BEHAVIOR OF SINGLE STORY LIGHTWEIGHT PANEL BUILDING UNDER LATELAR LOADS

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ABSTRACT

Construction of lightweight structures is needed to reduce the earthquake effects on the buildings. Lightweight wall panels fabricated from polystyrene, steel and shotcrete concrete are recently used in some countries such as USA and China to construct low rise lightweight buildings up to three stories. In the literature there is no enough data on the behavior of this new panel building system during earthquakes. In this technical note ½ scale model of a single story building constructed in the laboratory using this panel materials and the same construction technique used in practice were tested under lateral loads. Although the lateral loads were increased to four times higher load levels than the design earthquake loads, only minor fine cracks have been observed on the surfaces. The technical note documents the details of the test program, including specimen properties, test setup, instrumentation and test procedure. Test results and major observations are also presented and discussed.

Keywords: lightweight; panel, shotcrete .

INTRODUCTION

In high seismic regions of the world, including Turkey, there are too many residential low-rise buildings made of rigid masonry walls or flexible moment-resistant frames with brittle masonry partitioning walls. During even moderate earthquakes, some of these buildings due to inadequate lateral stiffness and unsuitable design suffer heavy damages and brittle failures leading to hundreds of people to lose their lives. Hence it is essential to build a house with lightweight materials that have an earthquake resistance with a proper safety. Recently in the United States and worldwide a new building system use fabricated lightweight panels is proposed for construction of low-rise residential buildings. The proposed prefabricated panel consists of a three-dimensional welded wire frame utilizing a truss concept for stress transfer and stiffness. Each surface of the wire frame has a 10 cm square welded mesh pattern of longitudinal and transverse wires of 3mm diameter, and are made of galvanized steel with yield strength of 500 MPa.. The expanded lightweight polystyrene core is placed between the two layers of welded wire fabric. The skin is welded and finished with shotcrete, which is a concrete material that is sprayed onto the wall at the job site. Cross section details of the panel are shown in Figure 1. The light weight of these panels (i.e. only weights a quarter of the masonry wall), easy handling, high construction speed, good heat insulation properties, in addition to their low cost by avoiding formwork and need for skilled workers ,make it an acceptable construction practice. Some preliminary laboratory tests on these panels such as uniaxial-loading tests [Ersin,1997], and out-of-plane loading tests [Karadogan et al ,1998] indicate that the panels are expected to have more ductile behavior, higher energy absorption capacity, higher safety margins and reparable local failures rather than overall brittle failures. In the literature an experimental data on the seismic behavior of this new panel building system are not available. Shaking table tests are the best way to determine the seismic behavior of any structure. However, shaking table tests are too expensive and are not available worldwide. In this research it is assumed that the seismic behavior of these panel building can be obtained using a static pushover tests relying on the assumption that the envelope curve of the hysteresis loops obtained from a shaking table test is similar to the pushover curve obtained from monotonic static test. This assumption is based on observation of experimental data by many researchers in relevant literature, such as Kato et al [1973]. In this technical note ½ -scale model of a single story building prepared in the laboratory using the lightweight panels and construction technique used in practice were tested under lateral static loads.

PUSHOVER TEST OF ½ SCALE 3D SPECIMEN

Specimen

A half scale, three-dimensional model specimen was constructed in the laboratory using the lightweight prefabricated panels. These are later converted to structural walls by means of shotcreting in situ. The scaled specimen were deigned to satisfy similitude requirements in the inelastic range of behavior. In most cases prototype materials must be used in the construction of the model and ballast is added to increase the density of the model to satisfy similitude requirements for the materials. As the scale of the model is reduced, its fabrication becomes more difficult. Similarity between a prototype structure and a small-scale model is maintained by proper scaling of significant physical quantities that govern structural behavior. The design of a model is initiated by performing a dimensional analysis. In a dimensional analysis, the first step is to identify the significant variables that affect the structure. The selection and production of materials is probably the most difficult step in a successful research investigation by using models. Exact duplication of prototype material properties is required if the model is to simulate elastic and nonlinear, inelastic behavior of structural system up to failure. Since the mass characteristics of the model are an important parameter, using artificial mass simulation can minimize the distortion of the mass density. In artificial mass simulation [Harris and Sabnis.1999], mass is added to the structure in such a manner that will not appreciably change its stiffness. For this project, the artificial mass simulation type was used following the project idea to use original prototype structure’s materials. However no supplementary mass was affixed to the specimen because the tests were static pushover tests .But in calculating the equivalent static earthquake design loads which affect the model specimen using the formulations giving in seismic design codes the additional mass due to simulation requirement were taken into account.

