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Full scale dynamic test of a two Storied Timber Frame Construction house using a 6-DOF Earthquake Simulator

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SUMMARY - A full scale dynamic test of a Timber Frame Construction was performed, using Earthquake Simulator 6 DOF. In spite of the heavy test conditions, no significant damage was recorded or observed.

KEYWORDS: Damping, dynamic test, earthquake simulator, earthquake resistant structures, eigenperiod, Kalamata earthquake (13.9.86), *timber frame construction.*

1. Introduction

A two storied Timber Frame Construction (T.F.C.) house was erected and tested using the six degrees of freedom Earthquake Simulator of the Laboratory for Earthquake Engineering, National Technical University, Athens, Greece. The scope and the purpose of the test was to demonstrate the earthquake resistance of simple wooden houses erected according to the Timber Frame Construction (T.F.C.) method.

Earthquake regulations are contradictory as far as the earthquake resistance of timber construction is concerned. In some codes, for example, timber constructions are favorized and in some others are penalized. This is due to the various kinds or types of timber construction, the different maintenance observed in various locations around the world, the various earthquake environments to which timber constructions have been exposed and the various foundation conditions.

The design of these types of structures is quite difficult, since, the analytical modelling becomes tedious, because of the inability to express the mechanical characteristics of the various structural elements and especially of their joints. The design and the construction of the most of the timber buildings are performed according to empirical rules.

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2. Description of the specimen

The dimensions of the specimen were choosen so that to exploit, at the maximum, the capacity of the earthquake simulator /1/. Nevertheless, the plan of the specimen may be considered as a module unit of a larger housing block.

The plan and elevation of the building are shown in Fig. 1. The dimensions of the plan are 3.6×3.6 m^2 and the height is 2.9 m (first storey) and 2.6 m (second storey). The Canadian Code of T.F.C. has been followed for the construction, while, as far as the dead and live load is concerned, the Greek Code is followed. In the outside face of the first storey and at the sides AB and BC (see Fig. 1, Picture 1 and 2) a plaster out of asbestos cement reinforced with plastic fibers was used, while at the sides CD and DA of the first storey (see Picture 3) the same plaster was used, but without the reinforcement mentioned above. The plaster was spread over a bituminous paper on which a chickennet metal was nailed.

In order to provide the dead and live loads specified by the Greek code for earthquake resistant structures, the following masses have been added:

180 kg/m^2 on the second floor and
80 kg/m^2 on the roof

using sacks filled with sand. The sacks were carefully tightened by means of heavy duty plastic ribbons on the underlaying wooden beams, (see roof in Picture 1 and ceiling of first storey in Picture 4). The sacks with the sand were distributed all over the available area of the roof and the second floor of the specimen. The total mass was 2330 kg on the second floor and 1040 kg on the roof.

3. Description of the test and the test results

It was decided to use the Kalamata earthquake (main shock) as a reference earthquake by which the specimen was excited along the three directions simultaneously, as it is shown in Fig. 2. In Fig. 3 the respective response spectra of the ground excitation are presented.

The main Kalamata earthquake struck the city of Kalamata on September 13, 1986 with a magnitude of 6.2 on the Richter scale and caused extensive damages to traditional and contemporary buildings. Most of the city turned to ruins in a minute, immediately after the shock. The epicenter was almost under the heart of the city, in a depth of about 5 km.

The specimen was equipped with a few accelerometers in order to register its response during the tests, as, partially, it is shown in Picture 4.

