STATIC AND DYNAMIC TESTING OF STRUCTURES WITH SEMI - RIGID CONNECTIONS

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Summary

The influence of semi-rigid structural connections on the static effects and dynamic characteristics of typic prefabricated construction "MINOMA", developed at the Civil Engineering Faculty in Niš, Yugoslavia, is discussed in this paper, based on the results of experimental testing and theoretical analysis.
Experimental tests has been carried out under static and dynamic load separately. This results are in close agreement with obtained analytical values.

1. Introduction

Researches carried out on the Civil Engineering Faculty in Niš, Yugoslavia lasting several Years have led to quite new system of typic reinforced concrete prefabricated structure called "MINOMA".
This construction includes all advantages of prefabricated construction system, but is more economoical than similar ones known up to nowadays. As it is designed based on a new concept with semi-rigid connections and prestressing by means of a tie, it requires extensive investigations of long duration, both theoretical and experimental. Precision of some mathematical model parameters can be verified only by testing of considered structure. So, aforementioned structure has been tested under static and dynamic trial load and the results are presented in this paper.

2. Basic characteristics of structure type "minoma"

Carring structure is formed of straight precast concrete members wich are fixed in joints by means of either steel or aluminum connectors. The typic frame is supported so that the columns are fixed into prefabricated footings. The main characteristic of "MINOMA" structure is that joint stiffness is a little bit higher concerning the member stiffness.
Columns and beams are prestressed by adhesion, made of appropriate strength clas of concrete, with shaped crossection, reinforced byribbed bars.

The tie is made of high-quality steel wire according to IMS system (tendons 6 Φ 7 or 12 Φ 5 mm). Distance between frames is from 3m up to 6m, while columns lehgth is changeable and depends on hall purposes.
Roof covering can be of durisol, gas-concrete or clasic one consisting of concrete, timber or steel purlins.
Up to now, it has been investigated construction types: "MINOMA-1" span 12 m, "MINOMA-2" maximal span 20m and "MINOMA-3" up to maximal span 28 m.

3. Testing under the static load

Test under static load are based on Jugoslav code JUS U. M1. 047. Structure tests at the site have been carried out through two phases.
1st phase: Test up to elastic limit (serviceability limit).
2nd phase: Test up to failure (test of some members and substructures up to failure).
Static test have been performed through three phases of loading. Load which simulates dead load q=253 daN/m' was applied by means of ties which where fixed into reinforced concrete floor and into the contra-beam constructd in the plane of the frame. The tie forces where observed by maesuring strips with authomatic temperature compensation. Inictial force in the system tie was 83 kN.
Also, designation and disposition of measured cross-sections are shown in Fig. 1. and description of the construction is given in [7].

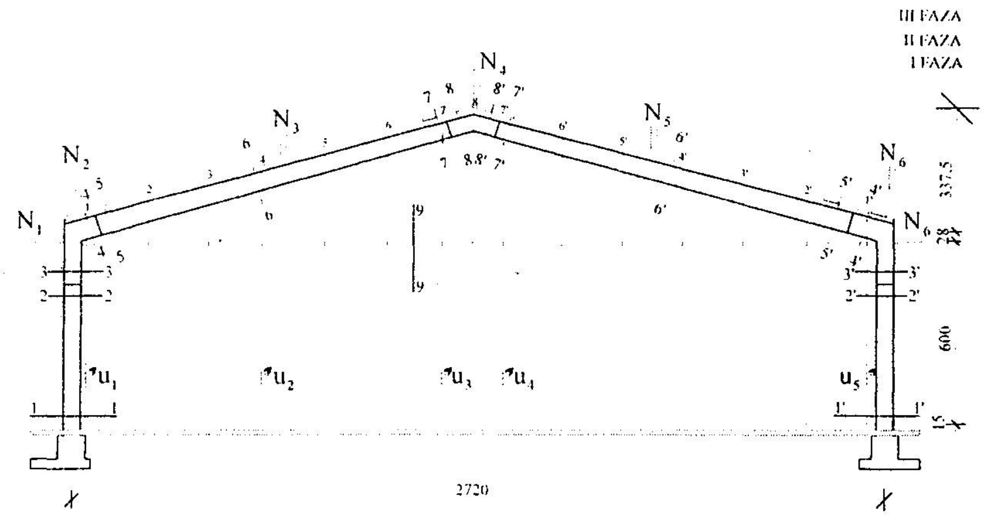


Fig. 1. Designation and distribution of measured cross-sections for static test

Measuring points along the frame where chosen at the sections with maximal static effects in order to be possible to observe them under trial load. Measuring instruments are placed according to principle"encireling of the section although the cross-section is symetrical one. Deflections were observed by means of survey instruments as well as by the following measuring instruments:
-measuring strips LY 10/120 and 100/120 Hottinger Baldwin
-deformeters with base L=250mm, p=4,0x10^{-6}mm/mm
-dilatometers with base L=190mm, p=5,1x10^{-6}mm/mm
-klinometers with scale precision p=1 s
-deflectometers with scale precision p=0,01 mm

