape-model- and level of accelerations.

Fig. 4 - Detail of joint cracking.

Table 1 — Dynamic characteristics - model -

Stage		Transversal		Longitudinal		Torsion	
		T (sec)	ν (%)	T (sec)	ν (%)	T (sec)	ν (%)
Non loaded		0.173	0.98	0.208	0.84	0.209	1.00
Loading	Non cracked	0.246	0.90	0.298	0.81	0.295	1.07
	Appearition of crackings	0.261	1.27	0.303	0.86	0.304	1.15
	Development of crackings	0.273	1.46	0.316	1.05	0.316	1.23
	In vecinity of failure	0.345	1.76	0.369	1.70	0.367	1.40

Table 2. Synthesis of results of seismic testings

Max results / stage	Quasi - elastic	Appearition and development of crackings	In vecinity of failure
a_o (m/s^2)	4.24	5.63	7.95
a_3 (m/s^2)	6.48	7.34	11.86
d_3 (mm)	13.73	20.18	48.65
$d\ \sphericalangle_i$ ext. (mm)	0.63	1.68	5.27
$d\ \sphericalangle_i$ int (mm)	0.49	1.18	1.98
$\varepsilon^{steel}_{max}$ -	$1{,}036 \times 10^{-6}$	$1{,}373 \times 10^{-6}$	$2{,}932 \times 10^{-6}$
$\varepsilon^{concrete}_{max.compr.}$ -	440×10^{-6}	589×10^{-6}	$1{,}542 \times 10^{-6}$
$\varepsilon^{concrete}_{max.tension}$ -	236×10^{-6}	270×10^{-6}	$1{,}485 \times 10^{-6}$