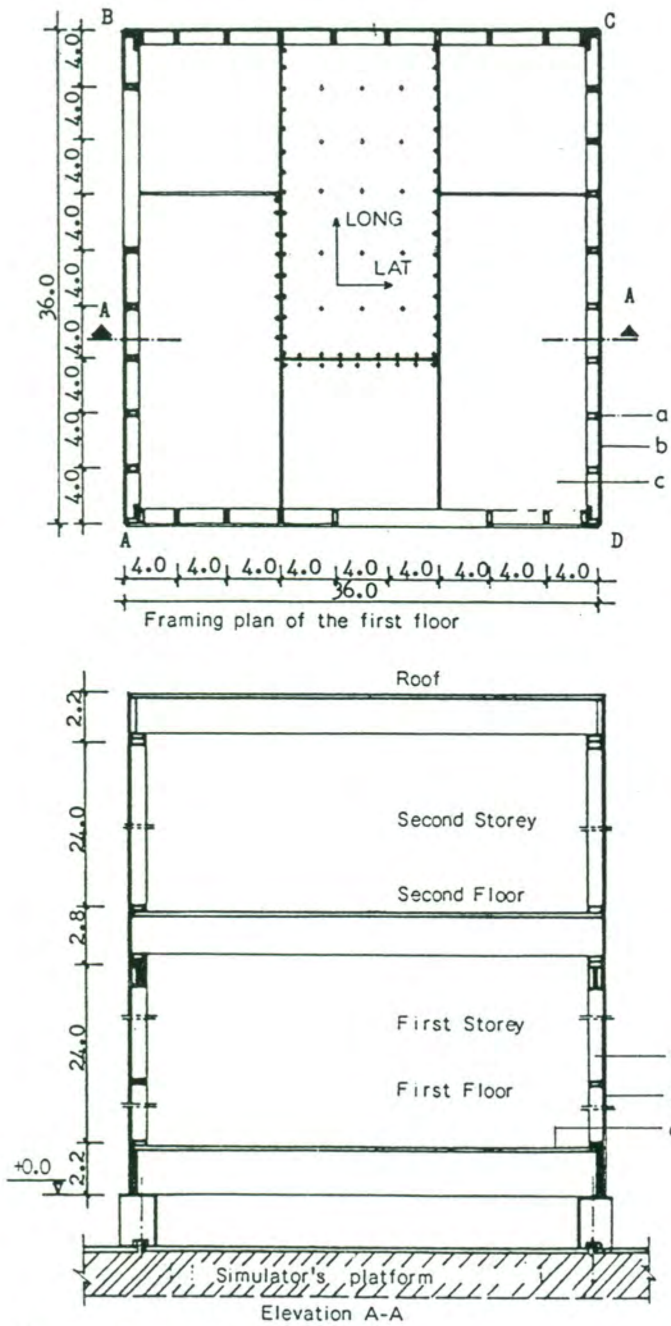
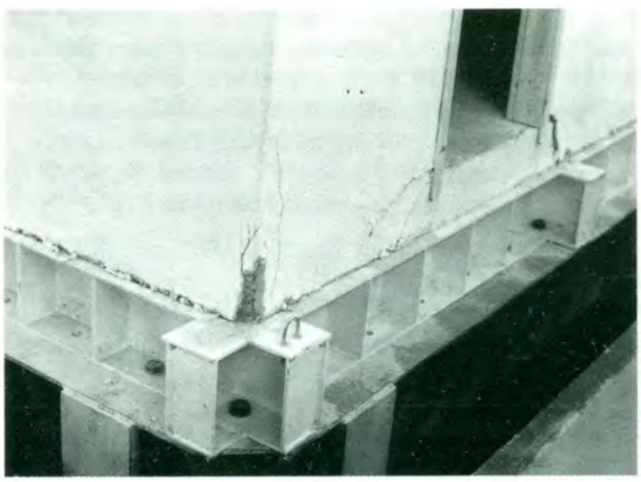
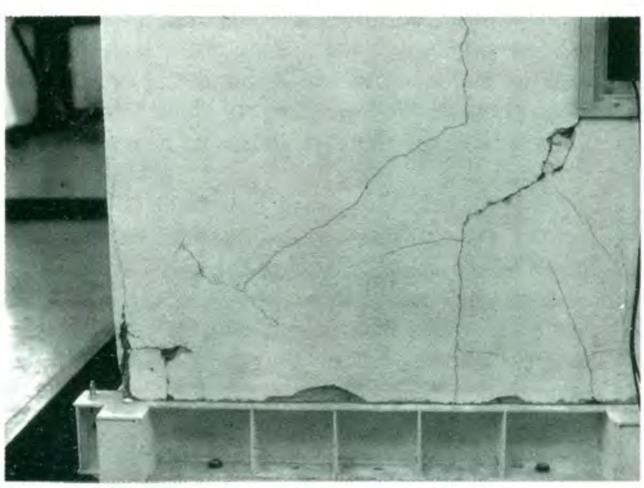