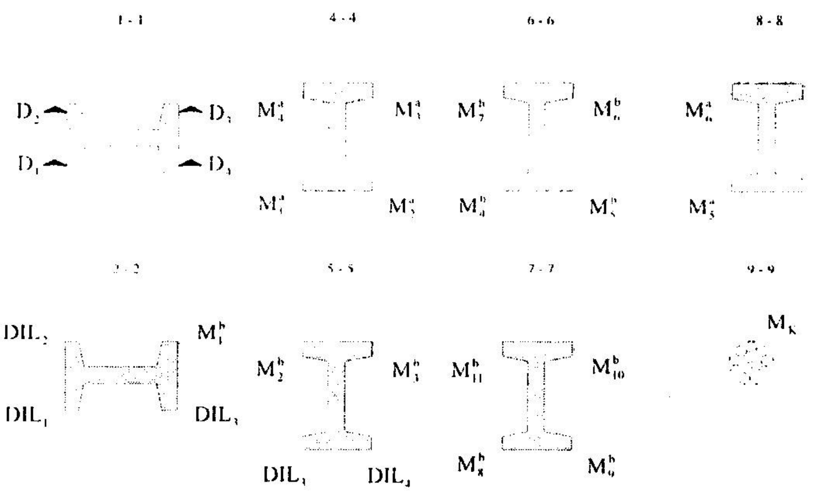


Fig. 2 Designations and distribution of measuring instruments at the cross-sections

3.1 Results of static testing

The results about stresses, and deflections based on the measuring data are given in [8]. Bending moment diagram obtained on the base of test data is included in Fig. 4.
These values are olso calculated according to slope-deflection method by use of STRESS-program and compared with corresponding obtained by testing. Agreement is not satisfyng, in addition to everything else, constitutive equations of slope-deflection method according to STRESS-program do not include elasticity of connections of some members in joints.
So,according to expressions of mentioned refined theor derived in [8], based on experimentaly determined fixing degrees of connections column-foundation and column-beam, bending moments due to dead load and applied load are calculated for the structure shown in Fig. 3 taking in account the real stiffness of these connections.
Effects of uniformly distributed load with intensity q=253 daN/m' and applied tensile force into the tie S=0,80Z=66,40 kN are calculated separately and after that they are summed. Initial force in tie 83,0 kN is reduced 20% because of loss during prestressing of the structure. According to previously given measuring data, fixing degree of connection column-to-foundation is μ_{ik}=0,4 and of connection column-to-beam μ_{ik}=1,0. Bending moments diagrams with analyticaly obtained values are given in Fig. In the final bending moments diagram, values calculated on the base of test data are given in brackets.

