Aseismic Masonry Building Model for Urban Areas

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ABSTRACT

Masonry buildings are likely used on urban areas of developing countries. Masonry as material, frequently shows difficulties in the quality control, especially in brick units. These units on developing countries are handmade fabricated and in few cases machine fabricated. In most of the cities in Peru, the units belong to the first group. Because this fact, a study on masonry was developed in UNI, where brick units, piles, and mortars were studied to find the basic properties of the average masonry. However, housing are commonly built by walls. Walls are confined by concrete elements with minimum reinforcement for a height in average of three stories in the typical building. In this paper, a shear wall test series is presented to study the behavior of confined wall system. To find the appropriate parameters for the called modeling of the typical building, solid walls and walls with openings of one and two stories were tested monolithically and cyclically. On the based of this results, a full numerical earthquake behavior simulation of a two stories building subjected Lima earthquake are presented, considering a simple brace mechanisms model. The model has been calibrated with the test results and the dynamic properties of the structure were measured considering a force vibration test. To assured the validity of the model, a two stories model simulation is compared with the results of an on-line test performed in Cismid-UNI. A Good agreement of the numerical analysis and test results id observed.

INTRODUCTION

In the early sixties engineers became aware of seismic requirements as an important consideration in design. A seismic code was adopted for the first time, although this effort was mainly directed towards tall concrete buildings. In Peru, it was not until after the earthquakes of 1966, 70 and 74 that some thought was given to regulate seismic design with materials other than concrete. About twenty years ago a masonry construction code was adopted. The Japan Peru Earthquake and Disaster Mitigation Center of the National University of Engineering has been developed a urban optimal masonry building project since 1988. This project has different research levels. On the first level, the masonry brick block, joint mortar, and piles has been studied for the different classes of masonry. On the second level a series of experiments on solid walls were tested. On the third level a full scale masonry model has been tested, to developed analytical tools for practical design and set proper limits for the different rates of damage on a real model.

Al this levels has been developed in order to had an standard building using confined brick masonry. This building will used an appropriate sizing of all structural elements involved, walls columns, beams, and also through a redistribution of the reinforcing elements a substantial reduction of the building cost is reached.

THE STRUCTURAL MASONRY SYSTEM IN PERU

Peruvian masonry traditional houses have been based in the following structural system:

- Footings: usually connected type, where the walls are supported in order to transmit the loads to the soil.

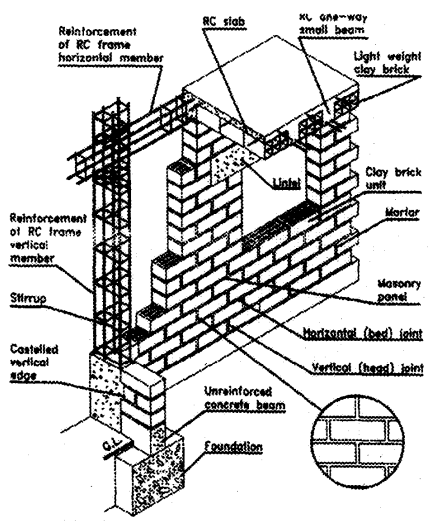

Figure 1 : Structural Masonry System

- Structural Walls: transmit horizontal and vertical loads between floors. This kind of wall are confined by horizontal and vertical concrete elements with minimum reinforcement.
- Story Slab: a kind of rigid diaphragm to distribute the vertical and horizontal loads according with the walls stiffness. In Peruvian's traditional housing the story slabs are built by T concrete beams filled by light

masonry blocks created for this purpose.

-Confined Beams and Columns: They work as collar beams and columns to confine the masonry as a frame. An illustration of the above described structural system is presented on Figure 1, showing each of the parts of the system.

STANDARDS

The construction and allowable stress of this structural system are ruled by the Peruvian Standards E-70 ININVI, 1982. Minimum values of stress distributions of walls and units are given in this code. Most of the values has been affected by high security factors to prevent the poor quality control on handmade units, which are likely used in expansion areas of the urban zones, like shinetowns. Table 1 presents the minimum values of the Peruvian Standards.

TABLE 1

PERUVIAN CONFINED MASONRY STRESSES

Stress Type	Formula (Kg/cm2)
Compression due to axial load in Walls	Fa=0.20 f'm f'm: compression resistance of masonry
Compression due to bending	Fm=0.40 f'm
Tension due to Bending - Normal to horizontal joints	 Ft=1.00
Shear	Vm=1.2+0.18fd < 2.7 fd: dead load normal stress
Crushing on Masonry - In whole area - In 1/ 3 of area	 Fca=0.25 f'm Fca=0.37 f'm
Elastic Modulus Shear Modulus	Em= 500 f'm Ev=0.4 Em

EXPERIMENTAL RESEARCH AT CISMID-UNI

A first level of research was carry out on CISMID-UNI, where different kinds of bricks units were tested in order to find an average resistance under compression stress (f'b) . Table 2 present a resume of results, where Type 1 to 8 represented the different kind of brick produce in Lima and taken from different factories and considering also a sample of handmade production (Type 6).