Fig. 1 – Plan and elevation of the tested building. All dimensions are in dm. *a*) 0.8 × 0.4 stud; *b*) plywood (wall); *c*) plywood (floor).

Picture 1 – The two storied wooden building during testing.



Picture 2 – Detail of the base corner B in Fig. 1 after test.



Picture 3 – Left hand side of facade A D in Fig. 1, after test.

Picture 4 – Ceiling of the first storey. The two accelerometers are shown attached to the main beams. Some of the plastic ribbons tighting the loading sacks with the sand, were broken after a number of tests. One wooden beam was broken after the 20th repetition of the earthquake.

The specimen was tested to about 40 repetitions of the Kalamata earthquake shown in Fig. 2 and Fig. 3.

The specimen finally neither collapsed nor presented any heavy damage. After the test, the following were observed and/or calculated:

3.1. Damage

After the application of a few number (about 3-4) of repetitions of the excitation, the nails at the base were loosen and needed refixing. The plaster on the outside face was cracked but this did not correspond to any damage of the wood. After the 40th Kalamata earthquake the biggest remaining cracks of the plaster had a width of the order of 2 mm. It must be mentioned here that the cracks observed on the outside plaster after about the 20th repetition of the Kalamata earthquake had not been significantly enlarged with the further repetition of the tests which followed.

One beam of the second floor was broken after about the 20th excitation, as it is shown in Picture 4.

