O 31. EVALUATION OF CAPACITY AND SEISMIC PERFORMANCE OF BRICK MASONRY BUILDINGS WITH AND WITHOUT STRUCTURAL INTERVENTIONS

Marjo Hysenlliu[1], Altin Bidaj[1]

[1]*Polytechnic University of Tirana, Tirana, Albania*

E-mail: mariohysenlliu@yahoo.com, altinbidaj@yahoo.com

ABSTRACT: Unreinforced masonry [URM] is the dominant structural type for low to moderate-rise buildings in the Albania. Its dynamic response is highly inelastic, and generally shows high vulnerability to earthquake loading. Also many buildings of these type in Albania have structural interventions like added floors, or wall openings, especially in the first floors of the buildings, which are near main roads, because of great demand for shops and stores. In literature, there are a number of methods available to evaluate the seismic performance of these buildings. The choice of the proper model to use is a matter of paramount importance, as many aspects must be taken into account in order to reach a good approximation of the structural behavior. Within this context, this paper aims to make seismic performance assessment by following the equivalent frame approach based on macro-element modeling. Due to the resource and time efficient computations, this approach is becoming more popular among the practitioners and field experts in this area and allows simulating the non-linear behavior of masonry buildings. This method will be applied to three old masonry buildings from the Albanian construction practice that are representatives of low- and mid-size residential buildings. These buildings are of the same template but some of them have structural interventions. It must be said that in Albania, masonry buildings have been built using templates all over the country, so both models with and without intervention are common. Capacity curves of the investigated building will be determined to assess the most probable seismic response of the investigated housing construction in the region. Also the Finally, estimated results will be used to evaluate the seismic performance of the tested structures.

Keywords: Unreinforced masonry buildings, Macro-element approach, seismic vulnerability, TREMURI software, unreinforced masonry buildings

1.INTRODUCTION

1.1 History of masonry structures

Albania in all of history has known many different developments in engineering and architecture. Nowadays, the most common type of residential buildings and when the major part of the population lives, are of principal masonry materials. Masonry as a cheaper material was the most used and mostly used as unreinforced masonry, with building up to 5 story high, especially in the 45-90s era. Building codes also, have played a significant role. KTP-1963, KTP-1978 and KTP-1989 have significant changes within one another, but also very verified deficiency. This comes from lack of knowledge of the time especially on seismic calculations, compared to nowadays accepted worldwide codes like EC and ASTM. Lacking of seismic analysis in KTP-63 and low considered demand of KTP-78, implies that the entire stock of pre 89s era to be reconsidered and reanalysed with today updated codes.

1.2 Basics of analysis

From the stock are choosen three buildings, from the most used templates of each era, reffering here to code of design. Bricks and mortar samples are extracted from these buildings and six tests are performed to evaluate the mechanical properties of the materials used and masonry bearing walls. Three dimensional models of buildings are prepared for modal, pushover and performance analysis by a user-friendly software as 3muri, specialized for masonry buildings. This software uses macro-modelling technique with pier and sprandels and takes in consideration the non-linear phase of the masonry material, as in EC normative. Pushover analysis is performed, for 24 cases of loading in both direction, eccintrency, and shapes. The spectrum approach for seismic design is a very useful and easy solution comparing to more complicated analysis as time history analysis or fragility analysis. It gives a limited solution, but its data is acceptable for most of the cases. Seismic loads in this approach are represented by response spectrum function which are derived from the time history records of earthquakes in a specific area. Performance evaluation as N-2 normative and EC, gives a view of the seismic risk for each building.

1.3 Various common interventions on masonry buildings

For many buildings especially those that are near main roads serious problems can be noticed. The subfloors were intended for magazines, with small openings, but due to commercial request for shops, stores etc, in many times interventions are done. Even though masonry structures are designed with load bearing walls This not only weakens the structure, but seriously affects seismic resistance. Examples like this, and of similar intervention on Albanian masonry structures are very widespread. Since lots of time has passed since the time of construction of these structures, all types of damage effects like physicals, chemicals, and from human intervention are present in these buildings. walls are demolished on the first floor and replace with two columns and a beam sustaining all the loads coming from above. Another very wide spread intervention in Albanian building stock is the phenomenon of added stories. After the collapse of the communist regime in the 90s, because of the great demand in cities for housing, in many times stories were added in various buildings using light materials. These additions were done in a hurry and without design and projects during this time. But later at the 2000s due to the policies of the time, these additions were legalized and still exist nowadays. In this study buildings with this intervention will be studied and compared with the design and project of original template.

2.CASE STUDIES

2.1 Brief history

The housing problem in the socialist state could only be solved through multi-story buildings built on projects based on template section designs. The first template section archived was two story adobe building in 1949. The beliefs of the regime were also projected in the buildings body. The institutes and government made laws for equality and standardization. So buildings were made by combination of standard apartments approved. Since these buildings, have been built in a long time, around 45 years, their diversity is very wide. Although the use of template sections, facilitates the process of classification, still diversity is noted, and affects directly structural efficiency.

2.2 Classification of masonry buildings stock

The basis of classification for masonry structures are denined by four pillars: time of construction, height of building, material used and building location. From time of construction buildings can be classified as:
-Buildings constructed before 1963: Based on prior experience, no seismic evaluation
-Buildings constructed from 1964 to 1978: Based on KTP-63, very low seismic consideration
-Buildings constructed from 1979 to 1990: Based on KTP-78, low seismic consideration
-Buildings constructed after 1991: Based on KTP-89, small population of buildings with load bearing masonry walls.
The classification of height is based on the number of stories each building has. The Albanian building stock has maximum 6 story buildings with load bearing masonry walls.Most of the buildings prior of KTP-63, were no more than 4 stories, and later up to 5. In many buildings problem are the added stories, that impies an increased seismic demand, with all the deficiency that KTP-78 itself has. The tallest buildings are the ones, in wich is excpexted more damage and risk in seismic scenario.
By the materials used these buildings can be classified in two major groups: unreinforced masonry and confined masonry. Unreinforced masonry are most common and before KTP-78, very few buildings had confinement columns, on the load bearing walls. These buildings are of both clay bricks masonry and silicate brick masonry. Buildings with clay brick masonry perform more resistent to atmospheric agents comparing to silicate ones. For the compressive strength of the bricks used on most of the stock the clay bricks are with $f_k = 7.5MPa$, meanwhile the silicate bricks used have more compressive strength $f_k = 10MPa$ on most of the buildings. Mortar strength also varies and mostly are used cement or lime mortar

with $f_k = 2.5MPa$ and $f_k = 5MPa$. The bonding between clay and mortar is better than silicate-mortar, giving so a greater value of f_{vk} shear strength of masonry. The confined masonry buildings are of the 1978 to 1990 era, and have perimeter columns of C12/15 for increasing lateral resistance of the shear walls. Also the slab types varies on buildings and era of construction but most of them are rigid slabs of reinforced concrete. Foundation are constructed with stoned of M>200 and are calculated for [σ]=2kg/cm2.
Location of the buildings affects many factors of the performance of the buildings. Site conditions, climatic effects and seismicity of the zone as the most governing factor. Albania can be divided in three zones, from the seismic risk, where the intensity scale of projection varies VI, VII and VIII. Also some zones where considered with lower seismic intensity in KTP-63 and KTP-78, implying a lowered seismic consideration on projection.

2.3 Selected buildings
The buildings chosen from the stock are of template A1 wich is very used all around the country, especially in Tirana. This template and building is of the oldest in Albania of 1940s, but the buildings are near the "ish blloku" zone in Tirana, and they are buildings with good maintenance so no severe damage is observed. The buildings has plan dimensions of (56.65*11.65)m. Building has two entrances and four apartments and is symmetric. Building has two stories of 2.8m height. In some of the buildings of these template are built extra stories later in the after 90s period (in two of these building also known as MOSKAT). Inside and outside walls of the building are 25cm and non load bearing walls are 12cm. For masonry are used clay bricks of strength 5MPa as given in the project. The mortar used is lime mortar as defined in the project with ratio 1:3 (lime : sand). Specifications of the mortars and the procedure of preparing are given in [K.Cika 1969].For 1m^3 sand is used 0.333m^3 lime and 200liters water.

