IMPROVEMENT ON LOW COST HOUSING THROUGH NON-CONVENTIONAL CONSTRUCTION SYSTEMS

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SUMMARY

Five non-traditional construction systems and their performance under lateral seismic forces are presented. Maximum seismic forces for each system using the NT-E030 RNC Peruvian standards are presented as threshold values of comparison of the performance of each system to recommend the proper reduction factor for each of this system, the one could be used in the future as a complement of NT-E030 RNC standards. Interstory drifts are recommended from the experimental results for two groups of systems: systems with displacements among their components a value of 9/1000 is recommended, and systems based their behavior on shear distortions a drift of 4/1000 is recommended.

INTRODUCTION

On recent times, different construction systems orientated for housing appear in Peru. Most of these systems has been imported from first world countries and many have not been adapted to the Peruvian earthquake standards. This invasion of technology was originated after the announce of the reconstruction plan for affected areas due to El Niño phenomena and Nazca earthquake. On the other hand many of these systems were applied in countries without earthquake problem and most of them use foreign supplies. In the case of Peru, structural systems should be designed according with earthquake standard E-030 of the National Construction Code.

On the other hand Peruvian researchers in the last 15 years developed different solutions for construction systems using national supplies and most of them had been tested and have the approval

and registration of state office of normalization, SENCICO.

The present report introduce five construction systems that have been tested on the structural laboratory of CISMID -Faculty of Civil Engineering of the National University of Engineering Lima, Peru.

NON CONVENTIONAL CONSTRUCTION SYSTEMS

On December 1997, SENCICO publish an inventory of 44 non conventional systems which have been accepted and satisfy the Peruvian standards for earthquake design. Most of these systems propose solutions for walls and slabs systems using prefabricated panels, wood panels, trust systems, light concrete, light wood panels with concrete, light gauge steel frames with panels and mix of such kind of structures.

Because the difference among our geographical regions, three zones are distinguished coast, highland and jungle. Each region produce its own materials which is predominant on each region, on the case of the coast the confined masonry is widely used, and in the case of the highland the buildings are made by adobe or stone blocks, and in the jungle most of the houses are build by wood or concrete blocks.

Recently, different natural disasters occurred on these regions, earthquakes, floods, etc., showing the virtue and defect in some of the construction systems. Mainly in the case of earthquakes the strict drift control of the 1997

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earthquake standard.   E-030 and the effects of Nazca earthquake, shows the reason why such kind of strict drift control.

NON TRADITIONAL SYSTEMS TESTED IN CISMID

Experimental studies on full scale models have been carry out in the last two years in the Structural Laboratory of Center for Earthquake Engineering Research and Disaster Mitigation - CISMID of the Faculty of Civil Engineering at UNI. Among the studied systems five of them shown particular improvement in the cost comparing with the traditional construction systems. Each system will be designated by an alphabet character, and in two groups:

1- Systems with displacements between their components: A,B

2. Systems based on shear distortion: C,D,E

The first Group uses flexible joints that permit local energy dissipation on the joints; in this way the lateral forces are absorbed by the joints or the friction between components of the structural system. This kind of system could be used as one floor housing system.

The second group of system (with exception of system E) are light structures and have flexible behavior presenting large drift angles between the floors showing small deterioration on the system. These systems tried to emulate the behavior of the traditional systems but due to their large flexibility have interstory drift which are not considered on the Peruvian earthquake standard E-030. These systems could have two floors.

The five systems with experimental studies carried out on CISMID Lab are presented as follows.

3.1 Systems with displacements between their components

3.1.1 System A

The system is integrated by concrete panels of 0.97 m. x 0.97 m. confined by a frame of light gauge steel shape, formed by vertical forms spacing 0.95 m., and upper and down shapes on the boundary of each panel.