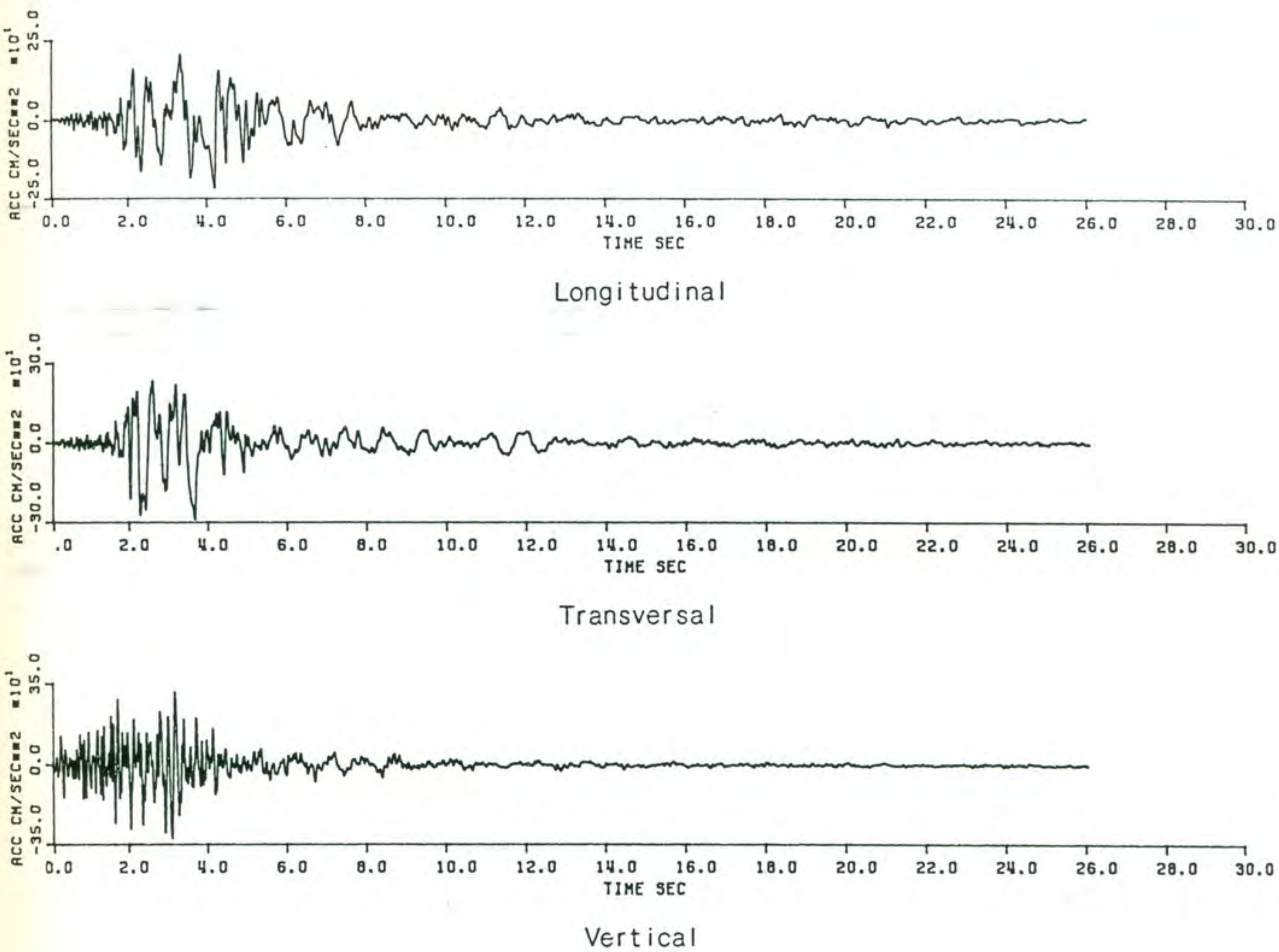


Fig. 2 – The three acceleration components of Kalamata earthquake (September 13, 1986). *L*: Longitudinal, *T*: Transversal, *V*: Vertical.