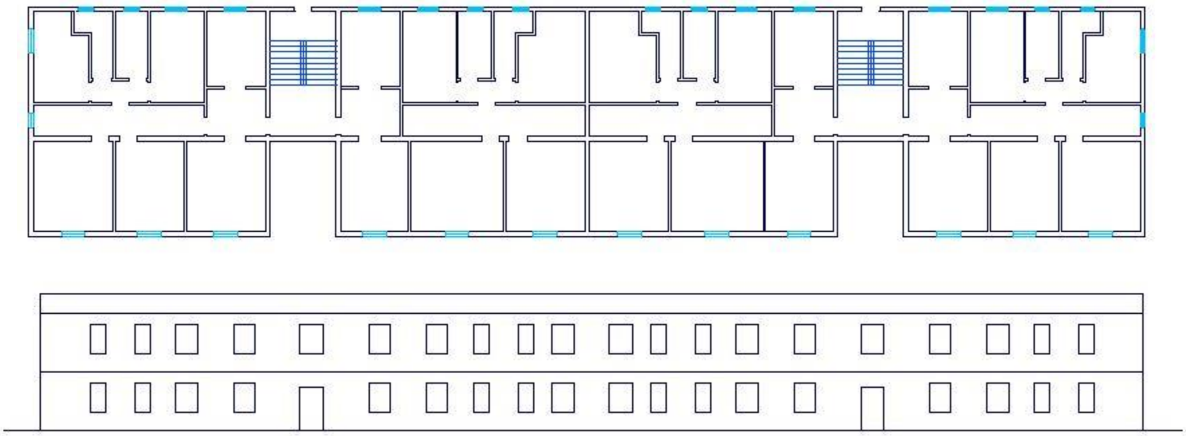

Figure 1. Building A1 plan view and facade view

3.MECHANICAL PROPERTIES OF BUILDINGS
The basics characteristics for modeling masonry structures are:
-Characteristic compression strength f_k
-Elastic module in vertical shear E
-Elastic module in tangential shear G
Values and recommendations are given for correlation between material and element properties. These are based on compressive brick strength and compressive mortar strength. Below is given a summary of the basic parameters and their calculation, from EC and some other recommendations
Compressive strength of masonry
$f_k = K * f_b^{0.7} * f_c^{0.3}$ (values of f_b and f_m are normalized with δ factor)
Young modulus $E = 1000 * f_k$
Compressive fracture energy $G_{fc} = 15 + 0.43 * f_k - 0.0036 * f_k^2$
Tensile strength $f_t = 0.05 * f_k$
Tensile fracture energy $G_f = 0.1MPa$

Shear strength $f_{vk} = f_{vko} + 0.4\sigma_d$
$f_{vko} = 0.2$ when clay bricks are used or silicate bricks M-10
$f_{vko} = 0.15$ when silicate bricks M-7.5 used as recommended in EN,
the maximum value of $f_{vk} = 0.065f_b$ $\sigma_d = 1\text{MPa}$
$f_{xk1} = 0.035f_b$ with filled and unfilled perpendicular joints
$f_{xk2} = 0.035f_b$ with filled perpendicular joints $f_{xk2} = 0.025f_b$ with unfilled perpendicular joints
Shear modulus $G = 0.25E$
Poisson ratio $\nu = 0.2$
Values taken by the project blueprint are revised after the laboratory tests on the selected buildings. The laboratory tests are done to the guidance of ASTM codes. They are divided in three basic sections:
- the brick tests
- the mortar tests
- the masonry prism tests

The tests are done to compare the values of the project with the real values from the tests. This because many buildings are built before 50 or more years and materials are degraded with time. EC and ASTM give formulas and correlations for defining masonry characteristics from the brick and mortar properties, but prism test are also done to verify this values.

3.1 Brick testing

For the determination of the solid brick compressive strength the procedure in ASTM C67-09, five full specimens of dimension (250*125*60) mm should be tested. The test specimens should consist of dry half bricks, full height and width of the unit, with length equal to one half the full length of the unit.

Figure 4. Brick compression and tensile flexuaral test

Compression strength of bricks fbt is derived from this test.Tensile strength for bricks is obtained by the brick tensile flexural strength ASTM C67-10. Tensile strength is tested on a series of single bricks supported by steel roller bearings, simple beam system. Load is applied gradually through steel rod on top of the bricks acting like a concentrated load. The samples are of dimensions (40*40*160) mm.

3.2 Mortar testing

For the mortar tests, for unreinforced masonry, samples of mortar are collected in the areas where the connection between solid bricks units and mortar has failed. Due to the irregular shape of the samples, capping is required to be done according to ASTM C109/C 109M-02 regulations [ASTM,2008]. The depressions at the samples are filled with mortar composed of 1 part by weight of cement and 2.75 parts of sand. The specimens are aged at least 48h before capping them. In this perspective, samples of mortars with (500*500)mm dimensions are prepared in the moist closet or moist room. The average compressive strength of the 5 samples is taken as the compressive strength. When it is impossible to take samples of the mortar the strength is taken according to the project and KTP. The same procedure is for the flexural strength of mortar samples. The samples are constructed of dimensions 40*40*160mm. Tensile strength is tested on a series of mortar samples supported by steel roller bearings, simple beam system. Load is applied gradually through steel rod on top of the bricks acting like a concentrated load.

Figure 5. Mortar samples compression and tensile flexuaral test

3.3 Mortar testing

Prism testing is a laboratory test for calculating the compressive strength of a masonry prism. A minimum of three prisms should be constructed, using the same materials and workmanship as used in the project. The mortar bedding, joint thickness, joint tooling, bonding arrangement and grouting pattern should be the same as in the project. No structural reinforcement should be included, however, metals wall ties may be included if used in the project. The prism thickness should be the same as that of the actual construction. The prism length should be equal to or greater than the prism thickness. The height of the prism should be at least twice the prisms thickness or a minimum 375mm.

Figure 6. Prism masonry test and tripet shear test

The ultimate compressive strength of a prism is calculated by dividing the maximum compressive load by the cross-sectional area of the prism. The strength of masonry is related to the strength of prism with the formula: fk = Cf * fprism
where Cf is correction factor varying from h/t ratio

Table 1. Correction factors for different h/t ratios[1]

Correction factors for different h/t ratios							
Ratio of height to thickness (h/t)	1.3	1.5	2.0	2.5	3.0	4.0	5.0
Correction factors for prism	0.75	0.86	1.00	1.04	1.07	1.15	1.22

[1] Standard Test Method for Compressive Strength of Masonry Prisms ASTM C1314-12 ASTM international, INC., 2012

Triplet testing of masonry is a test for determining the shear strength of masonry walls. The shear strength of masonry triplets was obtained as described in EN 1052-3:2002.
The specimens consist of three bricks bonded with mortar of same recipe and workmanships as in the original projects. Three sets of triplets are tested under no compressive force for determining f_{vko} value. Then three others sets of triplets are tested with the presence of compressive test as given in the Code. Two load cells were used to carry out the shear tests. One load cell was used for applying the shear force and the other applying the compressive force acting perpendicular to the shear force.

3.4 Investigated building and test results

The investigated building A1 is located near "ish Blloku" in Tirana In the figure below are shown the positions were the samples were extracted.

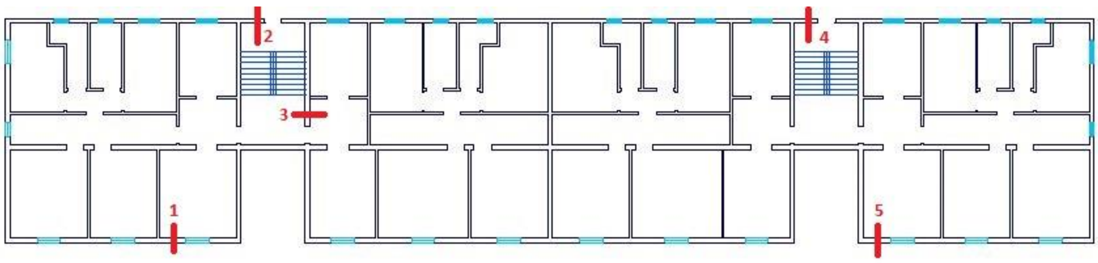

Figure 7. Locations on plan where samples are extracted from masonry

Below are given the test results and the derived mechanical properies from them using the correlations given above.

Table 2. Revised brick and mortar properties for analysed building

Building	Brick properties			Mortar properties		
	Type	$f_b\ [MPa]$	$f_{bt}\ [MPa]$	Type	$f_m\ [MPa]$	$f_{mt}\ [MPa]$
A1	Clay	5	1.1	Lime	2.3	0.45

Table 3. Revised masonry wall properties for analysed building

Building	f_k $[MPa]$	f_{vk} $[MPa]$	f_{vk0} $[MPa]$	f_t $[MPa]$	f_{xk1} $[MPa]$	f_{xk2} $[MPa]$	E $[MPa]$	G $[MPa]$	G_{fc} $[MPa]$	G_f $[MPa]$	ν
A1	1.43	0.3	0.15	0.072	0.180	0.129	1430	358	2.38	0.1	0.2

4. BUILDINGS MODELS AND PUSHOVER ANALYSIS

Modelling of masonry structures has always been a difficult problem because of the presence of joints as the major source of weakness and also nonlinearity and discontinuity of the material. A proper model must take in consideration both the behaviour of brick and mortar units and the interaction between them.
In this paper is used a macro-modelling technique. The materials are not modelled as divided elements, but with equivalent elements (like plates for example) that have equivalent properties. 3muri is based on a finite element methodology for modelling masonry structures. The software proposes the line finite element, which is represented by its axisThe non-linear macro-element model, representative of a whole masonry panel, proposed by Gambarotta and Lagomarsino (1996), permits with a limited number of degrees of freedom (8), to represent the two main in-plane masonry failure modes, bending-rocking and shear-sliding (with friction) mechanism, on the basis of mechanical assumptions.