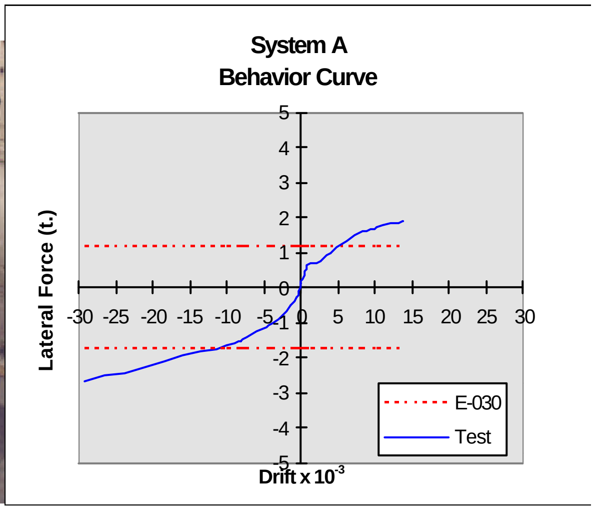

Photo 1: Test Specimen System A

Figure 1: Behavior Curve System A

The testing specimen was formed by panels and fixing with the light steel shapes with roof structure with use plates of fiber-cement. The specimen was build over a 150 mm. thickness concrete slab with length of the module of in the direction E-W of 6800 mm. and width parallel to the N-S direction of 5800 mm.; there was not connectors between the slab and the structure. The walls of the specimen had length of 5850 mm in the E-W direction and 5000 mm. in the N-S direction. Each wall is formed by a mesh of panels of 30 mm. of thickness and dimension 970 mm by 970 mm. the ones are inserted between the vertical elements of 2300 mm. to 2900 mm. length; the approximate weight is 6000 k.; Photo 1 shows the specimen before testing.

Lateral loads were applied to the specimen, applying a displacement control using an on-line actuator system in the level 1380 mm. height of the module. Drift angles 1/5000, 1/2500, 1/1250, 1/650, 1/500,1/250, 1/125 were reach on each of the cyclic of load. The displacement was register step by step using an static measuring system to produce hysteretic curves in the experiment. As a result of the test an envelop of the stable cyclic provide the maximum reach points to reproduce the behavior curve of the specimen presented in Figure 1. From Figure 1 is possible to read the large drift of 1/100 found during the experiment.

3.1.2 System B

This system is formed by prefabricated panels of 2400 mm height by 450 mm width. The panel has a thickness of 30 mm on the plane zone and variable thickness on the border ring with values of 50mm to 100 mm in the external part, as is shown in Figure 2. On the border ring there are sockets to introduce connectors to join the panels. Each socket is made from polyethylene of high density. The walls of the specimen are formed by panels connected by the sockets.

The test specimen had a supporting footing ring with section 300 by 900 mm. and a length of 3900 mm. on each side. In the central part of the footing a light steel channel of 100x50x3 is inserted to be used as a guide to insert the panels to fix the panels to the footing. Four walls form the testing module, two of them use 6 panels of 450x2400 and 2 corner panels of 225x2400, giving a 3220 mm length wall. The other two walls has openings for door (900x1900) and windows (900x1000). The module is shown in Photo 2

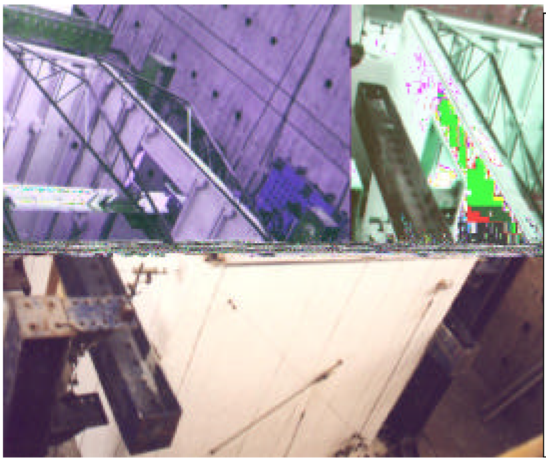

Photo 2: Specimen of System B

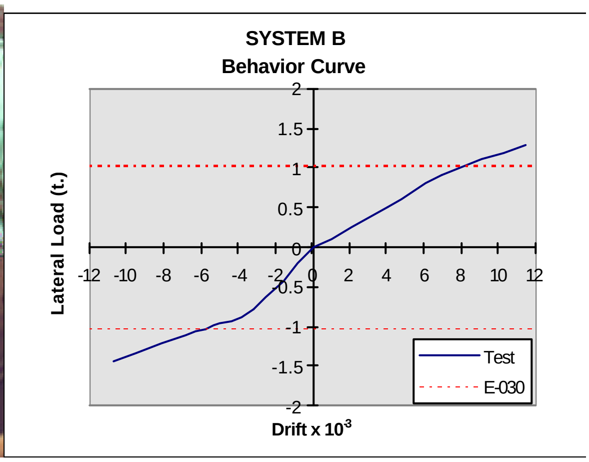

Figure 2: Behavior Curve System B

The approximate weight of the specimen is 3450 kg. and was tested through control displacements at level 2/3 height measure from the bottom of the module. The lateral displacements were applied to produce drift on the applied level of 1/200 , 1/100, 1/50. Figure 2 presents the behavior curves given by the stable cyclic developed by the specimen; from the curve is possible to read the specimen reached drifts of 10/1000 to 9/1000.