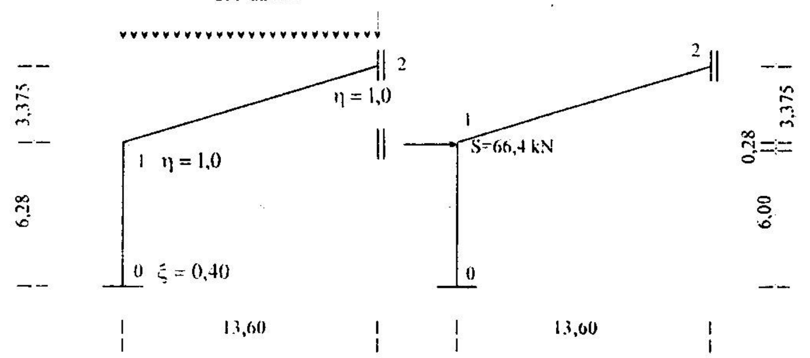


Fig. 3 The structure subjected to applied load and to the tie force

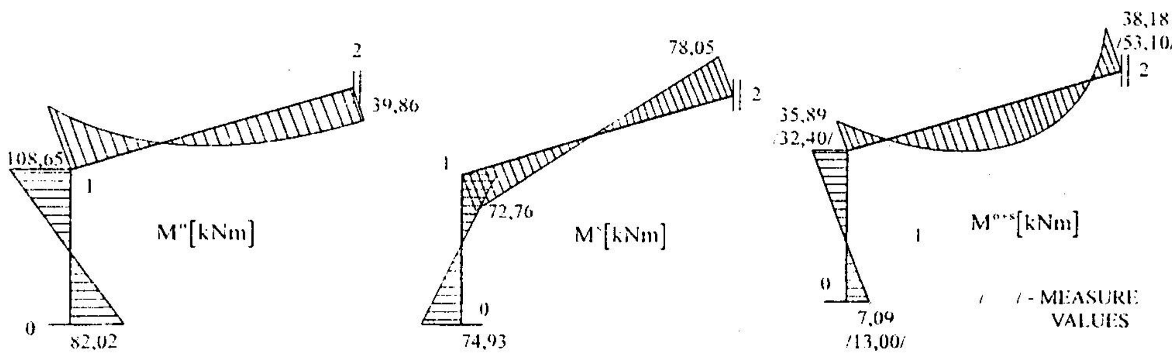


Fig. 4 Bending moment diagrams due to: a) applied load, b) tie force, c)summ under a) and b).

4. Testing under the dynamic load

The purpose of dynamic testing of structures is to define its real dynamic characteristics, i. e. resonant frequencies of basic modes in horizontal and vertical direction, shapes of vibrations at this frequences, as well as corresponding coeficient of viscous damping. All of these parameters are the base for each mathematical modeling of a structure.

Experimental testing of dynamic characteristics of typic prefabricated structure "MINOMA-3" has been carried out applying the following experiment types:

1-Experiments with forced harmonic excitation

2-Free-vibration experiments

3-Experiments with ambient vibrations

Equipement for dynamic testing of structures in full scale consists of two basic systems that have to be compatibil each to other in the sense of diapason of frequent and amplitude composition. These two systems are: system for vibration excitation (Mechanical or electrohidraulical and registration system).

In the case of experiments with forced harmonic excitation, it was used the following equipment: Function Generator HP-3310A, Power Amplifier Model-114, Electrodynamic Shaker Model-113, as well as Kistler Accelerometer Model-305A, Kistler Amplifier Model-515, Spectrum Analyser Hp-3582A, Ploter Hp-7045B.

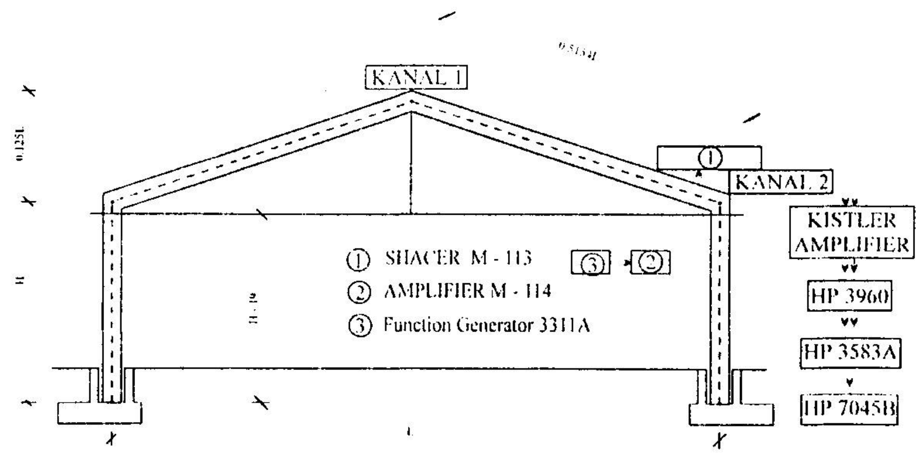


Fig..5 Functional presentation of measuring procedure of forced harmonic vibrations and free vibrations

Free vibrations have been generated in two different ways, so these experiments can be accomplished as:
-experiments with initial displacement,
-experiments when the external harmonic force is switched off.
In the case of experiments with ambient vibrations it was used the following equipement: Ranger Seismometer Model SS-1, Signal Conditioner Sc-1, Tape recorder HP-3960, Spectrum Analyzer HP-3582A I Ploter HP-7045B.