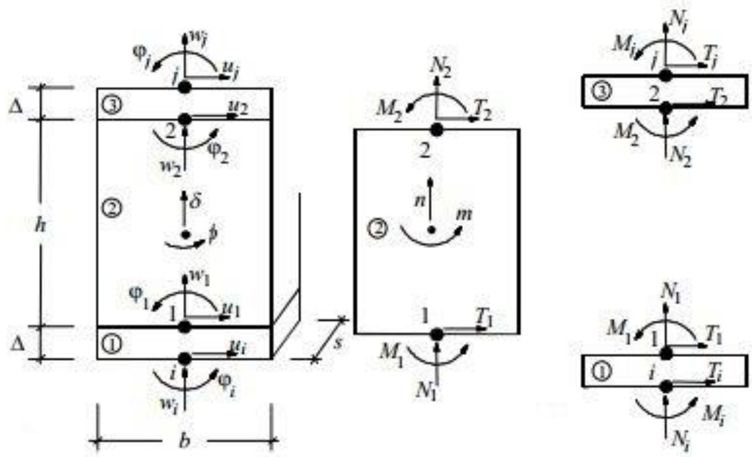

Figure 8. 3Muri finite element view[2]

The static pushover analysis is based on the assumption that the response of the structure is controlled by the first mode of vibration and mode shape. The shape remains constant throughout the elastic and inelastic response of the structure. This allows ,theoretically ,transforming a dynamic problem into a static one for easier solution. The response of the MDOF is related to the response of an equivalent SDOF. A non-linear incremental static analysis of the MDOF structure can now be generated, to determine the force-deformation characteristics of the equivalent SDOF.

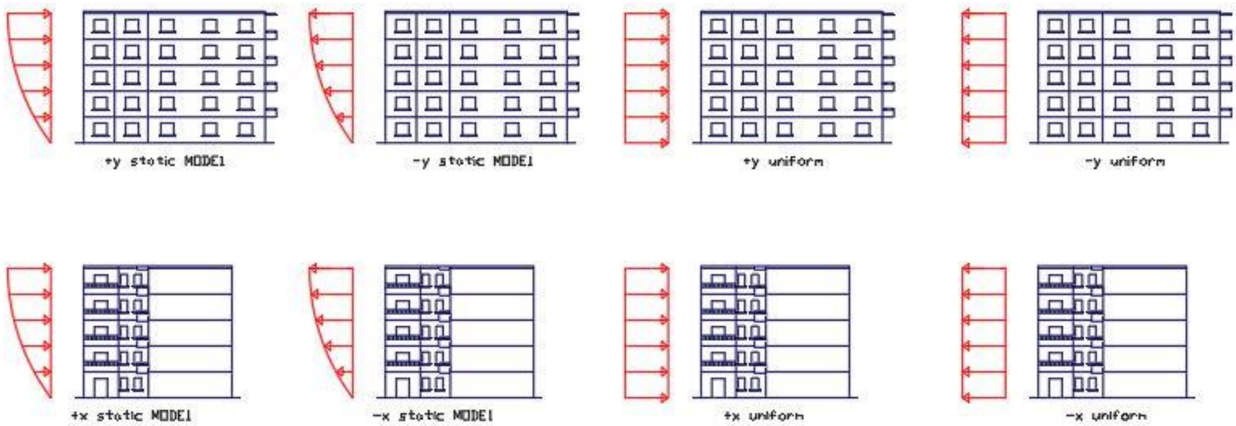

Figure 9. Load patterns and different cases of pushover analysis of template B4

The outcome of the pushover analysis is the diagram of the global force versus top displacement curve or capacity curve. In order to perform a pushover analysis for a MDOF system, a pattern of increasing lateral force needs to be applied to the mass points of the system. In 3muri approach are 2 load pattern applied: first mode shape distribution (static), based on the fundamental mode shape of the structure, and an uniform load distribution to all stories. The two are performed in two directions X and Y and with positive and negative values. So in total 8 analysis: +x MF1, +x uniform, -x MF1, -x uniform, +y MF1, +y uniform, -y MF1, -y uniform. These analysis are done for 3 more combination. Without eccentricity of gravity load and with eccentricity of two different levels. For every building, are computed 24 analysis, for all load combinations, earthquake direction, with and without eccentricity. The worst cases are chosen as representing the pushover curves for both x and y direction of buildings.

4.1 A1 buildings

This building is symmetric and are separated from one another, only half of the building, is considered.

[2] Seismic assessment of masonry structures by non-linear macro-element analysis. A.Penna, S.Cattari, A.Galasco S.Lagomarsino

Loads are consided as below:
Dead gravity loads $= 4kN/m^2$
Probable live load $= 2kN/m^2$
Also two more buildings are modelled with one story and two story plus, since some of these buildings have these added stories. For the added floors the joints connections between the original stories and the added one are modelled as rigid joints because this interventions are done before many years and are consolidated. The walls are modelled as non-linear materials, with brick strength $f_b = 7.5MPa$, mortar strength $f_m = 5MPa$, density of wall $\rho_{wall} = 1200\,kg/m^3$, masonry strength $f_k = 2.5MPa$, shear strength $f_{vk} = 0.4$ and $f_{vk0} = 0.2$. Modulus of elasticity of masonry is taken as $E_m = 2500MPa$ and $G = 700MPa$. the same as the typical plan of the building.

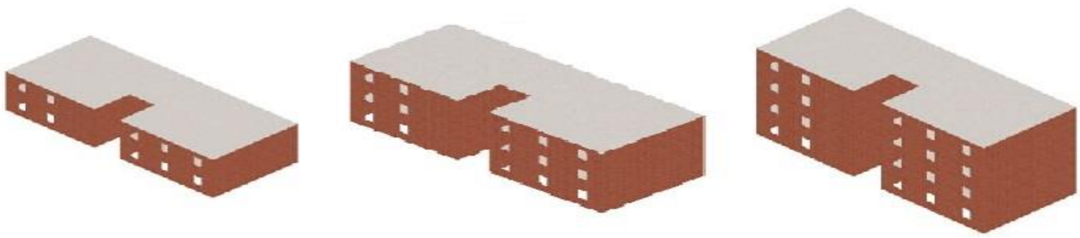

Figure 10. A1 buildings models

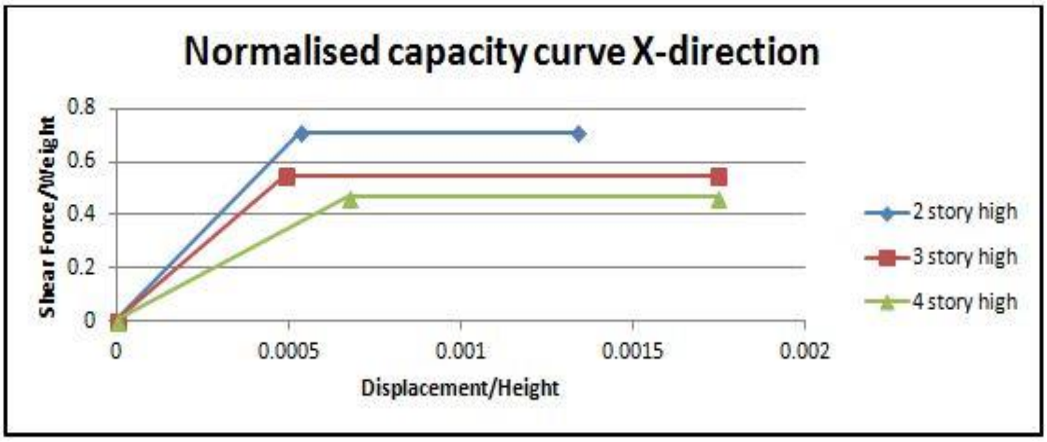

Figure 11. A1 buildings normalised capacity curves in x-direction

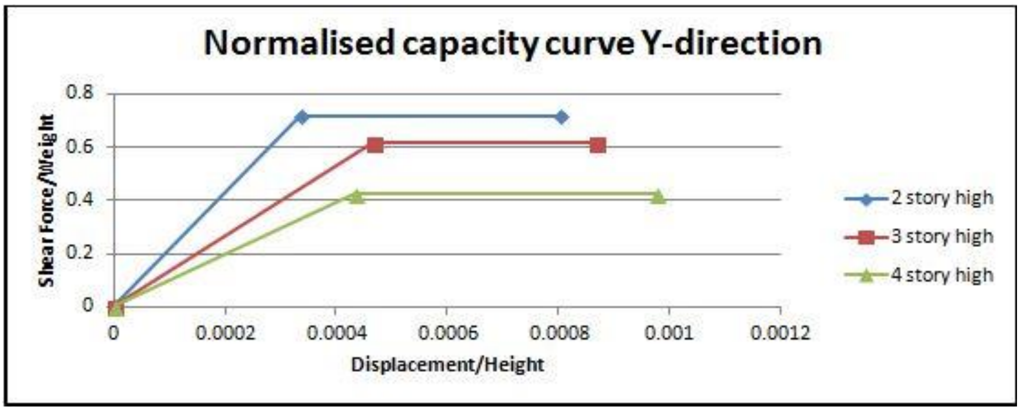

Figure 12. A1 buildings normalised capacity curves in y-direction

If we compare the parameters from the pushover curves, the shear force / weight ratio decreases significantly, while the ductility index increases with the addition of stories. Also the initial stiffness of the buildings decreases with height addition. If the fail mechanism are compared, in the buildings with more stories, in the upper stories walls have more from shear damage and some parts shear failure.