General layout and cross sections of the 3D specimen are given in Figure 2.The specimen was anchored down to the mat foundation that had been tied to the testing floor by post-tensioned high strength bolts. Vertical and horizontal panel connections were well detailed to prevent local failure in these connections. The connections between walls were made by means of U-shaped and L-shaped 3-mm diameter confinement steel, similar to the cage steel reinforcement around the polystyrene foam sheet. The confinement steel spacing was 50 mm. The connection details of two walls and three walls of the specimen are shown in Figure 3. Very good heat insulation, reduced total weight, and very high construction speed are challenging basic features of this simple construction technique. The specimen has been designed for 60 kN base shear force which corresponds to 25% of total weight of the structure and satisfies the requirements of new Turkish earthquake Code1998. Wet shotcrete method was used and the shotcrete pressure was very low to reduce the losses in shotcrete mortar. The shotcrete mortar is largely plaster. Cylinder tests indicate that the shotcrete mortar has the average compressive strength of 15 MPa . It has been indicated that cylinder tests are reliable measure indicate the shotcrete quality [Saruhan, 1998].

Testing setup and tests

Lateral loads were imposed to the top of the specimen by means of two hydraulic jacks placed in horizontal position between the specimen and a RC reaction wall. The imposed jack’s loads are divided into two equal parts first. And one of the loads is divided again as can be seen in Figure 4, so that the loads transferred to each wall will be proportional to their initial lateral rigidities (i.e loads distributed according to the shear area of the cross section of each wall). Then each of these lateral loads is distributed along the walls by means of the shear studs embedded into the specimen and rigid loading arms that are placed on top of them. After this procedure, the lateral concentrated loads coming to each wall are transformed more or less to uniformly distributed loads on the wall. The loads transferred to the walls named W1 and W3 in Figure 4 are recorded simultaneously through the load cells shown in Figure 4. Therefore, the loads, which go to middle wall W2 can be computed simply by subtracting the loads taken by W1 and W3 from the total load applied to the specimen synchronously by two jacks. All in all, it can be said that the lateral load distribution has been kept almost equivalent to the distribution of actual inertia forces expected in an earthquake. Since the structure is relatively rigid structure an elastic behavior is expected to the level of design load, this assumption is valid at least up to that level. It is assumed that the walls perpendicular to W1, W2 & W3 are not carrying shear loads. The lateral load was monotonically increased up to four times design load level. In plane, out of plane displacements at each end of the specimen, and the possible relative slippage on the loading floor are all automatically recorded, and the proceeding displacement curves have been achieved, see Figure 5a, and Figure 5b respectively. It has been observed that slippage on the floor and out of plane displacements are negligible. The 3D model specimen top displacement - total lateral load relationship were plotted and presented in Figure 6 .It should be noted that, even at the maximum load level, only minor very fine distributed cracks were observed. No local failure detected.

Load deflection curves obtained from individual walls and crack patterns at each surface of the walls are presented in Figure 7, Figure 8, and Figure 9. It should be noted that, even at the maximum load level, only miner very fine distributed cracks have been observed. No local failure detected.

FURTHER RESEARCH

In the future it is recommended that more specimens be tested before the results are finalized, however early test results are promising. The use of a higher quality shotcrete mortar with ballast material for the small fractions should be integrated in the future to compare how this would affect the results.

CONCLUSIONS

Based on the results of the experimental investigation, the following conclusions are drawn:

1. Fine reinforcement mesh of the panel acts to prevent or limit shear cracks.
2. Although the lateral loads applied to the ½ model panel building were increased to roughly four times higher load levels than the design earthquake loads, no important local failures have been detected and only minor fine cracks have been observed on the surfaces.
3. In the end of tests no failure were observed at wall to wall connection or wall to roof connection which verify the satisfactory of connection detailing used in construction practice. It was also interesting to observe that no separation have been occurred between two layers of each walls.

