SEISMIC RESPONSE DIAGNOSIS ON MASONRY HOUSING USING EXPERIMENTAL MODELS ON AN SCREANING METHOD

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Abstract

In the evaluation of the seismic vulnerability on towns and cities, the seismic response diagnosis of masonry buildings could be reduced approximately on the basis of the geometry of the structural system obtained during a screening inspection. In this report a simplified method for evaluation is presented, which takes into account an equivalent one degree of freedom system and uses behavior curves from actual tests performed at Structural Laboratory on CISMID/FIC/UNI. The curves were reduced to non-linear models with parameters proposed herein. This model used different seismic demands, regarding the maximum peak ground acceleration (PGA) and the wall density on the structure as main variables. As a result a series of seismic response curves were generated for its use as a simple tool for screening evaluation.

Introduction

The evaluation of seismic vulnerability on buildings can be developed as a deterministic problem if we consider the geometric characteristics, material, reinforcement, soil characteristics and quake demand. However, on the evaluation of seismic vulnerability of 1000, 5000 o 10000 buildings, it means the evaluation of global seismic vulnerability of a city, the application of a deterministic method became time consuming and costly. For this reason, the called screening evaluation methods based on a fast evaluation or visual evaluation become an alternative for the evaluation of an area with high density of buildings. These methods used evaluation checklist, field surveys, database and other tools to produce a diagnosis of the seismic response of big amount of buildings. An approximated method for evaluation of the seismic response was presented on the study of the seismic vulnerability of housing on La Molina district, Lima [1], where the natural period of the structural system was used as parameter, as a function of the structural type and height of the building.

In this report a simple method for evaluation of the seismic response of masonry buildings based on the wall density and seismic demand is presented. The method is based on non-linear behavior curves obtained in 18 years of wall tests performed at the

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Experimental models

In the evaluation of the seismic response of masonry walls, sophisticated models of finite elements (micro models) and simple models based on strut (macro models) can represent the global characteristics of a wall. A comparison of both alternatives was presented on [2], where it is showed that, for maximum values, the application of a macro model does not lead to a wrong response of the structural system.

Using the experimental data of wall tests [3], [4], [5] y [6] performed on full scale at the Structural Laboratory on CISMID/FIC/UNI, a database of different types of wall, which represents diverse variables such as confinement, concrete quality, brick arrangement and type of joint was generated. From this data, testing walls were classified on 13 types presented on Table 1.

Table 1: Types of walls considered in the diagnosis

Tipo	Junta	Aparejo	Refuerzo	Calidad	Espesor	Longitud	Altura	Esbeltez	K1(t/m)	K2(t/m)	Vmax (t)
1	Endentado	Cabeza	4 Φ 1/2	Artesanal	0.20	2.65	2.30	0.87	15517.33	471.97	17.74
2	Endentado	Soga	4 Φ 1/2	Artesanal	0.12	2.40	2.30	0.96	7768.40	425.90	9.50
3	Endentado	Soga	4 Φ 1/2	Industrial	0.13	2.40	2.30	0.96	14707.00	486.30	19.13
4	Endentado	Soga	4 Φ 3/8	Industrial	0.12	2.40	2.30	0.96	9433.03	488.27	17.40
5	Sin Endentar	Soga	4 Φ 3/8	Industrial	0.12	2.40	2.30	0.96	7752.50	737.50	16.65
6	Endentado	Soga	4 Φ 3/8	Industrial	0.12	1.80	2.40	1.33	3880.90	132.10	11.37
7	Endentado	Soga	4 Φ 3/8	Industrial	0.12	2.40	2.40	1.00	5310.55	237.20	17.40
8	Endentado	Soga	4 Φ 3/8	Industrial	0.12	3.60	2.40	0.67	7894.05	384.75	23.56
9	Endentado	Soga	4 Φ 3/8	Industrial	0.12	2.40	2.20	0.92	3932.40	45.69	22.41
10	Endentado	Soga	4 Φ 1/2	Industrial	0.12	2.40	2.20	0.92	4341.96	0.00	13.86
11	Endentado	Soga	4 Φ 3/8	Industrial	0.12	2.40	2.20	0.92	4482.20	147.89	22.15
12	Endentado	Soga	4 Φ 3/8	Industrial	0.12	2.40	2.20	0.92	5499.00	335.27	22.21
13	Endentado	Soga	4 Φ 3/8	Industrial	0.12	2.40	2.20	0.92	5017.57	57.65	21.07

A bilinear model was generated from each of the behavior curves of the testing walls and type of wall. Figure 1 presents the generated curve (reference [6]) where the behavior curve is adjusted as bilinear curve.