Although the most damage still comes from bending failure in the lower parts of the inside walls of the buildings.

Table 4. Pushover analysis parameters of A1 buildings

	Initial stiffness	Max Force/Weight	Yield Disp /Height	Max Disp /Height	Ductility index
A1x	5884	0.7122	0.000533	0.001333	2.5
A1x +1	4596	0.5494	0.000489	0.001744	3.57
A1x +2	2717	0.4676	0.000675	0.001741	2.58
A1y	9465	0.716	0.000333	0.0008	2.4
A1y +1	5381	0.6141	0.000467	0.000867	1.8
A1y +2	3842	0.4245	0.000433	0.000975	2.25

5. PERFORMANCE EVALUATION

A performance level is a limit stage on the pushover curve that is used to classify the damage. They are different approaches to classify the damage limit states on masonry buildings. 3muri is based on EC so it classifies the damage in three limit states:

DL damage limitation 0.1% drift ratio
SD significant damage 0.3% drift ratio
NC near collapse 0.5% drift ratio

The drift ratio is the basic parameter for defining the performance points. For all buildings these limit state are calculated and by using the equivalent displacement method are compared with the EC spectra, giving a maximum ag for each limit state. This process is generated automatically from 3muri software. Buildings are supposed to be in category B soil conditions with parameters:

S=1.2 T_B=0.15s T_C=0.5s T_C=2.0s q=2 (URM)

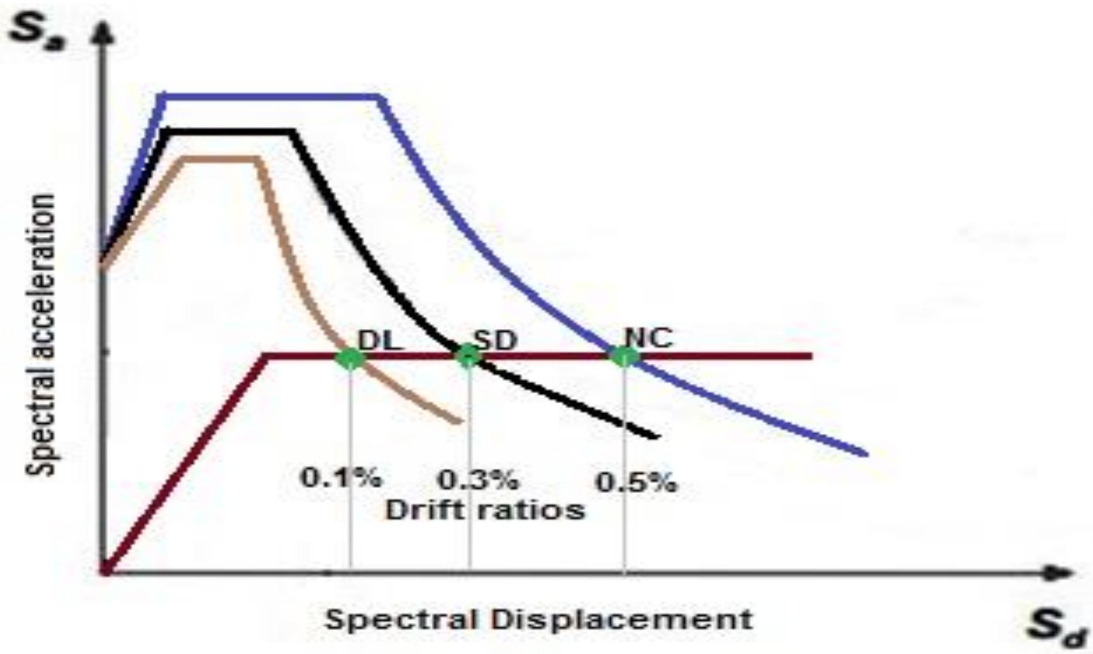

Figure 18. Performance evaluation on 3muri software based on EC

5.1 Buildings performance levels and seismic evaluation

On each buildings seismic equivalent analysis gives the maximum a_g for each limit state of buildings. In the below table are given the analysis results for each building in both directions.

Table 7. Performance evaluation and P.G.A level for each building in both directions

Building	dy (m)	dm (m)	Fy (kN)	a_g DL (m/s^2)	a_g SD (m/s^2)	a_g NC (m/s^2)	dt DL (m)	dt SD (m)	dt NC (m)
A1x	0.0021	0.008	1883	1.863	2.970	3.533	0.00269	0.00446	0.00623
A1y	0.002	0.008	1893	1.846	2.299	2.641	0.0026	0.0044	0.0062
A1x 3fl	0.0044	0.0157	2022	1.264	2.386	2.975	0.00553	0.00892	0.01231
A1y 3fl	0.0042	0.0078	2260	1.377	1.866	2.180	0.00456	0.00564	0.00672
A1x 4fl	0.0081	0.0209	2201	1.068	1.831	2.365	0.00938	0.01322	0.01706
A1y 4fl	0.0052	0.0117	1998	0.967	1.525	1.878	0.00585	0.0078	0.00975

5.2 Conlusions

If we compare the P.G.A values from Albanian seismic map, it can easily be spotted that some of these buildings have serious risk even of collapse if an earthquake with RP=475years happens. Especially the buildings of template A1 with 2 added floors, have no capacity of bearing a higher P.G.A than 2.0m/s^2. it must be said that similiar cases of buildings with added stories are spread all around the country so each should be checked for the zone P.G.A level. A retroffiting technique should be implemented on these buildings.

Table 8. Risk evaluation of each building for different P.G.A levels

Building	**0.15g**	**0.2g**	**0.25g**	**0.3g**	**Risk**
A1	**DL**	**SD**	**SD**	**NC**	**low**
A1 3fl	**SD**	**SD**	**NC**	**-**	**moderate**
A1 4fl	**SD**	**NC**	**-**	**-**	**high**

