THE RESEARCH INTO THE EARTHQUAKE-PROOF CAPACITY OF IN-SITU CONCRETE FRAMELESS RESIDENTIAL BUILDINGS BY VIBRO-TESTS OF THE LARGE-SIZE REINFORCED CONCRETE MODEL

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SYNOPSIS

The report deals with the objectives,methods and results of static and dynamic tests of a large-size 10-storey model of a frameless building, built from in-situ concrete on a natural soil foundation.

A brief descriprtion of the model structure and methods of its erection is given. The results of the model design considering the actual physical and mechanical characteristics of srtuctural materials and yielding of the soil foundation are shown. The joint behaviour of piers and lintels as well as the interaction between the model and its soil foundation under variously intense horizontal inertia loads applied by means of vibrators is analysed.

INTRODUCTION

The growing of construction of frameless in-situ r.c. public and residential buildings in seismically active areas of the USSR and the increase in their height has demanded the provisions for their reliable earthquake resistance along with the reasonable expenditure of materials for bearing srtuctures, mainly of reinforcing steel and concrete. The research into the behaviour of building structures suffering earthquake loads are carried at the Central Research & Design Institute for dwellings (TSNIIEP zhilischa) in three lines: theoretical research,tests of life-size buildings and their structural components, tests of large-size models.

STATIC AND DYNAMIC TESTS

The tests of a 10-storey model have been aimed at study-

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ing the features of actual performance of frameless r.c. buildings under forces of diverse nature and intensity and at developing more accurate design methods and calculation techniques, including design schemes at various behaviour stages. The erection of the model on a natural soil foundation also made it possible to study the intraction between the supporting structure system and soil foundation.

The model represented a section of the buildinf with load-bearing cross- and internal longitudinal walls built in the 1/4 life-size scale (Fig.1). The model dimensions in plan were 3.3 m x 3.34 m, the height being 7 m. The thickness of walls and floors was made 4 cm according to the adopted scale of geometric dimensions.

The areas of the in-situ r.c.cross-walls along both sides of an internal longitudinal corridor were joined by means of in-situ r.c.lintels thus creating cross load-bearing membranes.In-situ r.c. floor-slabs acted as horizontal membranes. The foundation of the model was a solid r.c.slab.

The model walls and floors were reinforced with flat welded meshes, and the lintels - with flat welded cage-like frames. The main reinforcement, i.e. the meshes and cages, was made of hot-rolled steel with rated resistance 2100 kgf/ per sq.cm.

The preliminary approximate design oa the model was made as if it was for a life-scale building with due consideration to vertical services and horizontal earthquake loads.

The rigidity and dynamic parameters of the system were defined taking into account the flexure and shear of structures assuming their behaviour being at an elastic stage and allowing for the foundation yielding under rocking vibrations. The initial characteristics were the modulus of deformation of the model concrete E_c equalling 140.000 kgf/sq.cm, and the co-efficient of foundation rigidity K_φ calculated for the soil of standard compressive strength 2 kgf/sq.cm.

The period of the first tone of rocking vibrations in the transverse direction was 0.195 sec which corresponded to the frequency of 5.1 hertz.

The carrying capacity of the model at an elastic stage was provided, in line with the preliminary design, for the earthquake load of no less than 8 MSK-64 points.

The moulding of the model structures was made by means of metal progressive gang forms.

The model was tested under horizontal both static and dynamic loads. Separate fragments of the model, too, were put under static tests which made it possible to analyse the effect of various structural factors on the behaviour of the system as a whole.

Static tests of the model were made by means of a frame--strainer. Horizontal loads were applied on the floor level. At the end of static tests the total horizontal load was increased up to the half of the design load, i.e. it was equivalent to 7 MSK-64 points in total transverse force applied at the upper level of the foundation slab. Under this load, as well as under less ones, the non-linearity of structural deformation was but small indicating their behaviour at the elastic stage.

Vibrators designed at TSNIIEP zhilischa were used for the dynamic tests. During these tests the dynamic parameters of the system, including the nature of vibrations, were determined and the nature of joint performance of structural elements as well as the interaction of the model and its soil foundation was studied as dependable on the intensity of force.

The vibrator was placed on the top floor of the model.

The first series of tests was made using a low-capacity vibrator, the second series - using a high-capacity vibrator.

The process of changes in the nature of interaction of the model and its soil foundation can be conditionally divided into three stages. At the first one the behaviour of all the structures was at the elastic stage while the soil under boundary zones of the foundation slab was partially compressed due to elastic- plastic deformations. The initial parts of the graphs for rigidity parameters correspond to this stage (Fig.2).