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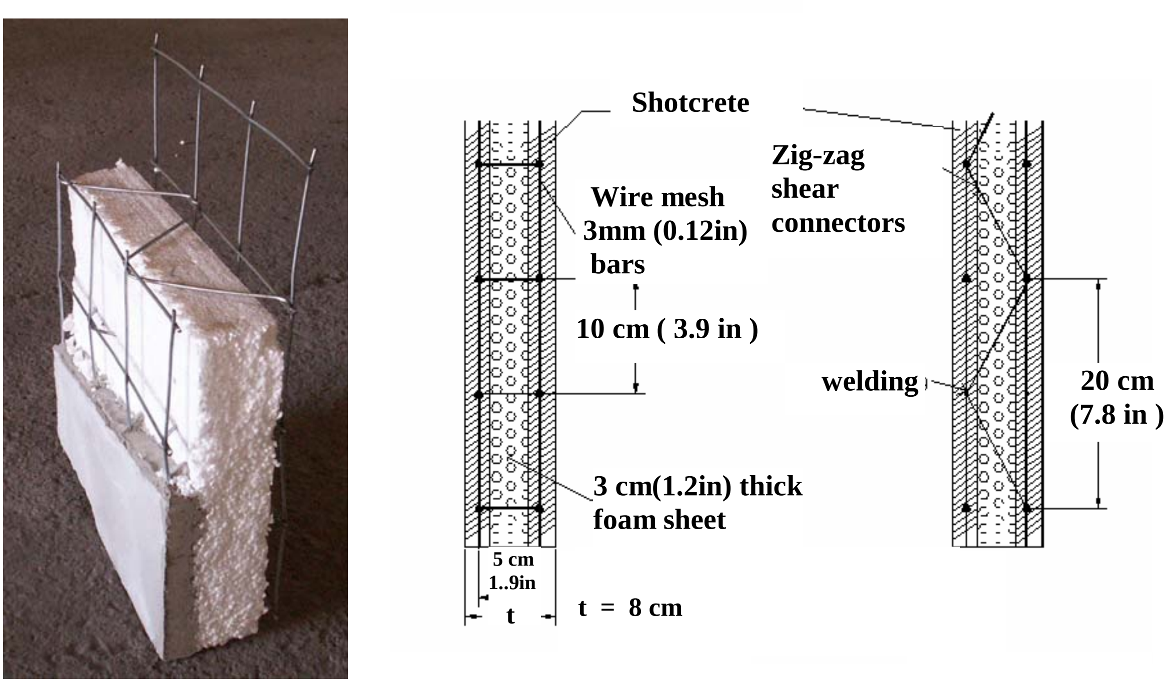
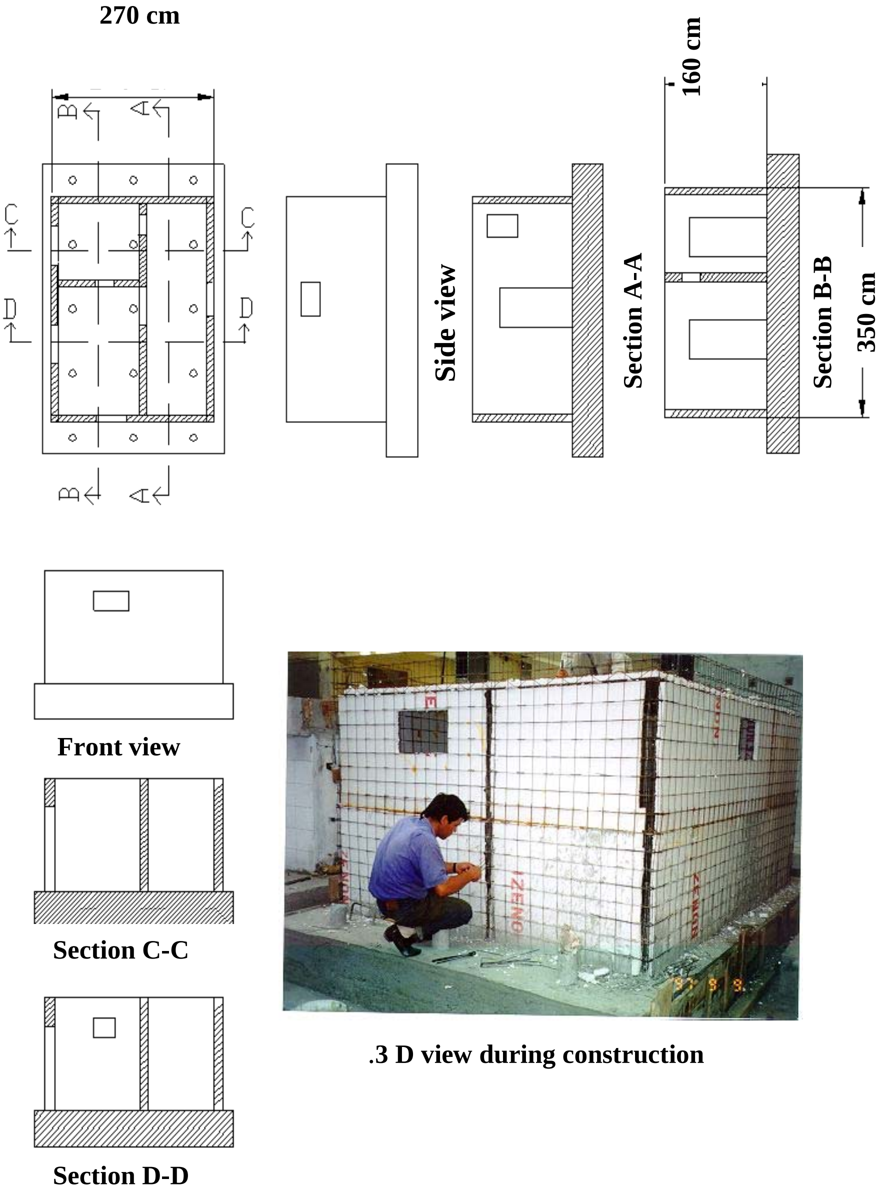