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APPENDIX

Section A
Building A1

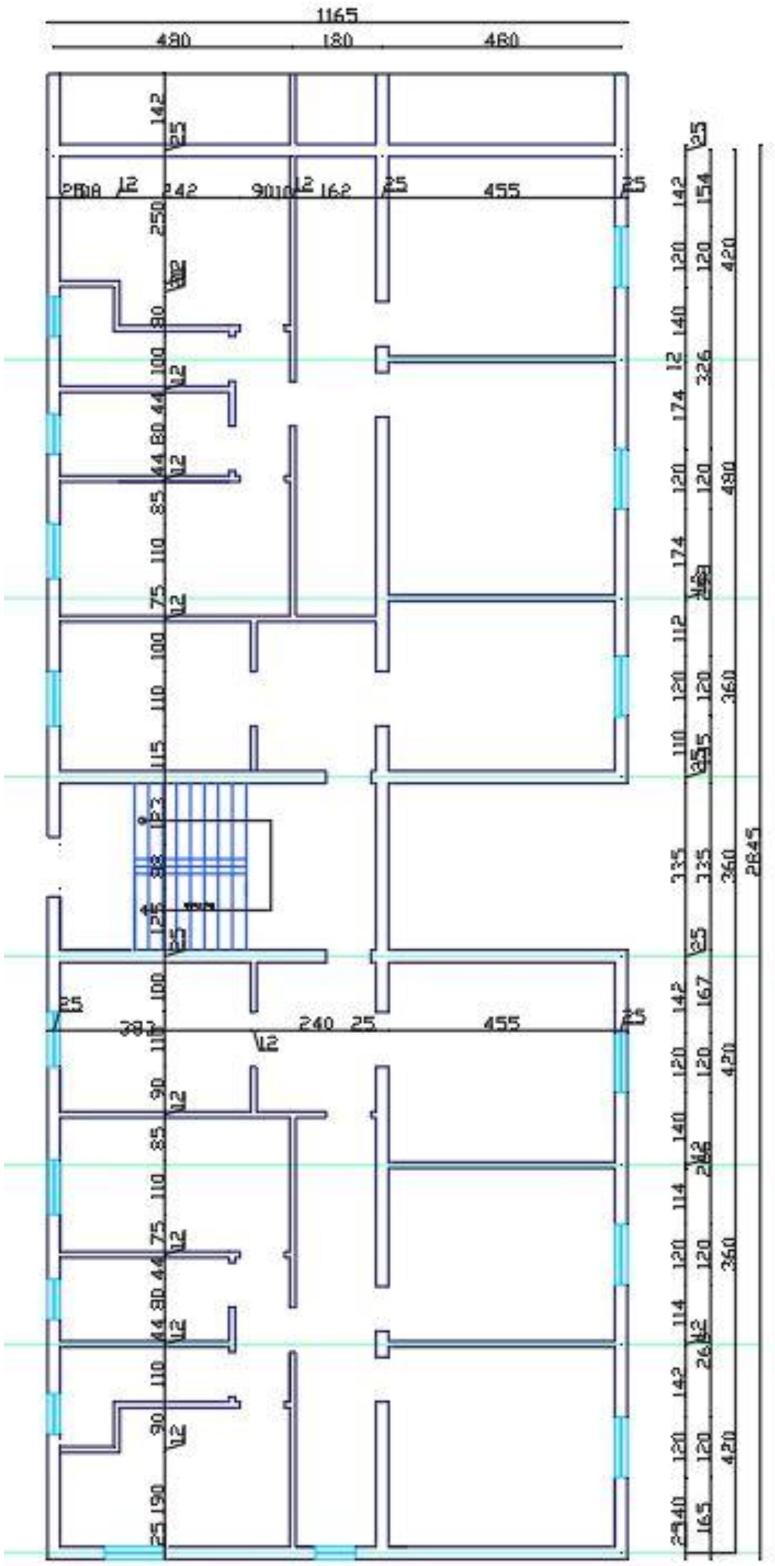

Figure 19. Plan view of building A1

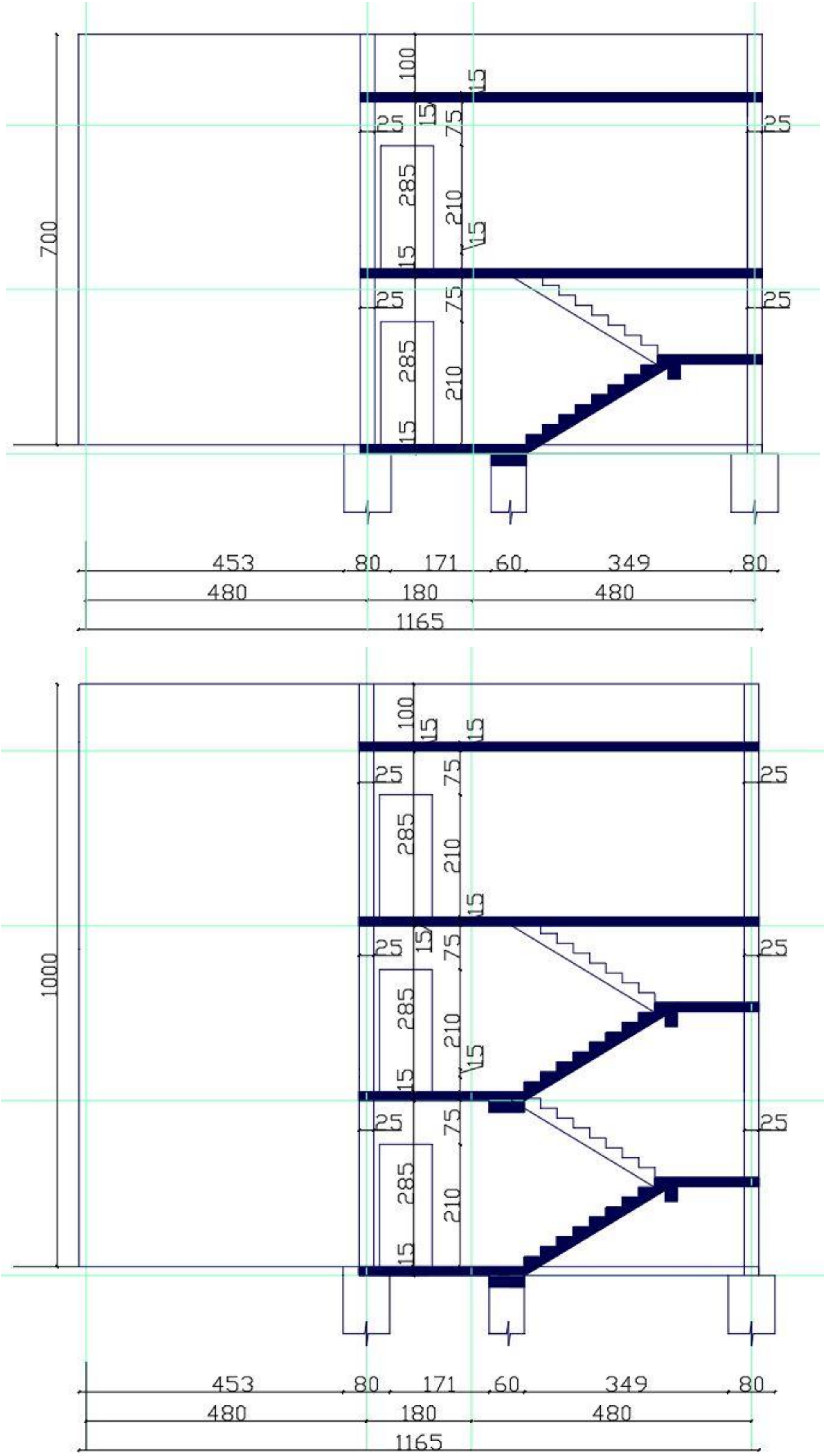

Figure 20. Cut view of building A1 for original building and building with one added story

