EARTHQUAKE RESISTANT DESIGN OF TWENTY ONF STOREY PREFABRICATED LARGE PANEL BUILDING

by

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INTRODUCTION

In order to define the seismic stability of a selected relatively high prifabricated large panel structural system, and according to the contracted obligations, the Institute of Earthquake Engineering and Engineering Seismology, Skopje, Yugoslavia, carried out detailed experimental and theoretical investigations providing construction of several appartment buildings in this structural system.

Engineering-seismological investigations were carried out on the selected Zemun-Beograd site for the purpose of the seismic effect definition in intensity and time duration. At the same time, experimental forced-vibration tests of embeded piles and foundation structure fragments were carried out.

Since a similar large panel building has been constructed on identical site conditions, full-scale forced-vibration tests were carried out on a 17-storey building in order to adopt the mathematical model of the system and use it in the preliminary analysis of a 21-storey building.

The results obtained by the full-scale analysis show that the joints of the considered system should be improved. The strength and the deformational properties of new joints were defined by experimental quasi-static full-scale tests.

On the basis of all these investigations, the mathematical model of the system, the soil-structure interaction as well as the seismic input data were finally defined.

Static and dynamic linear and non-linear analysis of the structural members and the system in general, considered as a three-dimensional one, was carried out.

The concept of monolith storeys as largest energy absorbers was adopted in the construction of lower storeys, providing suitable ductility capacity without strength and deformability deterioration.

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Note: In the work on this complex research project also took part a great number of the research staff members of the Institute as:J.Petrovski. B.Simeonov, D.Jurukovski, M.Stojkovic, N.Naumovski, etc.

Five such structures are already in the final stage of construction. A full-scale test is carried out on one of these structures, and correction is made between the results of the full-scale forced vibration tests and the results of the mathematical model analysis for definition of the elastic behaviour.

Design Problem

The existing structural system was not considered as suitable for construction in seismic zones regarding both its structural concept and height, especially for more than 20 storey height. Therefore, the research staff has suggested a programme of complex experimental-theoretical research for definition of an earthquake resistant system suitable for the particular site (Fig.1).

Starting from the proposed architectural design,concept, number of stories and production technology of the prefabricated system, an optimum solution of the structural system was searched, which would satisfy both safety and rationality criteria (Fig.2,3).

Definition of Earthquake Effects

The seismic parameters to be used in the design of the above structures were defined from the seismotectonic data of both closer and wider site area, and physical-mechanical properties and dynamic characteristics of soil surface deposits. Also, ground motion time histories i.e. analytical accelerograms having predominant periods which correspond to the size of the expected magnitudes were defined. A normalised ground acceleration spectrum of El Centro 1940, component N-S, was used. The expected maximum ground acceleration for the exploitation period of the structure and probabilistic criteria of frequency of occurence, were evaluated for 0.15g.

Soil-Structure Interaction Parameters

The physical-mechanical ground characteristics showed that pile foundation would be most appropriate. For the purpose of the definition of the design parameters, experimental dynamic and static tests of embeded piles were carried out. The tests were carried out on single and sets of piles under horizontal excitation. The soil-structure interaction parameters were defined which enabled mathematical model formulation under dynamic effects and foundation-structure interaction.

Structural Parameters

By detailed analysis of more variant solutions improvement of most important structural connections was achieved. By monolithization of the vertical panel joints was provided verticality of the wall panels. The floor structures are supported by the lower vertical panels, monolithically connected with horizontal belt courses. (Fig.4,5).

The structural system consists of three types of walls in longitudinal and twelve types of walls in transversal direction. The stiffness and strength characteristics and the nonlinear behaviour of joints and connections were defined experimentally following particular experimental research programme, applying quasi-static testing of vertical and horizontal structural connections.

Using two low frequency electro hidraulic pistons full-scale tests of 16 assemblages of connections were carried out for definition of their mechanical characteristics, ultimate strength capacity and the P-δ diagrams. Fig. 6 gives a hysteresis loop of vertical connections with scheme of load application.

Mathematical Model Analysis and Analytical Results

Applying structural parameters, complex mathematical model analyses of the structure, including static, dynamic, linear, nonlinear - both plane and three dimensional space analysis were carried out. The optimum structural solution was surched by trial procedure i.e. repeating the process of analysis several times. The computation was done by an IBM 1130, PDP 11/45 and CYBR 72-24 computers, using a programme for three dimensional analysis of building systems - TABS, the programme of the Institute VIBR4, etc.