3D View

Vertical
Cross Section

Horizontal
Cross Section

Fig. 1 – Light weight prefabricated Panel cross sectional details.



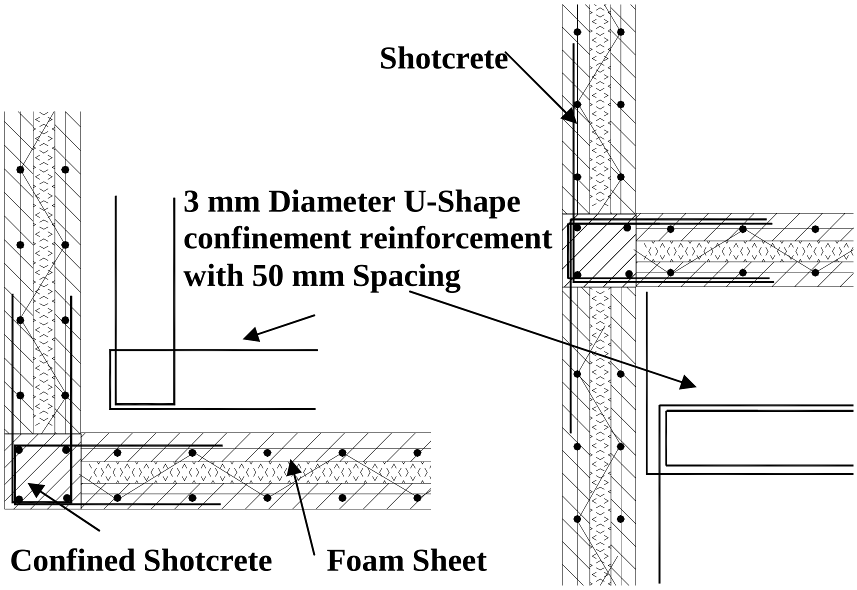
Front view

Section C-C

Section D-D

.3 D view during construction

Figure 2. General layout and cross sections of the 3D model Specimen.