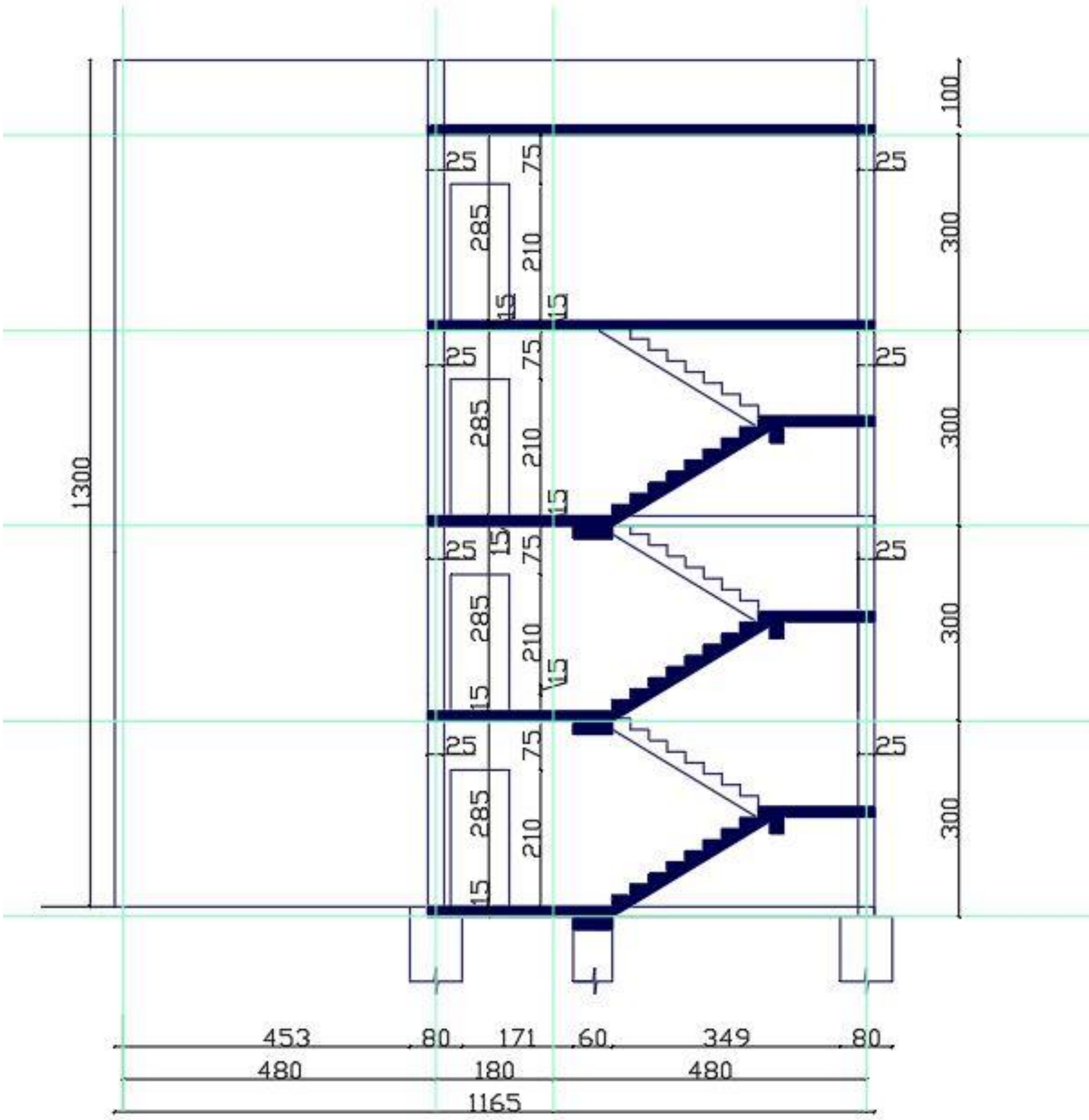

Figure 21. Cut view of building A1 with two story added

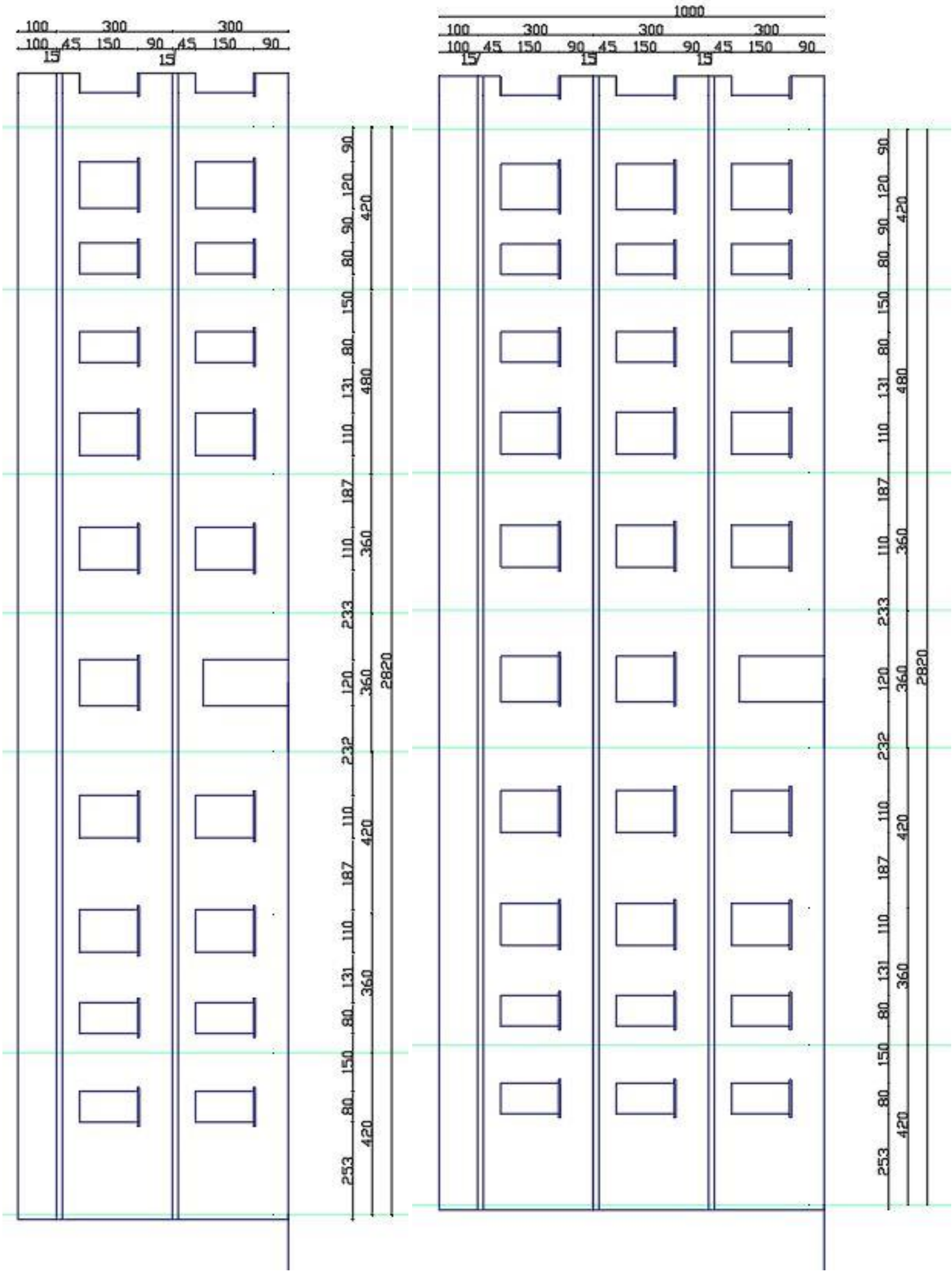

Figure 22. Facade view of building A1 for original building and plus one story building

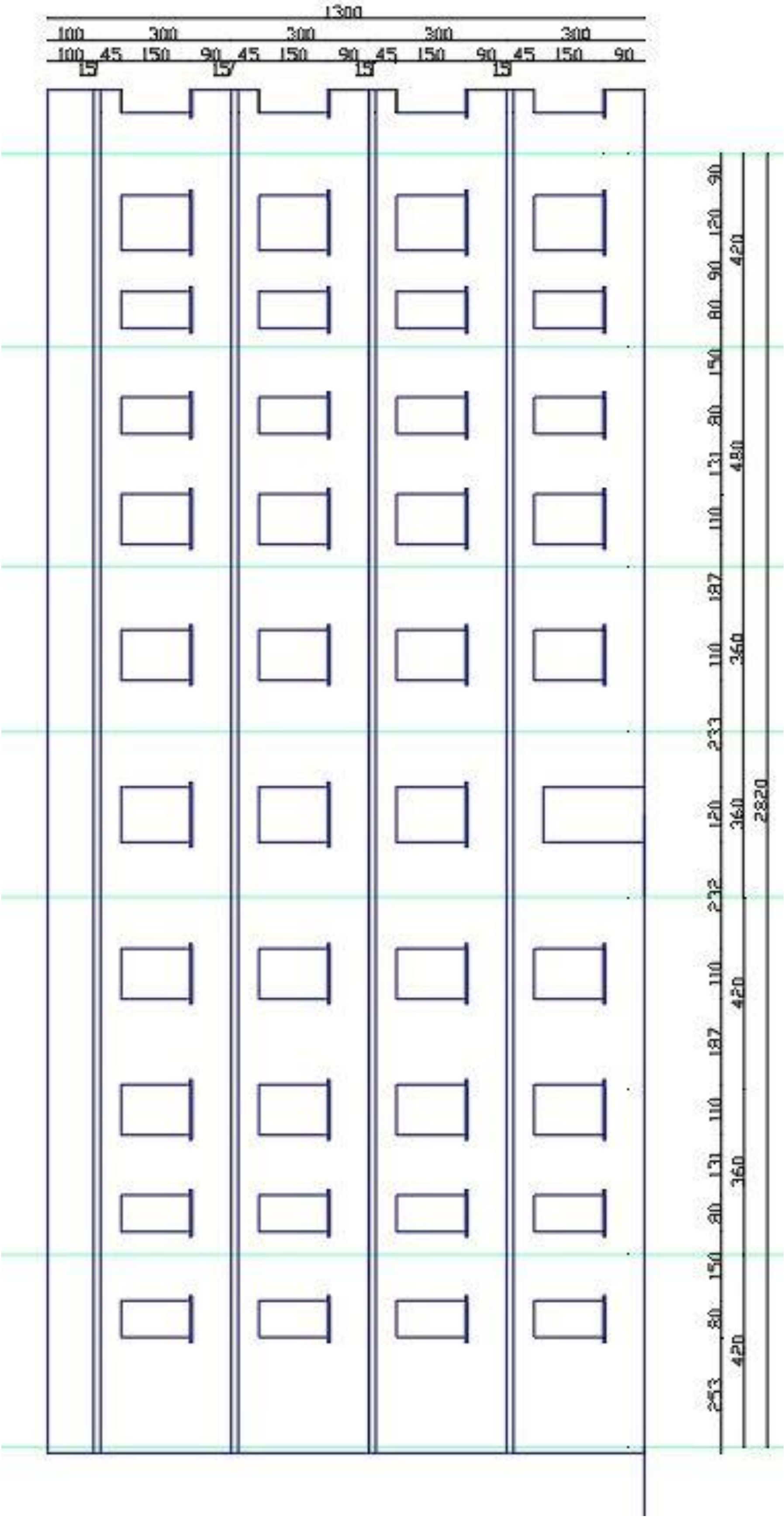

Figure 23. Facade view of building A1 for building with plus two stories

Section B
Test results for Building A1

Table 9. Compressive test of solid bricks

Compressive test of solid bricks (clay bricks)								
Sample	**Sample dimensions**				**Fracture force (kN)**	**Compressive strength (MPa)**	**Sample weight m (gr)**	**Sample density (kg/m^3)**
	Length L(mm)	**Width B(mm)**	**Height H(mm)**	**Area A(mm^2)**				
1	247	120	65	14820	72.3	4.88	2864	1486.557
2	246	118	64	14514	73.1	5.04	3100	1668.648
3	247	119	66	14696.5	74.2	5.05	2980	1536.132
4	248	119	64	14756	72.9	4.94	3012	1594.69
5	250	119	66	14875	75.7	5.09	2856	1454.545
				Average		5		1548