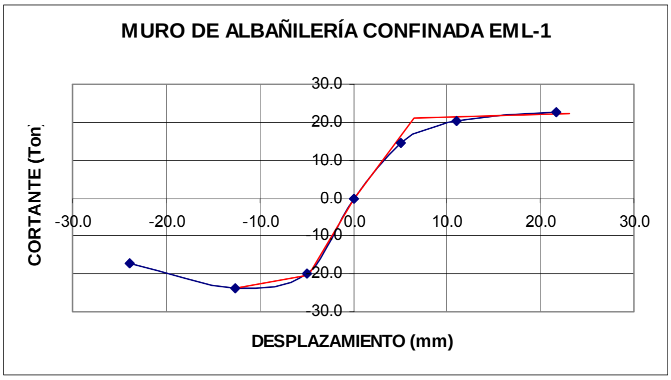

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Figure 1: Bilinear model from testing wall [6]

From these models a value of stiffness and initial diagonal cracking is found. As an example, on Figure 1 the elastic stiffness of 5017 ton/m, post-initial diagonal cracking stiffness of 57 ton/m with initial diagonal cracking load level of 21 ton, were found.
Each type of wall has its own elastic stiffness, post-initial diagonal cracking stiffness and shear level for initial diagonal cracking. These values represent the behavior of each type of masonry wall.

Diagnosis of the seismic Response

For the diagnosis of the seismic response a representative selection of Peruvian quakes were used, as Lima 17/10/1966, Huaraz 31/5/1970, Lima 3/10/1974, Nazca 12/11/1996, Atico 23/6/2001. The characteristics of Peruvian quakes are the high frequency content on the record.
For the evaluation of the stiffness on masonry building, the area of wall per unit of area, commonly named wall density, was taken as main variable. According with the characteristics of walls, the user can choose a wall type, from the experimental database, which represents the walls on the structure.
The number of stories of the building is considered as additional variable for each type of wall. If first mode is considering as representative of the response of the structure, it is possible the evaluation of an equivalent system using a one degree of freedom system, using uncoupled equations of motions and equivalent mass, stiffness and force on the system.
Then different allowable software for analysis of one degree of freedom systems as Nonlin, WaveAna, o Single, can be used for the evaluation of the non-linear seismic response on the structure.
The demand must be considered incremental, in order to evaluate the drift on the model for different demands. Then, a number of seismic responses for structures with different wall density like 2%, 4%, 6% y 8% with PGA of 100, 200, 300, 400 y 500 gals and each of the selected quakes were developed.

Figures 2, 3, 4 and 5 present the results of multiple seismic responses on models for 1 to 5 story buildings. As examples, the results on wall type 1 and wall type 3 are presented, where the parameter material is different. Here type 1 wall represents hand-made brick structure and type 3 wall represents an industrial-made brick structure.

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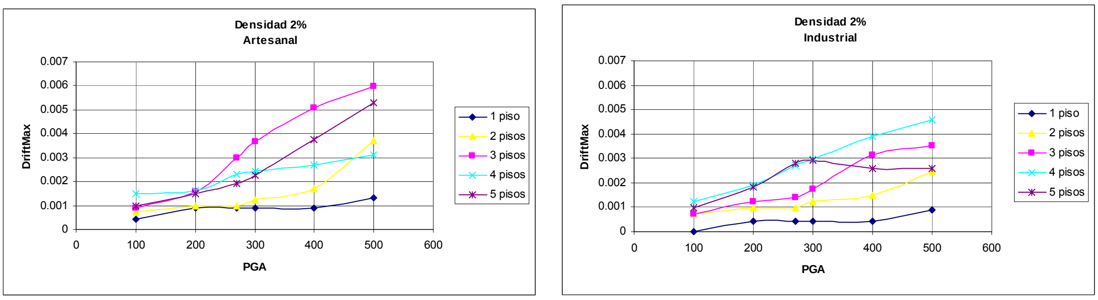