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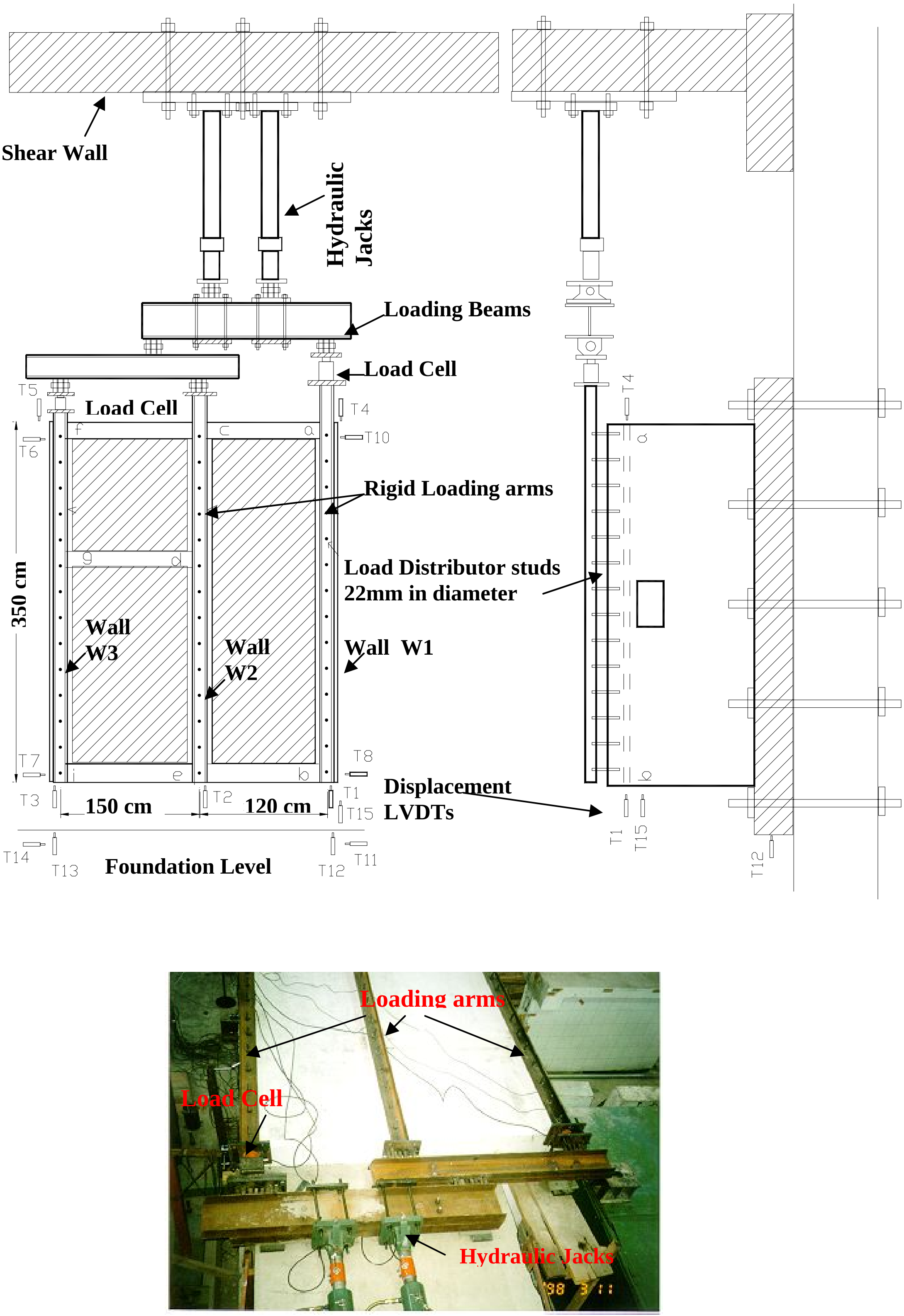
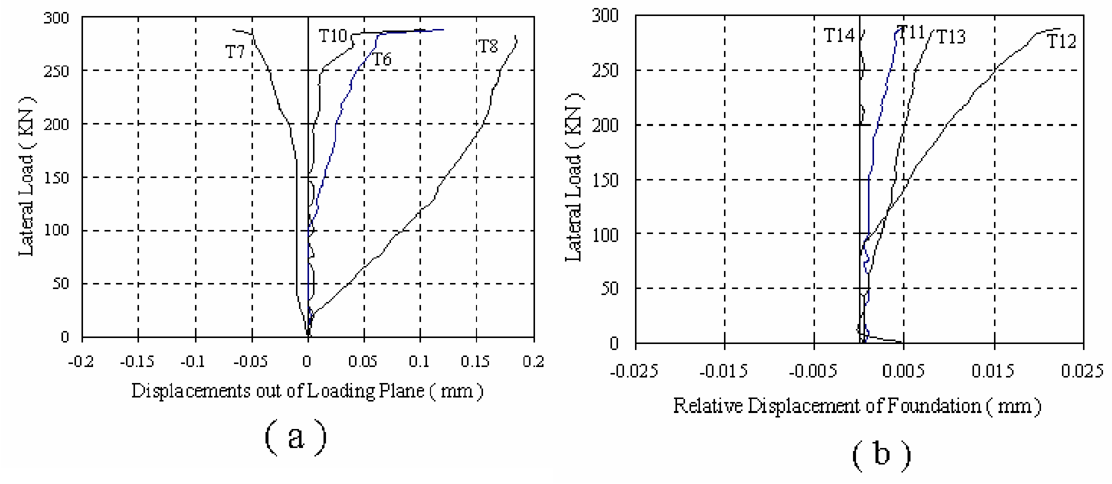