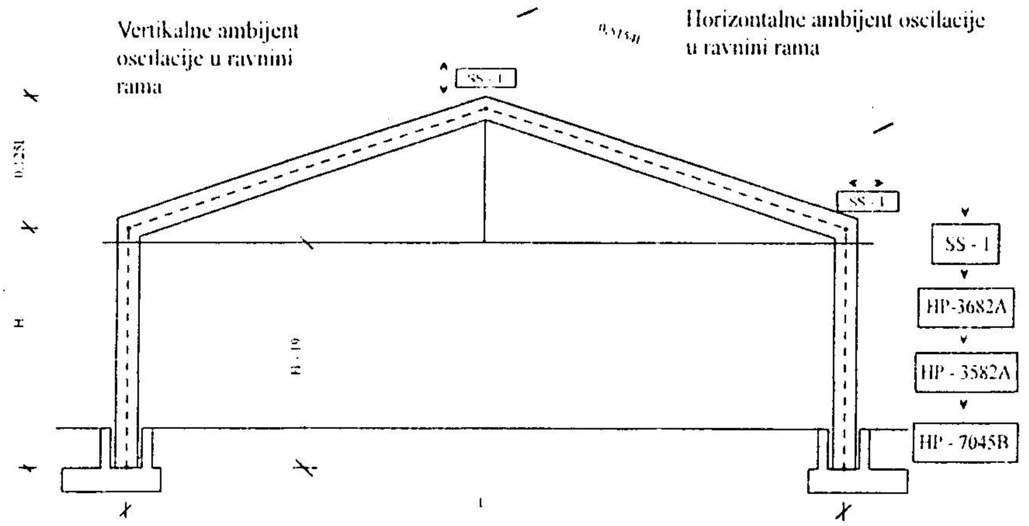


Fig.6 Functional presentation of measuring procedure of ambient vibrations

4.1 Results of dynamic testing

In the scope of detailed researches program, listed types of experiments have been performed. The results are given as time records of motion of material points of the structure and their mathematical processing in the form of amplitude spectrum (Furie transformation).

4.1.1 Experiment with forced harmonic excitation:

Functional presentation of the measuring procedure, applied equipment for measuring and generating of harmonic excitation are given in Fig. 5.
Obtained mode shape for horizontal direction of frame vibrations in plane is given in Fig. 7.

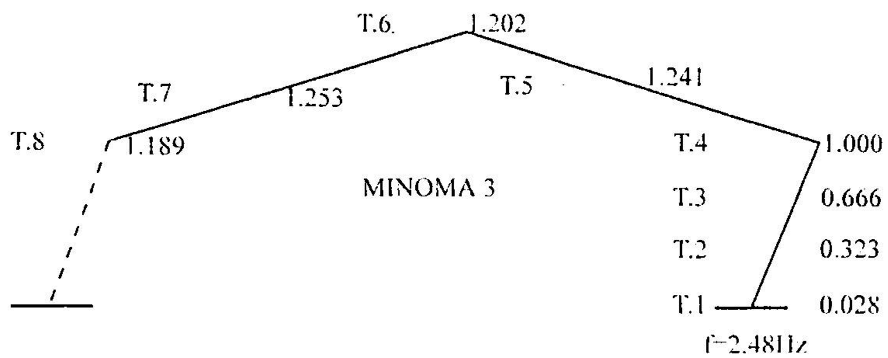


Fig. 7.

Time record of dynamic structure response and amplitude spectrum for horizontal direction is given in Fig. 8.