At the second stage, owing to the fractures that resulted from the breaks in concreting of joints between the slabs and the walls, a non-linear decrease in the rigidity of the system took place both in the footing and structures.

As the result of the irreversible densification of the ground the footing acquired a somehow rounded shape that led to the formation of a new residual surface and to the increase of the break-off area in the footing.

At the third stage oblique cracks appeared and developed in the walls of the ground and first floors.The further increase in the load resulted in the failure of concrete in the wall/foundation joining area,and then concrete splintered at the extreme areas of the ground floor walls and cracks also formed in the walls of two lower floors over their whole surface.Thus the integrity of walls was broken and the deformability of the model greatly increased.This was the major cause of the fact that non-linearity of the system behaviour continued to grow even to a greater extent than at the former stages.

By the moment the inertia load maximally grew,the first tone frequency of the system natural vibrations, amounting to 5 hertz at the beginning of tests,diminished 2.63 times as compared to the initial one, and the amplitude increased 33 times as shown in the charts, Fig.3.

A substantial reduction of the modelrigidity and of the whole system stiffness changed the nature of dependence between the amplitude and the inertia load: an ascending branch of the curve was replaced with a descending one. This major change reflected the process when despite the increase in counterweights on the vibrator and the growth of vibration amplitude of the model top,the total inertia force was already not growing but diminishing.Earlier such a phenomenon was prognosticated theoretically.

The loss of the carrying capacity of the system occured owing to the failure of the model ground-floor walls under cyclic loading,when in the boundary zones of piers an eccentric tension, which caused the failure of concrete in piers,alternated with an eccentric compression, that led to concrete splintering and reinforcement buckling.

CONCLUSIONS

1. Construction joints in walls, having been formed after the breacks in concreting at cyclic erection of walls and floors, contributed to the deformability increase of the model in-situ load-bearing structures.The same joints of the model lower floors were the zones of local damage (cracks).

2. Lintels were the most vulnerable elements in the model of the frameless in-situ reinforced concrete building. The first cracks appeared in lintels earlier than in other elements of the structure.

3. The non-linearity of the behaviour of the whole system increased with the growth of horizontal inertia loads.The extent of the non-linearuty effect upon the behaviour of the foundation or of the structure itself varied due to the irregular development of non-elastic processes in them depending on the amount of horizontal inertia loads.

4. As regards the load-bearing capacity, the limit state of the "building/soil foundation" system may depend on the fact whether the carrying capacity of super superstructure is exhausted,which is the reflection of their rigidity parameter relation.

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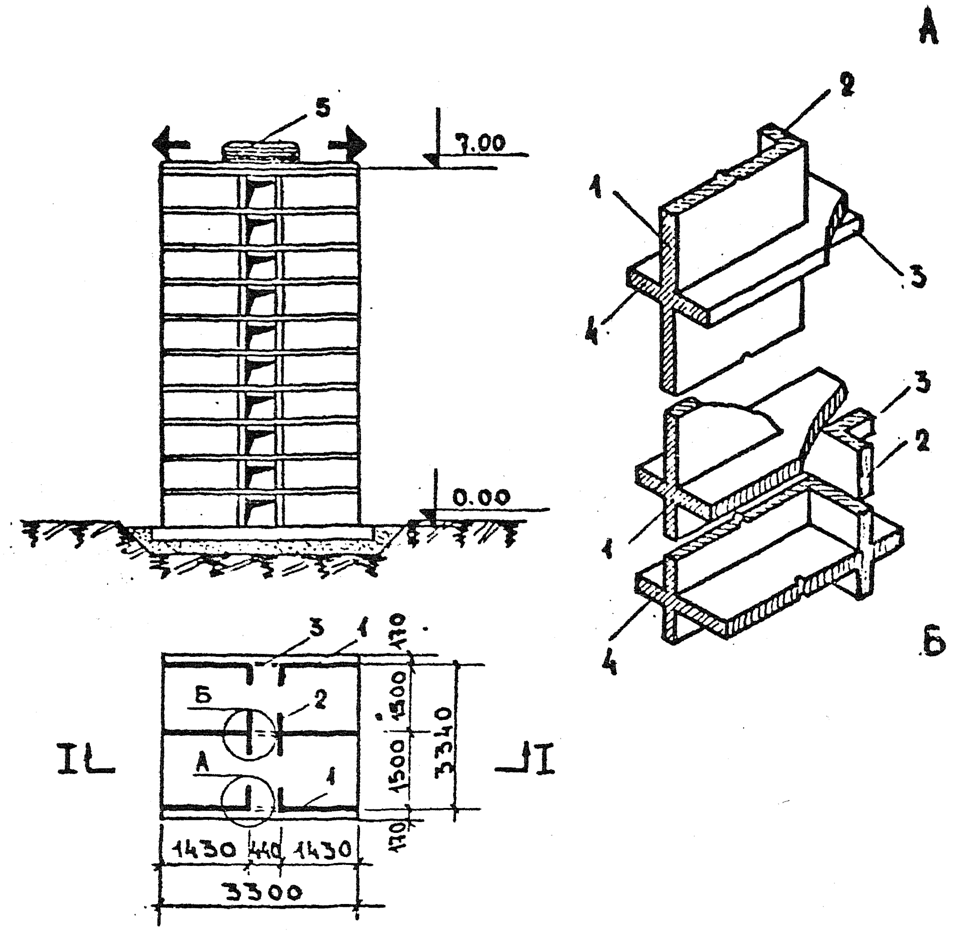