Figure4. Test setup of pushover test



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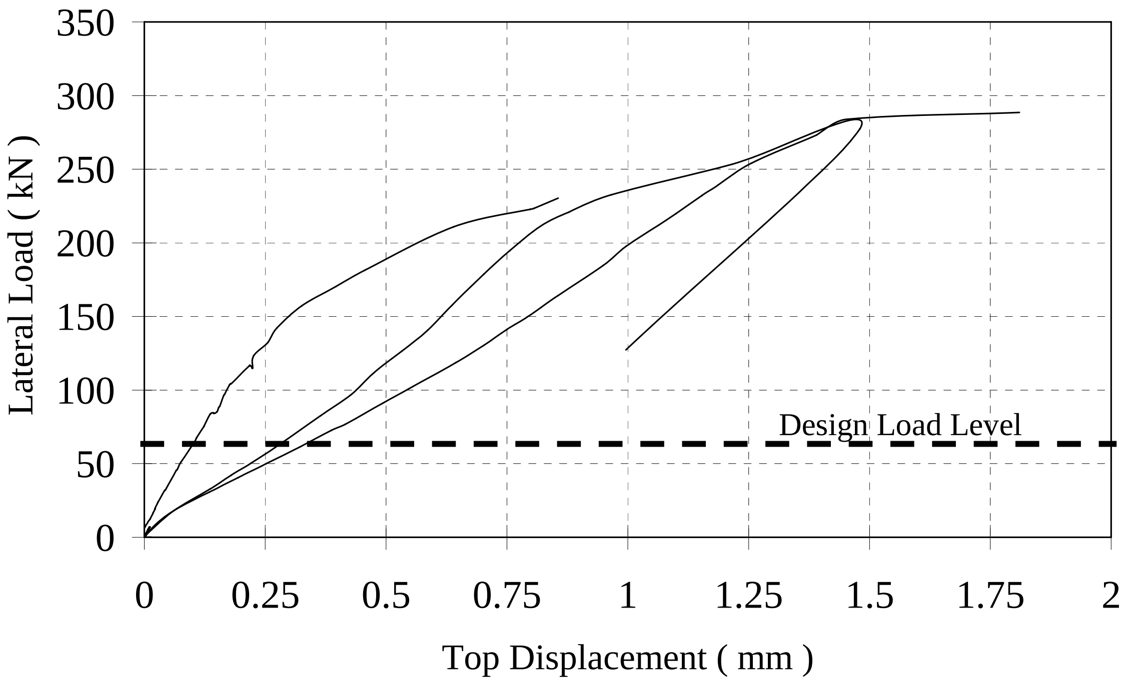