Table 10. Brick density and water absorption tests

Tensile flexural test of solid bricks (clay bricks)						
Sample	**Sample dimensions**				**Fracture force W (kN)**	**Tensile strength (MPa)**
	Length L(mm)	**Width B(mm)**	**Height H(mm)**	**Area A(mm^2)**		
1	247	120	65	7800	8.6	1.102564
2	246	118	64	7552	8.3	1.099047
3	247	119	66	7854	8.9	1.133181
4	248	119	64	7616	8.2	1.076681
5	250	119	66	7854	9.1	1.158645
				Average		1.11

Table 11. Tensile flexural test of solid bricks

Compressive and tensile flexural test of mortar samples								
Sample	**Compressive test**				**Flexural tensile strength**			
	Dimensions LxBxH (mm^3)	**Area A (mm^2)**	**Fracture Force F (kN)**	**Compressive strength (MPa)**	**Dimensions LxBxH (mm^3)**	**Area A (mm^2)**	**Fracture Force F (kN)**	**Tensile strength (MPa)**
1	50x50x50	2500	6.35	2.54	160x40x40	1600	0.7	0.44
2	50x50x50	2500	5.75	2.3	160x40x40	1600	0.9	0.56
3	50x50x50	2500	5.65	2.26	160x40x40	1600	0.7	0.44
4	50x50x50	2500	5.55	2.22	160x40x40	1600	0.6	0.38
5	50x50x50	2500	5.45	2.18	160x40x40	1600	0.5	0.31
6	50x50x50	2500	5.85	2.34	160x40x40	1600	0.9	0.56
		Average		2.3		**Average**		0.45

Table 12. Compressive test of mortar samples

Compressive test of masonry prism samples									
Sample	**Sample dimensions**				**Fracture force W (kN)**	**Compressive strength R (MPa)**	**Prism ratio H/B**	**Correlation factor n**	**Compressive strength f_k (MPa)**
	Length L(mm)	**Width B(mm)**	**Height H(mm)**	**Area A(mm^2)**					
1	248	242	401	60016	95.7	1.595	1.657	0.904	1.442
2	249	242	401	60258	95.5	1.586	1.657	0.904	1.434
3	250	240	401	60000	94.5	1. 575	1.67	0.908	1.43

4	249	240	400	59760	93.8	1.57	1.667	0.907	1.424
5	248	241	403	59768	95.03	1.59	1.672	0.908	1.452
							Average		1.437

Table 13. Triplet test of the samples with and without compressive test

Triplet test of masonry samples						
Sample	**Sample dimensions**				**Fracture force Q (kN)**	**Shear strength fv (MPa)**
	Length L(mm)	**Width B(mm)**	**Height H(mm)**	**Area A(mm^2)**		
1	202	119	250	29750	9.2	0.154202
2	201	119	250	29512	9	0.153348
3	200	119	249	29382	8.8	0.145296
				Average		0.15
1'	201	119	250	29750	18.4	0.31
2'	199	118	250	29880	16.8	0.28
3'	200	119	250	29750	19	0.32
				Average		0.3