Fig. 1. General view and structural nodes of the model
1 – transverse walls,
2 – longitudinal walls.
3 – lintels,
4 – floors,
5 – vibrator

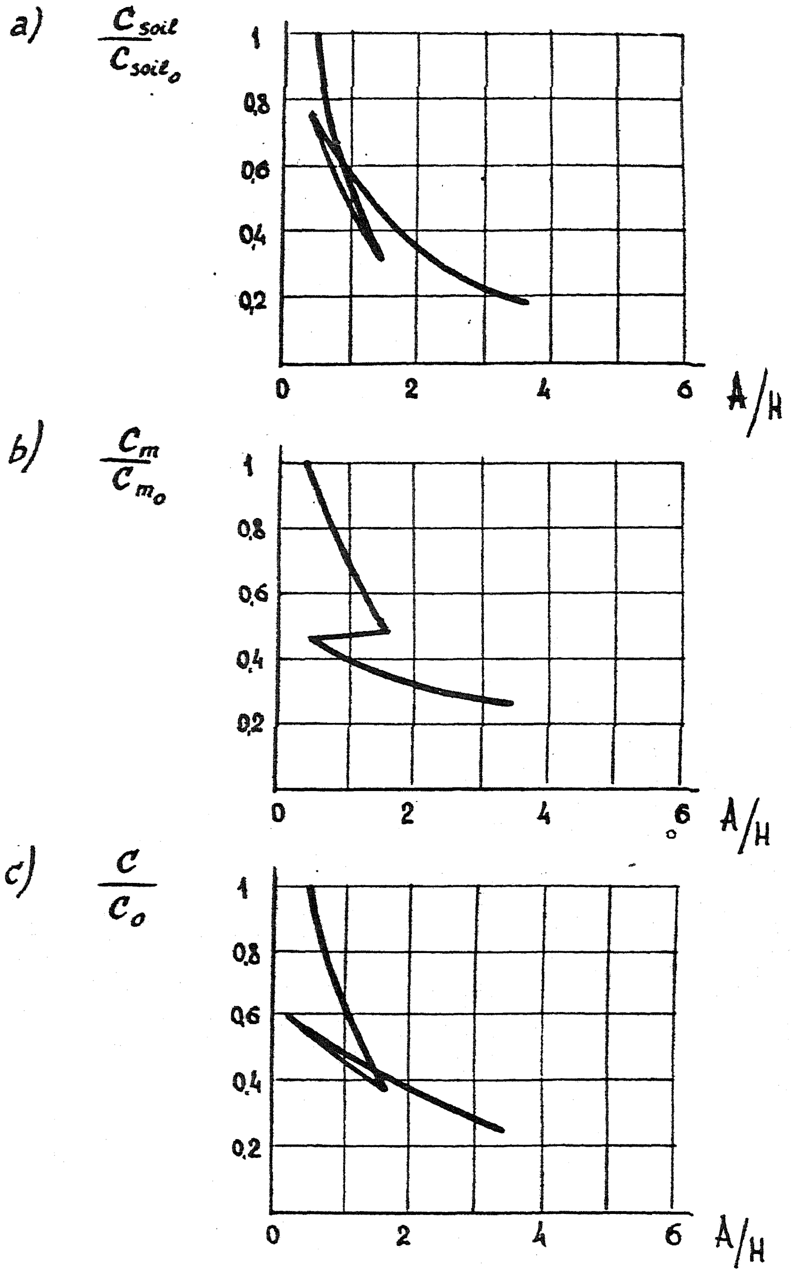

Fig. 2. Charts for rigity parameter variations of the System: a - soil, b - model, c - „model-soil" system.