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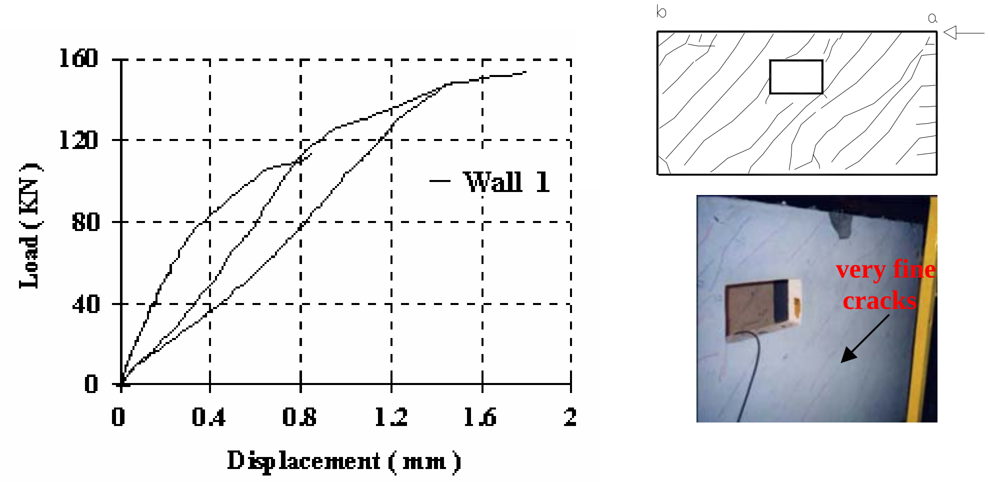

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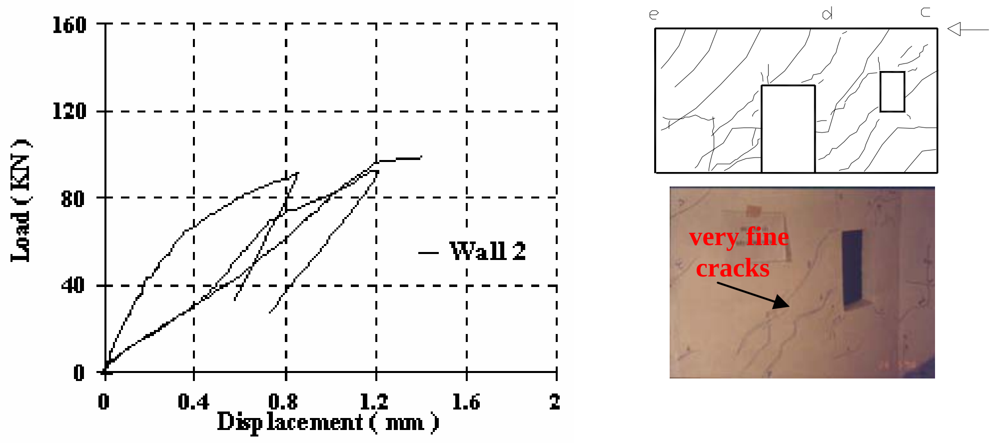

Figure 8 .Crack pattern and load displacement curve of Wall No 2

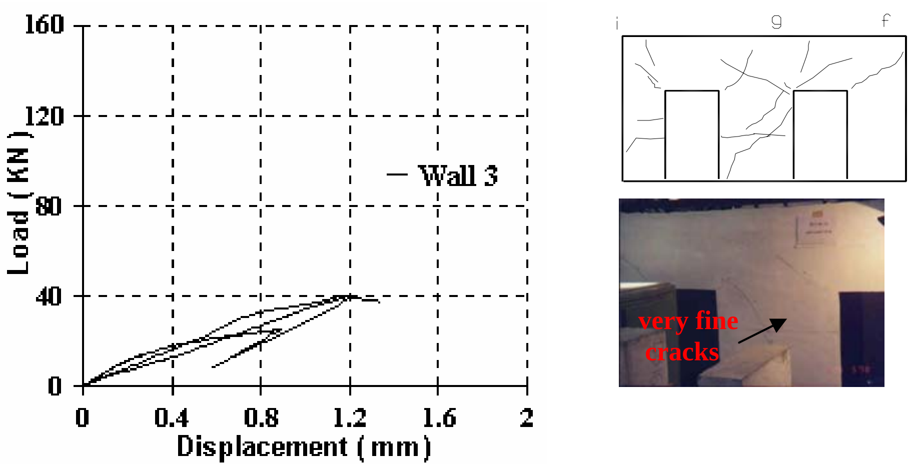

Figure 9 .Crack pattern and load displacement curve of Wall No 3