Section C
Pushover curves for building A1

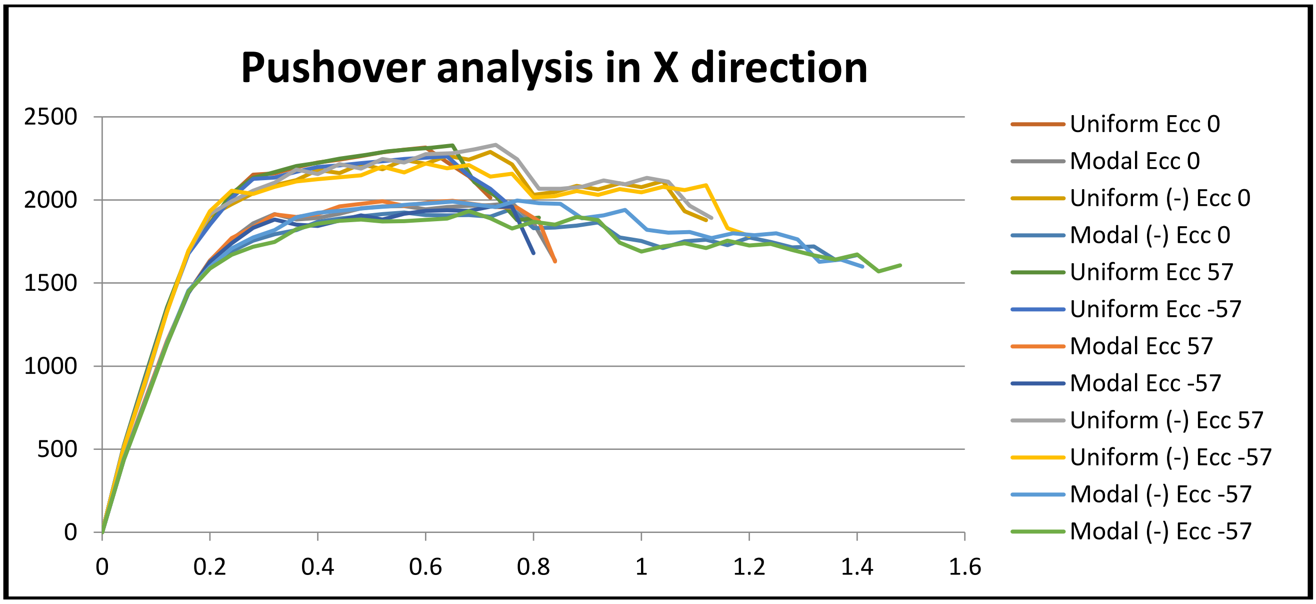

Figure 32. Pushover analysis in x-direction, 12 load patterns

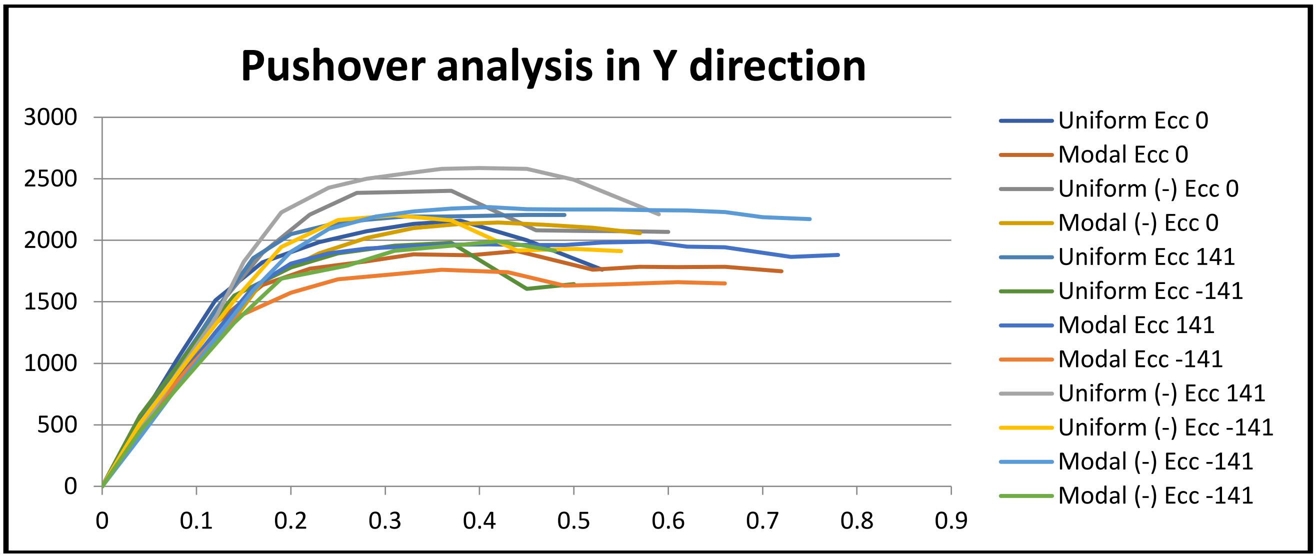

Figure 33. Pushover analysis in Y-direction, 12 load patterns

Pushover curves for building A1 3floors

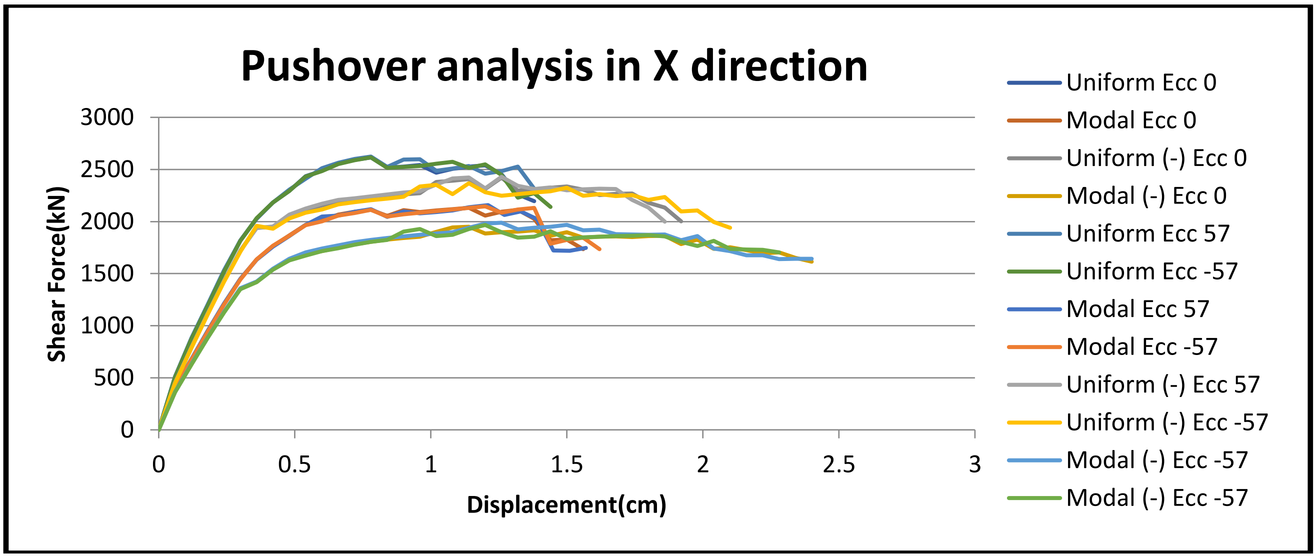

Figure 34. Pushover analysis for x-direction, 12 load patterns,

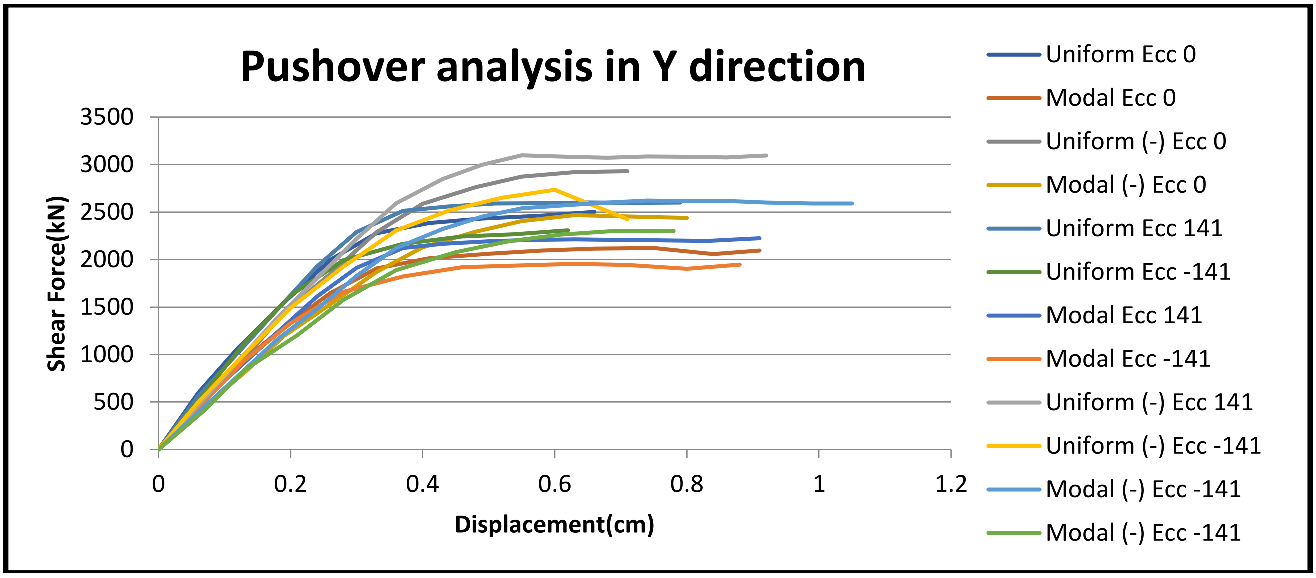

Figure 35. Pushover analysis for y-direction, 12 load patterns

Pushover curves for building A1 4floors

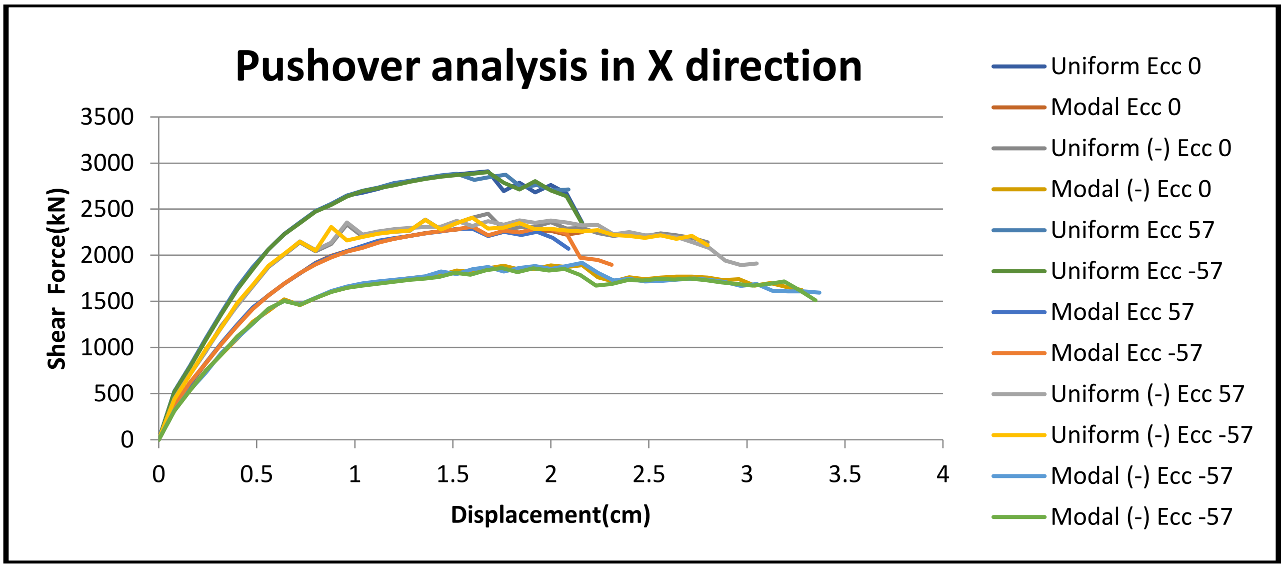

Figure 36. Pushover analysis in x-direction, 12 load patterns

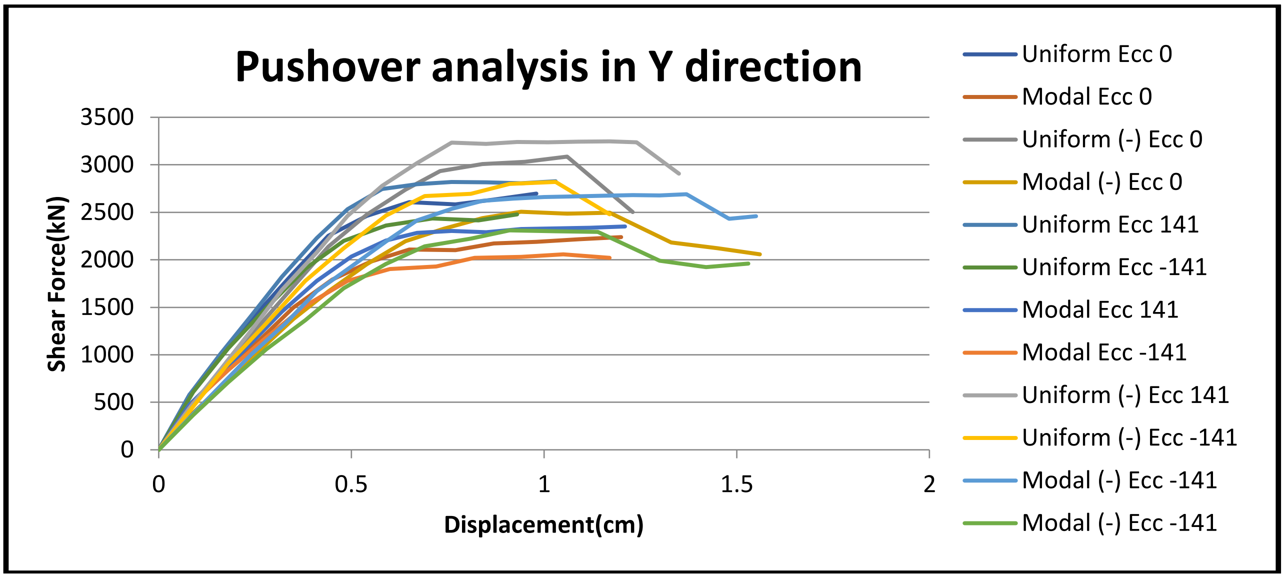

Figure 37. Pushover analysis in y-direction, 12 load patterns