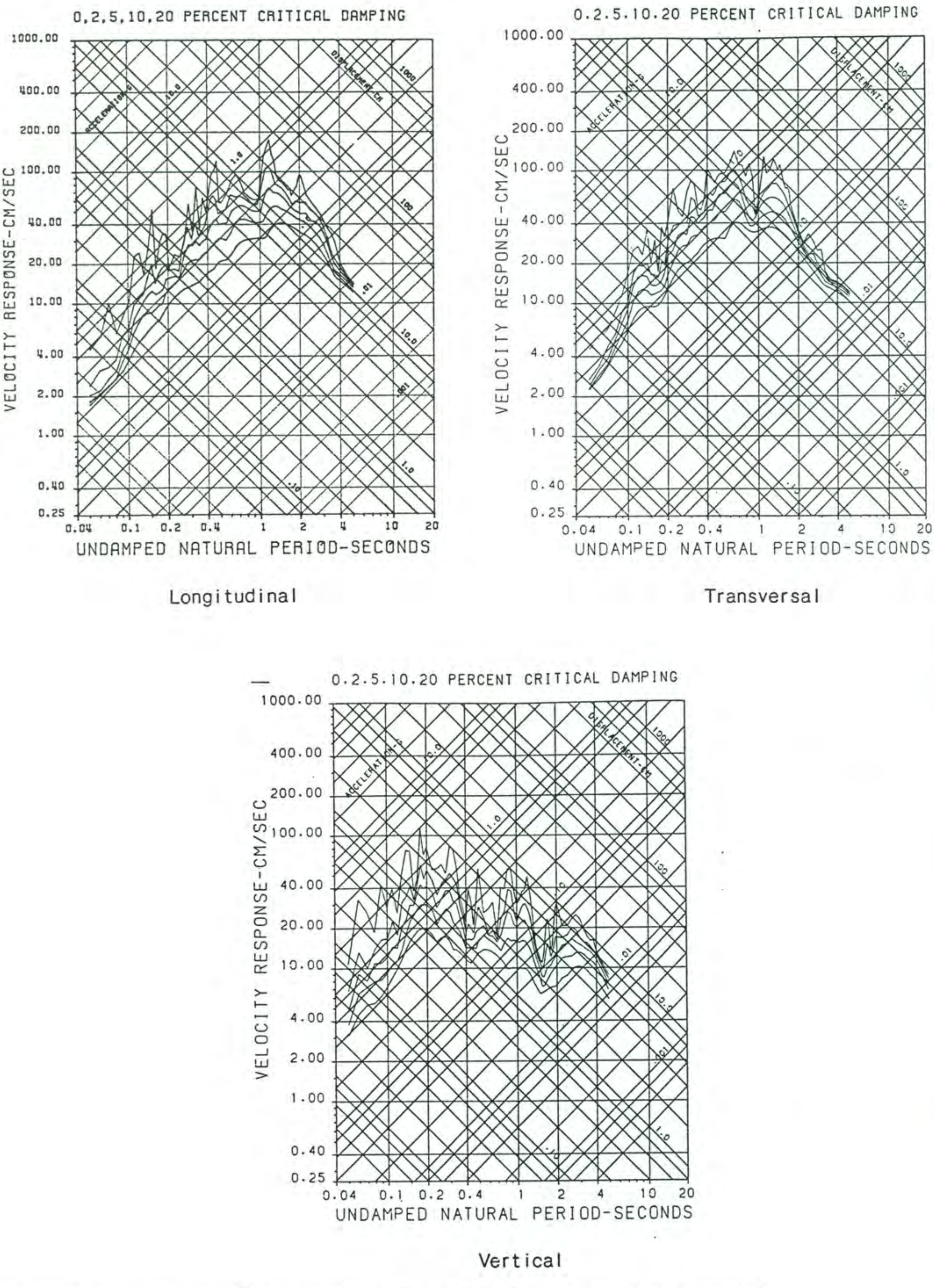


Fig. 3 – The response spectra of Kalamata earthquake, Longitudinal, Transversal and Vertical respectively.

With the continuation of the excitations lighter damages were observed in the nearby two beams of the broken beam of the second floor. The initial break of the beam occured on the existing knot, nevertheless, this damage may be attributed to the rather large masses applied on the floor and the quite high vertical acceleration of the Kalamata earthquake (for a damping ratio 17% and $T=0.17$ sec the spectral vertical acceleration exceeds 0.6 g, as can be easily estimated from Fig. 3, see also /2/).

3.2 Natural Periods

The measured natural periods of the structure are as follows:

For the virgin structure:

Longitudinal: 0.18 sec
Lateral: 0.18 sec
Vertical: 0.16 sec (at the center of the roof)

After the 20th earthquake:

Longitudinal: 0.21 sec
Lateral: 0.20 sec
Vertical: 0.17 sec (at the center of the roof)

After the 40th earthquake:

Longitudinal: 0.22 sec
Lateral: 0.22 sec
Vertical: 0.17 sec (at the center of the roof, while the period at the center of the second floor was estimated by resonance at 0.20 sec)

3.3. Maximum accelerations

The maximum accelerations, that the various parts of the structure underwent, were of the order of 2 g.

3.4. Damping

The damping that was measured differs according to the number of repetition test which almost coincides with the degree of damage of the structure. Around the 15th repetition, the damping of the structure was of the order to 17% of critical.

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