Figure 2: Responses for 2% wall density

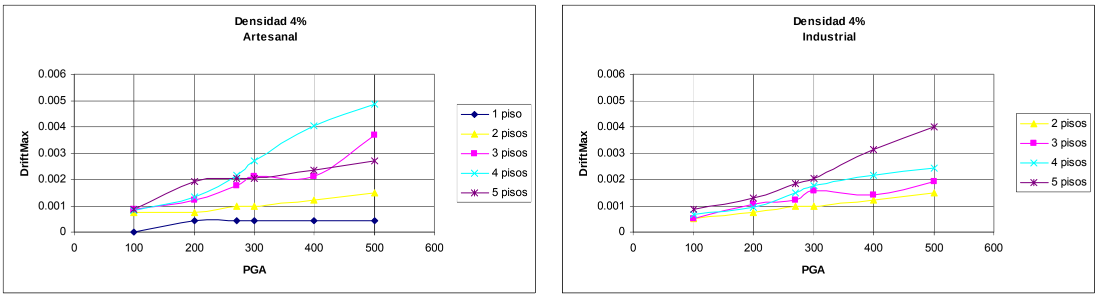

Figure 3: Responses for 4% wall density

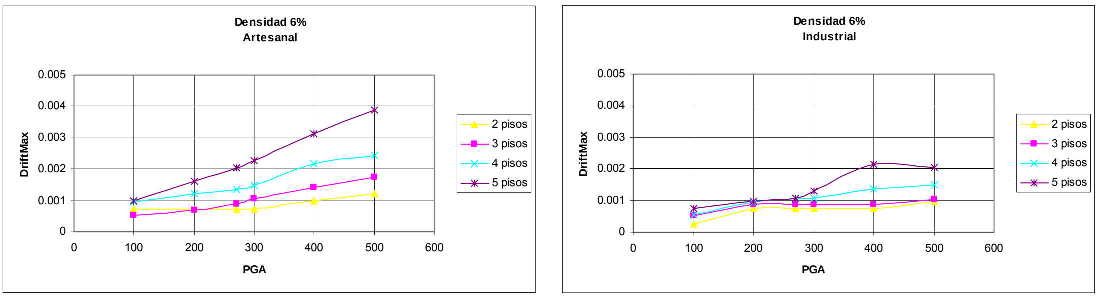

Figure 4: Responses for 6% wall density

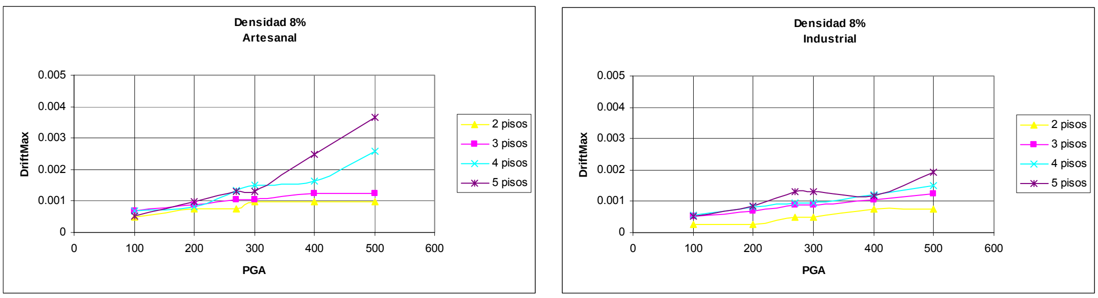

Figure 5: Responses for 8% wall density

From the figures it is possible to observe that the more wall density is, the smaller the seismic response, on structures built both with industrial or handmade brick. However, these responses are bigger on handmade brick structures, because the stiffness and the

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shear resistance of the handmade structures are smaller than those of the industrial made structures.

AGREEMENT CISMID/UNI - MUNICIPALITY OF LA MOLINA
SEISMIC VULNERABILITY OF LA MOLINA DISTRICT

LOCATION ....

BLOCK......................... **HOUSE**:...............................