Beside the stress analysis, safety was defined taking into account the maximum deformations, deformation time history, required ductility, number of cyclic displacement within structural members and time histories of acceleration, relative storey velocity and energy balance.

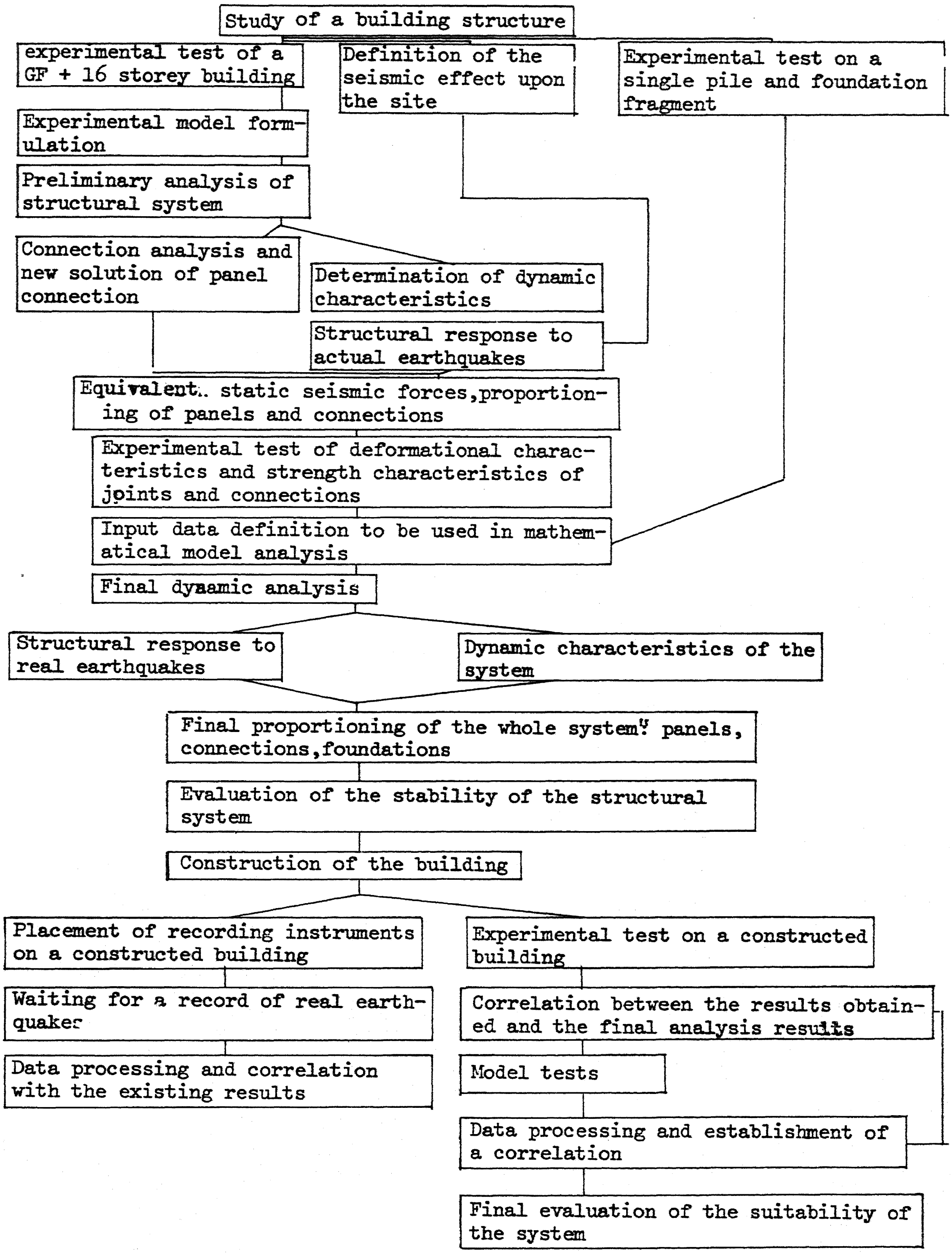
Figs 7 and 8 give graphical presentation of analytical results i.e. response of the mathematical model of structure.Linear and nonlinear structural responses for different shapes and intensities of earthquake effects are presented. Also, mathematical model of foundation was analysed including soil - structure interaction problem.