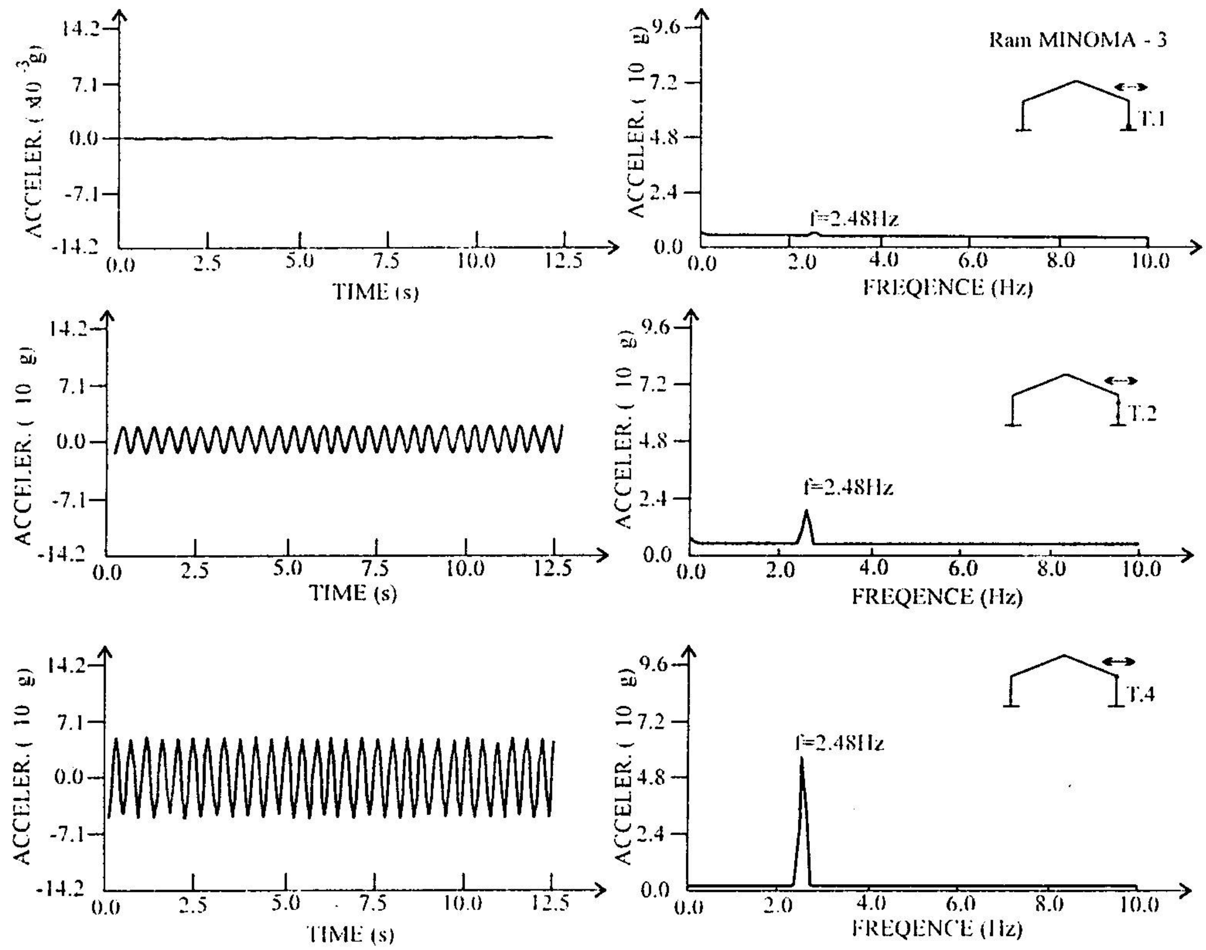
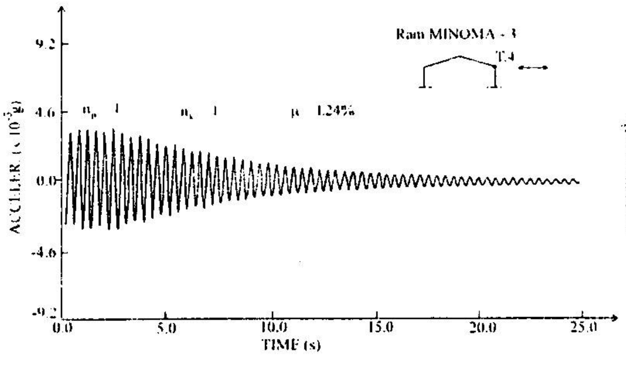


Fig. 8

Time record of harmonic decreasing functions and their amplitude spectra for horizontal vibration direction is shown in Fig. 9. and Fig. 10. This test was performed by sudden switching off the tie previously in the frame ridge.



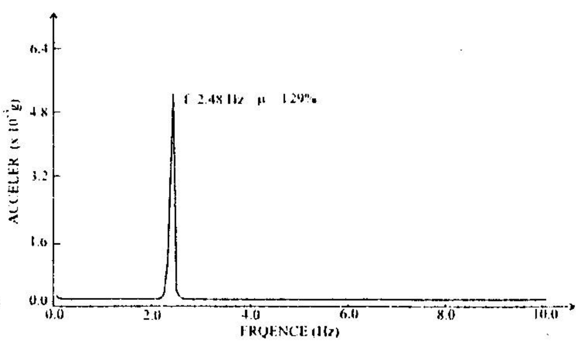
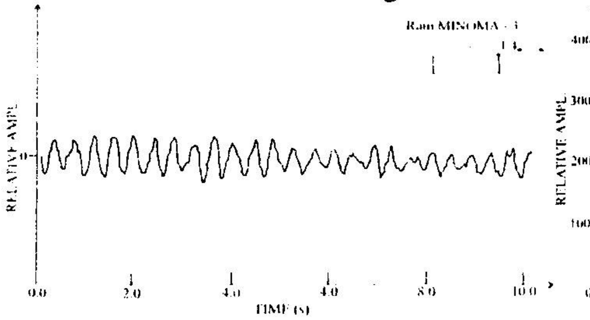