C_{soil}, C_m, C – rigidities of the soil, the model and a generalised rigidity of the „model-soil" system;
C_{soil_o}, C_{m_o}, C_o – their initial values, respectively;
A – amplitude of the model top;
H – model height.

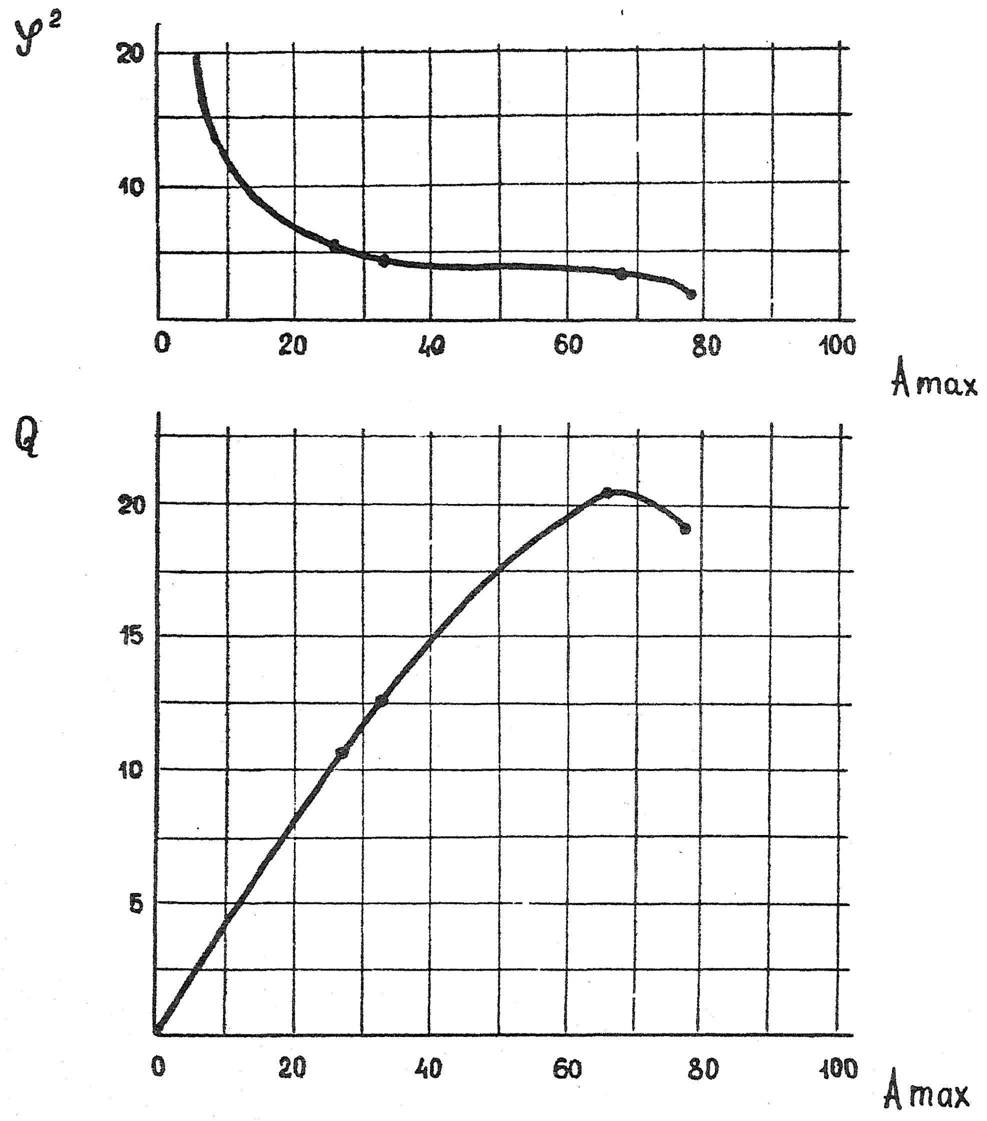

Fig. 3. Relationship between $\varphi^2 - A_{max}$ and $Q - A_{max}$.

φ – resonance frequency of vibrations;
A_{max} – amplitude of vibrations of the model top;
Q – total inertia force acting in soil foundation.