3.2- Flexible systems based on shear distortion

3.2.1 System C

This system represents the integration of an structure of cold formed shapes (columns each 0.60 m. and beams) and panels of fiber-cement of 1.22 m. width and 2.44 m. height, to form the structural system, where the floor system is made with the two kinds of structure.

A two floor specimen build using the system where the first floor roof have a cold formed structure with a 50 mm. reinforced slab, and the second floor roof used fiber-cement panels over a cold formed frame structure. The walls of the module had 3060 mm length and is formed with 1220 mm. panels which are fixed to the cold formed frame structure through simple screws. A view of the specimen is presented in Photo 3.

Control displacements load application to the specimen of 3500 kg. weight reproduce interstory drifts of 1/5000, 1/2500, 1/1250, 1/650, 1/500,1/250, 1/125 keeping a ratio of 1.00 to 0.50 in displacements similar to the first mode of the structural system.

Photo 3: Two floors Specimen of System C

Figure 3 presents the maximum stable cyclic peaks curve, named behavior curve, where is possible to read the end of the elastic range appear with a interstory drift of 4/1000 and the ultimate capacity of the specimen was found for a drift of 8/1000.

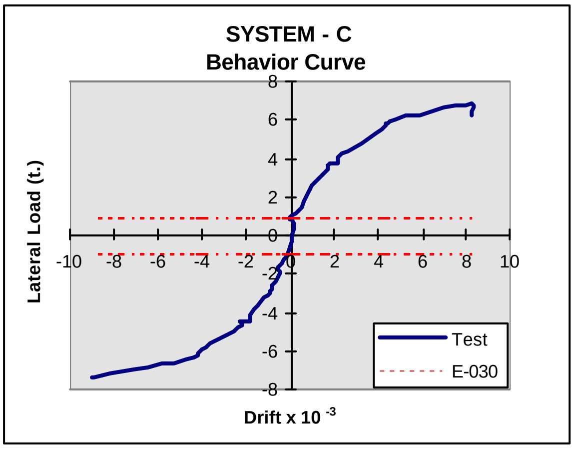

Figure 3: Behavior Curve System C

3.2.3 System D

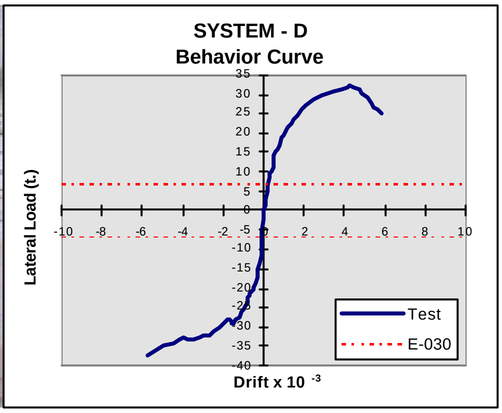

Photo 4: Test Specimen System D

Figure 4: Behavior Curve System D

This system is the integration of wood truss with a cellular structure made by bamboo and a concrete structure of 50 mm. thickness reinforced with meshes of steel in both sides, named cañacreto. The construction of the system could grow according the economical condition of the owner; at the beginning only cellular structure and part of the truss could be build; then truss could be completed and finally concrete and reinforcement is provided. For this system is integrated by walls and roof build using a cellular-modular structure; each wall had a length of 3150 mm. and is formed by modular panels of 150 mm. thickness with a height of 2500 mm. A vibration force test for 27470 kg. two floors specimen gave a free vibration frequency of 22 Hz. with 2.6% of damping.

A cyclic loading test applying displacement control using on-line actuator system was carried out in order to produce interstory drifts of 1/5000, 1/3500, 1/2500, 1/1500, 1/1250, 1/1000, 1/800, 1/650, 1/500, 1/400, 1/300, 1/250, 1/200 , 1/150 with 1.00 to 0.40 ratio between the second floor displacement and the first floor displacement to produce a deformed shape similar to the first mode of vibration of the structural system. Figure 4 show the results of the test where stable peaks enveloped is plotted. Here the elastic range ends with a 1/1000 interstory drift and the inelastic range presents 4/1000 to 6/1000 interstory.

3.2.4 System E

System F is a steeped construction module starting with 22.2 m2 area (living, salon, kitchenette and bath) in the step 1 of construction, an area of 34.5 m2 (adding closet and kitchen to step 1), 44.8 m2 (adding a bedroom to step 2) , the step 3 consider the addition of an stairway having an area of 50.9 m2 completing a one floor building; finally step 4 reach 89.60 m2 with the addition of one floor two these structure.

The structural component of the building is a concrete panel of 10 cm. thickness with low resistance concrete (approximately 100 Kg/cm2) with maximum slump (4 inches) workable and using a re-used encased forms.