SKETCH

TYPE OF BUILDING:

One family house ( ) Multifamily home( ) Home & bussiness ( )

Comercial ( ) Public ( ) Private ( )

CHARACTERISTICS:

Independent ( ) Dpt. on building ( ) Share ( )

Passage ( ) Other ....

OWNER:

Own ( ) Rental ( )

TIME FROM BUILT

.... Years

NUMBER OF PERSONS: ....

OCCUPATION

Professional ( ) Technitian ( ) Business ( ) None ( )

AREA OF THE LAND .... **X** .... **=** **m2**

AREA BUILT ....**X** .... **=** **m2**

NUMER OF STORIES .... **UNDERGROUND :** YES ( ) NO ( ) No ....

STORY HEIGHT ....

HALF UNDERGROUND ( )

TOTAL HEIGHT .... **mt.**

MAIN CONSTRUCTION MATERIAL :

Adobe ( ) Masonry ( ) Reinforce Concrete ( ) Other...

ADOBE	MASONRY	REINFORCE CONCRETE
FOOTING Stine and mud ( ) Stone and Cement ( ) Other .... **STATE OF CONSERVATION** Good ( ) Regular ( ) Bad ( ) No settlements ( ) With settlements ( )	**FOOTING** Beam without reinforce ( ) Beam with reinforce ( ) Other .... **STATE OF CONSERVATION** Good ( ) Regular ( ) Bad ( ) No settlements ( ) With settlements ( )	**FOOTING** Isolate ( ) Conected ( ) Other .... **STATE OF CONSERVATION** Good ( ) Regular ( ) Bad ( ) No settlements ( ) With settlements ( )
ADOBE	**MASONRY**	**REINFORCE CONCRETE**
ROOF SYSTEM Wood( ) Cain ( ) Mud ( ) Other:	**ROOF SYSTEM** Concrete Slab ( ) Light slab ( ) Other:	**ROOF SYSTEM** Concrete slab ( ) Light slab ( ) Other: ....
STATE OF WALLS GOOD ( ) REGULAR ( ) BAD ( ) WITH COVERING ( ) WITHOUR COVERING ( ) COMENTARY..	**STATE OF WALLS** GOOD ( ) REGULAR ( ) BAD ( ) WITH COVERING ( ) WITHOUR COVERING ( ) COMENTARY..	**ELEMENTS :** **COLUMNS ( )** WITHOUT CRACKS ( ) WITH CRACKS ( ) COMENTARY.................................. ....
REINFORCE ON WALLS	**VERTICAL AND/ OR HORIZONTAL REINFORCE**	**BEAMS :** ....
 YES ( ) NO ( ) COMENTARY	**IN WALLS** YES ( ) NO ( ) IF ANSWER IS POSITIVE FILL THE FOLLOWING: ONLY COLUMNS **( )** ONLY BEAMS **( )** BEAMS AND COLUMS **( )** WITH REINFORCE INSIDE THE BLOCKS **( )** COMENTARY :	WITHOUT CRACKS ( ) WITH CRACKS ( ) COMENTARY.................................. **CONCRETE WALLS:** .... WITHOUT CRACKS ( ) WITH CRACKS ( ) COMENTARY..................................

Figure 6: Survey evaluation checklist format

How to use these graphs

The graphs can be used for the diagnosis of the seismic response of masonry. Firstly, identify the type of masonry using Table 1. A field survey is required to assess the classification and state of the building. This format will also record the physical and material characteristics of the structural system, such as number of stories and wall

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density. Then considering the number of stories, wall density and probable demand on the location (maximum PGA) the response can be computed. By the consideration of these factors, it is possible to evaluate the maximum building drift for the demand quake. If the diagnostic drift is bigger than the drift threshold of the seismic standards, the structure will be considered vulnerable. If the diagnostic drift is lower than the seismic standards threshold, the structure will be considered to resist the quake without structural problems for the demand quake.

Final Commentary

This report shows the first steps in the development of a method for evaluation of seismic response of buildings, both in urban or rural area. We consider our experimental background to shear the behavior curves and maximum threshold for each type of wall. However there are many influences we continue studying such as the influence of axial loads, overturning moments and other external factors. The authors consider this methodology a diagnosis proposal for screening evaluation. We want to provide in near future a second version of the method with the consideration of the drift thresholds proposed on [4] to evaluate the damage by the quake demand.

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