Fig. 9 *Fig. 10*

4.1.2 Experiment with ambient vibrations:

Functional presentation is shown in Fig. 6.
In Fig. 11 it is shown time record of ambient vibrations and their amplitude spectrum for horizontal direction and in Fig 12 For vertical direction of vibrations in the plane of frame.



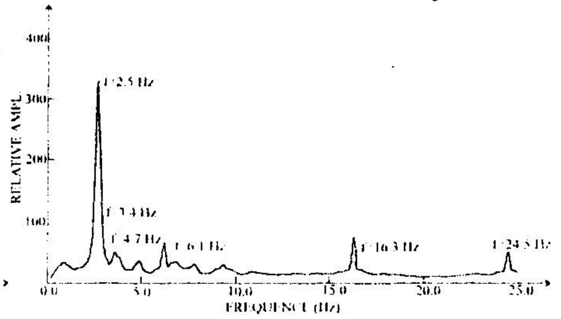


Fig. 11 *Fig. 12*

4.2 Calculating of frequencies for horizontal and vertical vibration direction

On the base of experimentally determined fixing degrees of connection column to foundation ($\mu_{ki} = \eta = 40\%$) and connection column to beam ($\mu_{ik} = \xi = 100\%$) bending moments are calculated, as well as circle frequencies for horizontal and vertical vibration direction, taking in account real rigidity of connections.

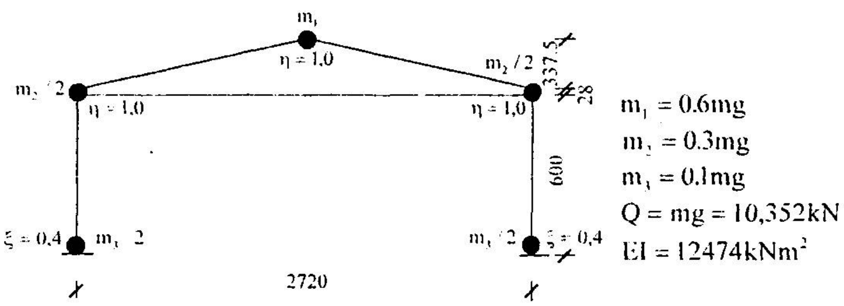


Fig. 13. Dynamically model of frame

Calculatedvalues of circle frequencies are: for horizontal direction ω_h=16.26 s^{-1} =2,58 Hz, for vertical direction ω_v=22,56 s^{-1} =3,59 Hz.

5. Conclusion

It can be concluded from obtained results that fixing degree should not be neglected, both in static and in dynamic design, and particularly it should be payed attention about that, in analysis of prefabricated constructions. At static and dynamic testing, prefabricated construction "MINOMA" has shown complex behavior whose details are not presented here. Experimental researches and numerical analysis of considered structure have confirmed already known data, but also have pointed out new ones, particulary in the case of prestressing by the tie, as well as in the case of design of structure with semi-rigid connections of members. Calculated values of circle frequencies, based on dynamic model of the frame (Fig. 13). are very closed to measured values for both directions of vibration ($\omega_{h,1} = 2,58Hz$ I $\omega_{v,1} = 3,59Hz$).

Obtained experimental results for dynamic characteristics represent the base for further experimental and analytical researches that would be carried out in order typical prefabricated system "MINOMA" security attest for all types of loading and influences according to available technical regulation. The first that follows will be testing of joints up to failure, as well as defining of design seismic characteristics (design spectra and design earthquake time histories of graund motion). Taking in consideration that in world literature and periodicals data about damping force (expressed in term of viscous damping) are poor for similar typic prefabricated structures, obtained results represents basic values for structural analysis under strong earthquake ground motions and for estimate of global seismic security.

The authors think that it is to be pointed out to the former circumstances in the corresponding regulations and supporting documents (comments or suggestions) because of missing the appropriate technical regulations for design and construction of the structures with members elastical fixed in joints at seismic regions.

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