The results obtained by experimental and theoretical analysis show that under no circumstances cracking or nonlinear shear deformations (brittle failure) would occur in structural members, under expected earthquake effects due to the large shear strength capacity of the structure. (Fig.9).

The system and the structural members are subjected to nonlinear deformation due to bending moments which provides a good prerformance of all plastic zones and hinges within the system both for maximum deformations and cyclic dynamic earthquake loads.

The size of nonlinear deformations, required ductility factor and the stress state necessary for elastic work of the system show that the system satisfies completely the safety criteria for gravity and seismic loads.

The results obtained from full-scale study of the completed structure show that the structural system both as concept and realization has satisfied the required safety criteria. Also a good correlation is shown between the experimental and analytical rezults for performance of this system in the linear range.


Study of a building structure
experimental test of a GF + 16 storey building
Definition of the seismic effect upon the site
Experimental test on a single pile and foundation fragment
Experimental model formulation
Preliminary analysis of structural system
Connection analysis and new solution of panel connection
Determination of dynamic characteristics
Structural response to actual earthquakes
Equivalent static seismic forces, proportioning of panels and connections
Experimental test of deformational characteristics and strength characteristics of joints and connections
Input data definition to be used in mathematical model analysis
Final dynamic analysis
Structural response to real earthquakes
Dynamic characteristics of the system
Final proportioning of the whole system: panels, connections, foundations
Evaluation of the stability of the structural system
Construction of the building
Placement of recording instruments on a constructed building
Experimental test on a constructed building
Waiting for a record of real earthquake
Correlation between the results obtained and the final analysis results
Data processing and correlation with the existing results
Model tests
Data processing and establishment of a correlation
Final evaluation of the suitability of the system