The step 1 structure was considered as a full scale model the one have an area of 21 m2. (without considering the bath)

The specimen of 14250 Kg. was subjected to lateral forces under displacements control with an hydraulic actuator applied at level 2250 mm. height The displacements were applied in order to produce drifts of 1/5000, 1/2500, 1/1250. Photo 5 shows the specimen during the test.

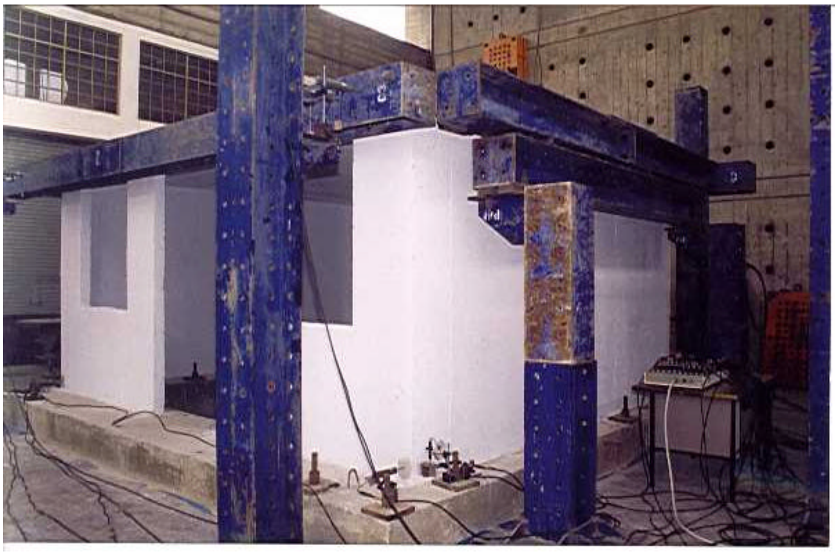

Photo 5: Specimen of System E

After application of the lateral displacements to the structure it was found the behavior curve presented in Figure 5. It is possible to read the maximum interstory drift of 1/1250 on the system at the end of the experiment

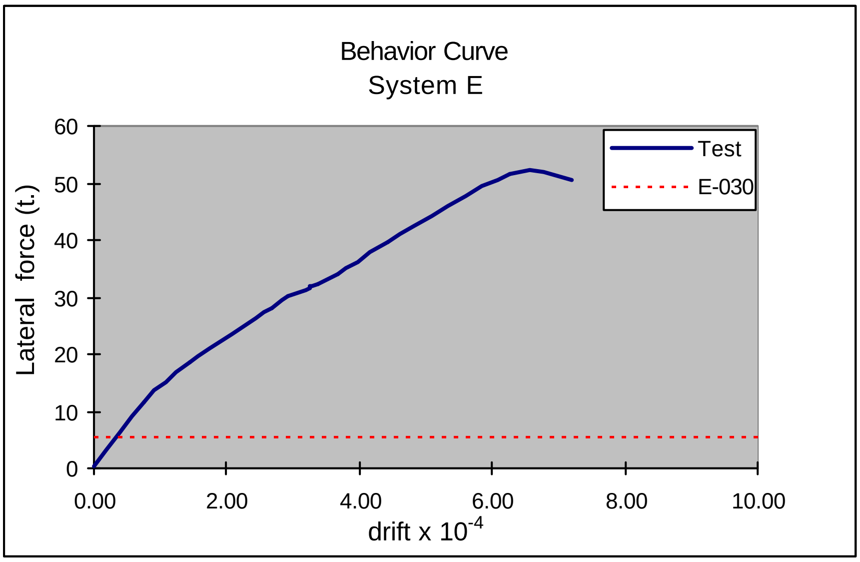

Figure 4: Behavior Curve System E

CONCLUSIONS

- Non conventional Systems fabricated in Peru has been presented. Two types of system are distinguished: the permit displacements among their components, and the ones based on shear distortion behavior.

- For the systems with displacements among their components (A y B) was found drift values of 9/1000 as limit security margin.

- For the systems based their behavior on shear distortions (C y E) was found a limit security margin drift of 4/1000.

- From the comparison between the threshold value of the Peruvian E-030 earthquake standards (dash line) and the test results presented on Figures 1 to 5, its is possible to conclude in each case the lateral force on the specimen is higher than the required by the standard. All of this construction systems had enough stiffness to resist the severe earthquake of the code.

- The proposal drifts values has been demonstrated experimentally and according with the full scale tests show a security margin for each case. A recommendation as been submitted to the Peruvian committee of Earthquake design standards in order to take in consideration these results for the next edition of the E-030 standard.

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