TABLE 2

COMPRESSION RESISTANCE ON BRICK UNITS (Kg/cm^2)

Type-1	Type-2	Type-3	Type-4	Type-5	Type-6	Type-7	Type-8
138.47	196.72	181.85	157.26	128.63	115.63	222.72	220.68

Piles of brick units and mortars were tested in order to verify the range of the compression resistance of the Pile (f'm). Eight types of piles were tested considering the different kinds of bricks which are likely used in the urban areas of Lima. Table 3 present an abstract of the results for the studied masonry piles.

TABLE 3

COMPRESSION RESISTANCE ON MASONRY PILES (Kg/cm^2)

Type-1	Type-2	Type-3	Type-4	Type-5	Type-6	Type-7	Type-8
101.52	111.21	97.36	96.14	103.91	75.27	118.17	141.14

The second level of the study on CISMID, involve the wall behavior research. Gibu et.al (1993) studied the confined masonry walls of eight types.

TABLE 4

GEOMETRY AND PROPERTIES OF MASONRY WALLS TESTED BY GIBU 1993

Wall ID	**Confined Beam Dimension (cmxcm)**	**Confined Columns dimension (cmxcm)**	**Wall Thickness (cm)**	**Wall Masonry Length (cm)**	**Wall Height Dimension (cm)**	**Confined Elements**
MCST1	30x20	15x25	15	190	220	Footing, Beam and 2 Columns
MCST2	30x20	15x25	15	190	220	Footing, Beam and 2 Columns
MC4C1	30x20	15x12.5	15	@ 63	220	Footing, Beam and 4 Columns
MC4C2	30x20	15x12.5	15	@ 63	220	Footing, Beam and 4 Columns
MLCC1	200x20 (slab)	15x25	15	190	220	Footing, Slab and 2 Columns
M-H	30x20	220x25 (Wall)	15	220	220	Footing, Beams and Lateral Walls

Cyclic control displacement test was performed on the mentioned specimens. For such kind of masonry brick it was possible to generated an empirical model based on the eight walls experiments. Figure 2 show the superposition of the experiments results.

MASONRY MODELS

There are many different kinds of models for the numerical modeling of structural walls. Models could be classified into two main groups: macro models and micro models. Macro models intend to model the overall behavior of a structural wall cross section over certain height. Micro models are based on the constitutive laws of the mechanics of solids and finite elements methodology.

A good discussion of this two major categories is provided by Vulcano and Bertero (1987) for the R/C shear walls. Also Linde (1993) showed a description of the current likely used micro models. Rojas (1994) predict the behavior of masonry wall through an adaptation of a micro-model application proposed by Noguchi (1986) for concrete walls.

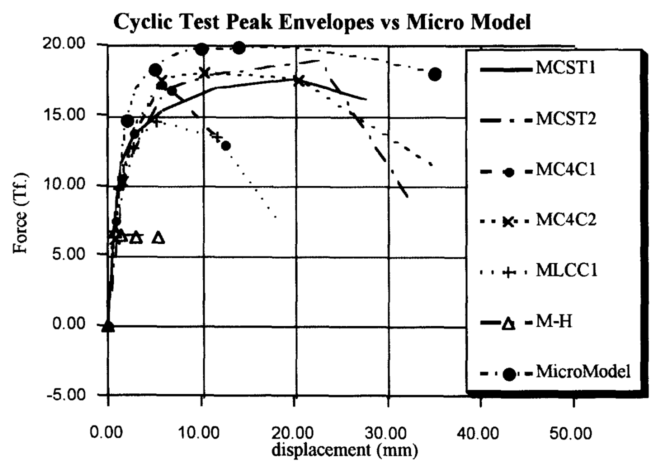

Figure 2: Experimental results by Gibu et.al.(1993)

Precision of micro models are quite accurate and it could be showed by the results presented by Rojas(1994) comparing the failure pattern and results with real standard masonry wall test, Figure 2 compares the results of Gibu et.al (1993) with the simulation performed by Rojas (1994). It is shown the good agreement between this refined model and the real test results. Unfortunately the practical applicability of such kind of models are quite difficult for daily engineering work, and it is limited to research job on developing countries.

On the other side, macro models are easy to implement and apply to practical applications and computational work is quite few. This motivated the authors to implemented a practical macro model considering a simple strut using the behavior characteristics of the walls failure pattern. Masonry Walls behave as a shear beam during the elastic range, where the stiffness of the wall is provided by the masonry itself and the confined columns. After occurs the first crack on the masonry, stiffness decrease gradually and crack propagation spread into the wall on different ways. The most likely is the X spreading due to shear cracks. It will decrease the stiffness of the masonry panel starting the action of the strut. It will acts as a brace that confine the frame with stiffness will consider the action width for the section of one quarter of the diagonal length. Figure 3 explains the actions and configuration of the strut model used.