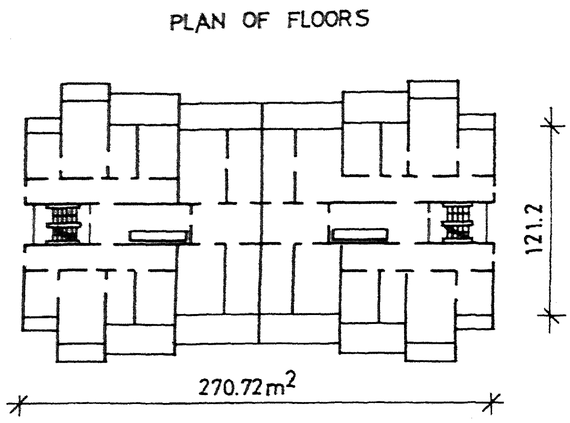


Fig. 2

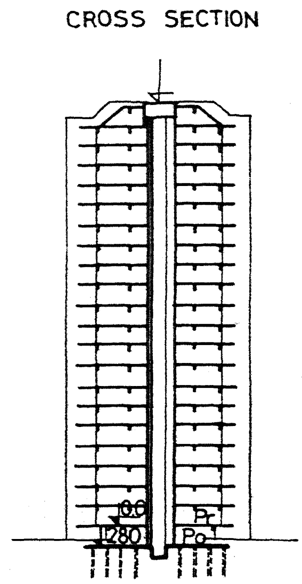


Fig. 3

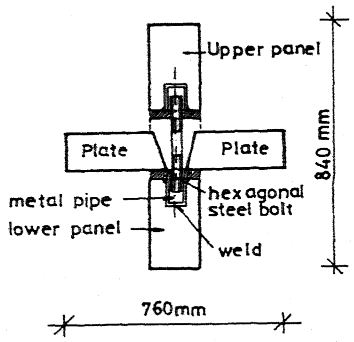


Fig. 4 DETAIL HORIZONTAL CONNECTION TYPE B_{II}

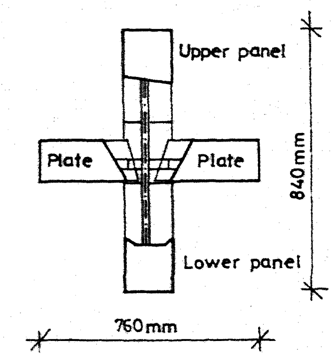


Fig. 5 DETAIL OF HORIZONTAL CONNECTION TYPE B_I

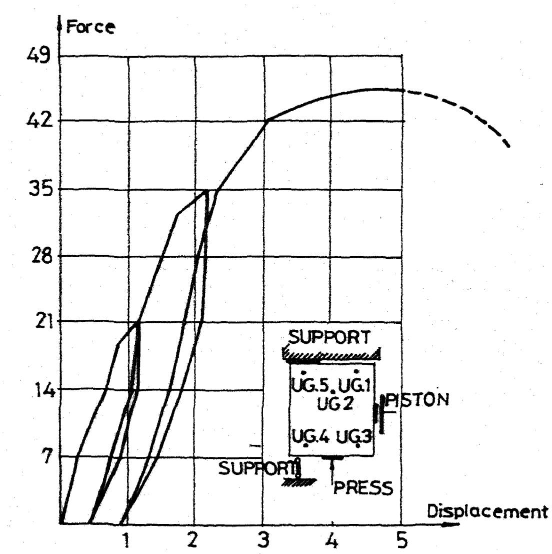


Fig. 6 P-δ RECATION OF A_3 MEMBER

STRUCTURAL RESPONSE
(Max recative floor displacements)
TRANSVERSE DIRECTION

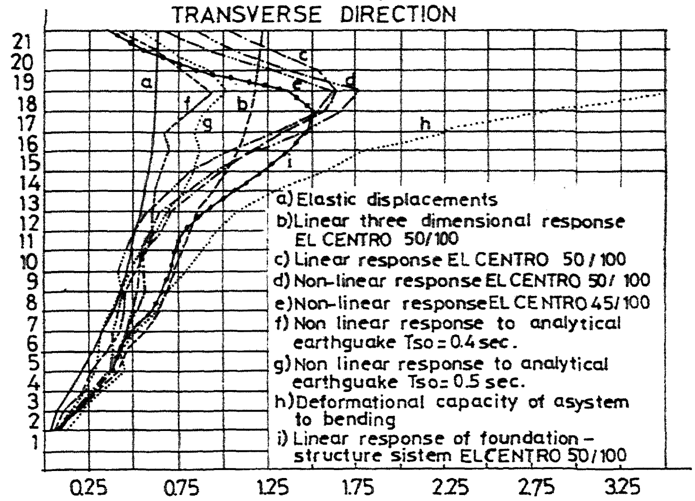
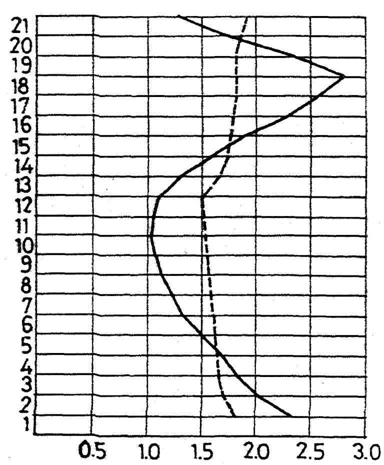


Fig. 7

REOUIRED DUCTILITY AND PSEUDO DUCTILITY FOR STRUCTURAL RESPONSE OF EL CENTRO 50 100 EARTHOUAKE

1. TRANSVERSE DIRECTION

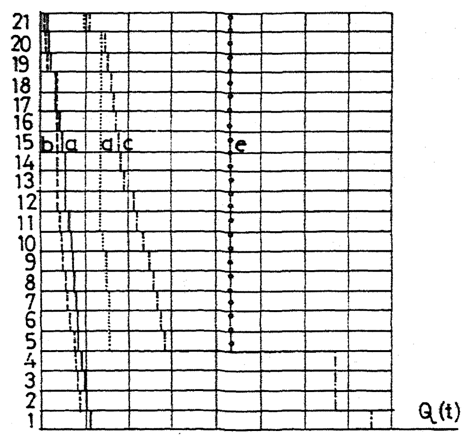


a) Ductility
b) Pseudo ductility

Fig. 8

FLOOR SHEAR STRENGTY

1. TRANSVERSE DIRECTION



a) Reguired transverse strength for linear three-dimensional response for el centro 50/100
b) Reguired transverse strength for non linear response for el centro 50/100
c) Shear strength capacity with vertical
d) Coading shear strength capacity without vertical loading
e) Experimental ultimate strength up to inital larger cracks occurence

Fig. 9