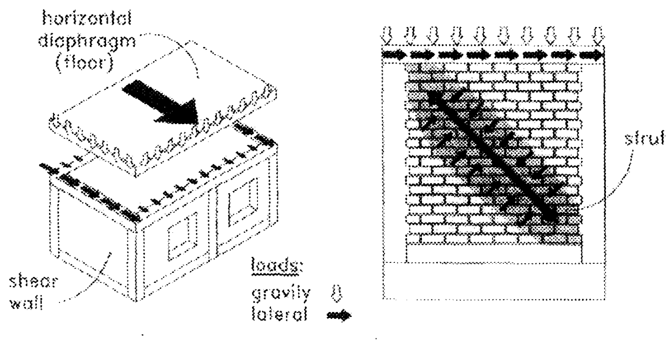

Figure 3: Wall actions under lateral and gravity loads

Using the strut model for masonry it is possible to simulate the behavior of the real wall. Properties of the strut model used in a simulation for a series of wall test is shown in Figure 4. Test results of Gibu et.al. (1993) micro model and strut model are presented on Figure 5. It could be observed the good agreement between the push over analytical curves and the cyclic peaks results. It shows with a simple modeling it is possible to simulate the real behavior of a wall.

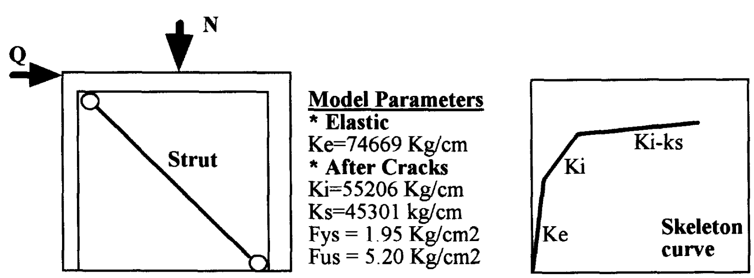

Figure 4: Properties of Strut Model for Wall Test Simulation

VERIFICATION OF THE STRUT MODEL

Scaletti, Cuadros et.al. (1992) performed a Pseudo dynamic test on a full scale two floors masonry building al CISMID. Forced vibration test prior to the on-line test was performed to determined the dynamic characteristics of the model. A natural period of 0.15 sec. was measure through a dynamic measuring system. For the pseudo dynamic test, the model was excited with Lima Earthquake 17-10-1966, with a peak ground acceleration of 269 gals. In order to verify the validity of the strut model a numerical simulation is performed, which intend to reproduce the response of the on line test.

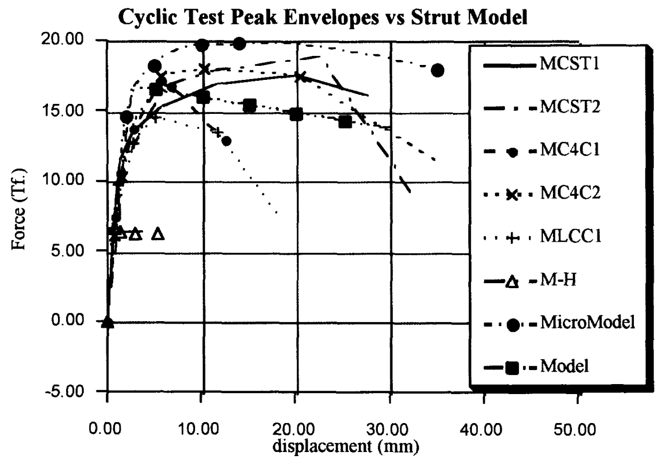

Figure 5: Strut Model and experimental results

Figure 6 compares the results of the simulation with the response obtained on the On-line test. It could be read an acceptable agreement between the curves, showing how a simple model can simulated the behavior of a real structure without great computational effort.

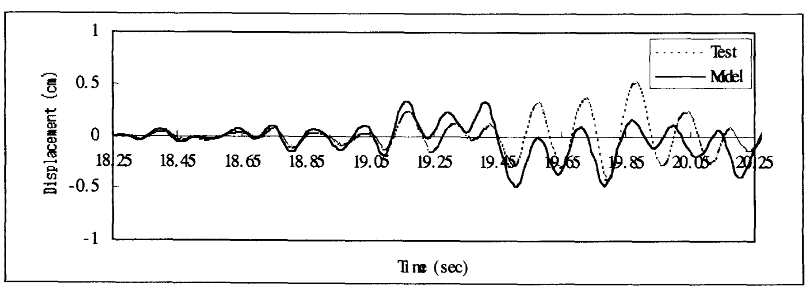

Figure 6: Comparison between PSD Test results and strut model

CONCLUSIONS

- A very brief introduction to CISMID-UNI masonry building research program has been presented. The program succeeds in the proposal of structural system to be used in urban areas with high probability of moderate earthquake activity.
- Among the results a simple strut based system has been presented. The results shown how a very simple macro model can simulated the behavior of non-homogeneous material like masonry with good approximation.
- Test results of different kinds of masonry walls are compared with strut model. From the comparison it is possible to read the good agreement of the curves. The results are also compared with a very refined micro model. Both results shown the capacity of simulate the behavior of the wall system.
-A full numerical analysis using the strut model is compared with Pseudo dynamic test results. Acceptable curves are presented, where the complicated mechanism of the masonry was simulated with the simple strut.

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