SEISMIC RETROFITTING OF PURE MASONRY STRUTURE

A Thesis Submitted
in Partial Fulfilment of the Requirements
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In

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By

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May, 2019

CERTIFICATE

This is to certify that this thesis entitled **"SEISMIC RETROFITTING OF PURE MASONRY STRUCTURE"** which has been carried out by Mr. PUNIT KUMAR TIWARI (Roll no. 1170444010) for partial fulfillment of requirement for the award of Master of Technology degree in Structural engineering (Civil Engineering) of Babu Banarasi Das University, Lucknow, is a record of his word carried out by him under the guidance and supervision. The result embodied in this thesis is not been submitted elsewhere for award of any other Degree or Diploma.

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DECLARATION

I hereby declare that this thesis entitled **"SEISMIC RETROFITTING OF PURE MASONRY STRUCTURE**" submitted by us in the partial fulfillment of the award of degree of **Master of Technology** in **Structural Engineering (Civil Engineering)**, Babu Banarasi Das University, Lucknow, is my own original work carried during the period from **August, 2017-June, 2019** under the supervision of **Asst**. **Prof. Shubranshu Jaiswal** is not submitted elsewhere for award of degree.

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ABSTRACT

In India most of the building structure, which is in the rural area and town area are constructed through the pure masonry structure. In the present time retrofitting is a method to provided external strength to the building under lateral loads. In the following thesis I compared different eight modal under lateral loading, through response spectrum methods. In the following research thesis I use Etabs 2015 for the analysis of structure. There are different loads such as live load, dead load and seismic load. There is different 26 load combination which is use in the seismic analysis. In the following thesis there are following parameters has been used these parameters are maximum story displacement, maximum story drift, overturning moment and story shear. In this thesis we focused on the subject that how to make masonry structure better as RC frame structure through retrofitting by bracing system.

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TABLE OF CONTENTS

LIST OF FIGURE

LIST OF TABLE

CHAPTER 1

INTRODUCTION

1. **GENERAL-**To prevent the disaster in future earthquake, the retrofitting play an important role in the structural fundamentals. When we concentrated on the world retrofitting first question plugged in our mind. What is the retrofitting? In general way if we can explain the retrofitting can be define as a techniques which is use to maintain a structure to resist any lateral force such as seismic forces. Due to seismic activity the seismic force worked in to wave form. The seismic waves effect on the building structure in the form of lateral loading. To prevent the structure from this lateral loading there are following methods, which is use for retrofitting. For different types of building structure such as masonry structure, RC frame structure, we use different type of techniques which is point out as below. Concrete jacketing is considered as an important method for strengthening and repairing RC beam. Jacketing of RC beam is done by enlarging the existing cross-section with a new layer of concrete that is reinforced with both longitude and transverse reinforcement. Use of steel plates retrofitting has been used as a method of enhance the shear strength and ductility of square reinforcement (RC) column. Wrapping with fibre reinforced polymer sheets to improve the seismic capability of structure. Retrofitting is the process of additional of new features. The older buildings, heritage structure, bridge etc. Retrofitting reduces the vulnerability of damage of an existing structure during a near future seismic activity.

Figure 1.1- bracing system in the structure.

Steel bracing system is the one of the most important fundamental which is use for the retrofitting of the structure under the seismic load condition. The bracing system provide maximum strength to gain lateral load under seismic condition. Lateral loads effect on the building structure and it is cause of deformation. Steel bracing system are define in various types such as X bracing system, V bracing system, inverted V bracing system and various other. On the basis of different location of the bracing installation that gives different result and improve the structure seismic fundamentals. In the above figure we can see the X bracing system in the structure.

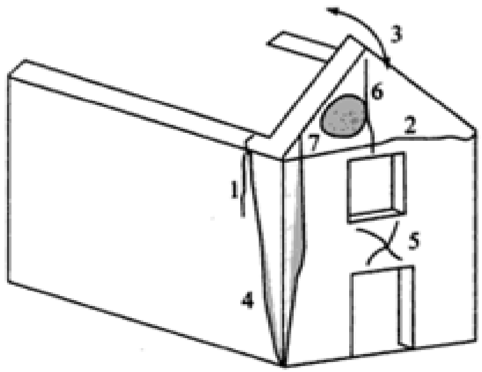
Figure1. 2 bracing in masonry building

2. **Concept of Seismic Retrofitting-** Seismic retrofitting is a way to improve building structure to make the structure more resistant under seismic activity, ground motion or soil failure due to earthquake. In the present time various structures made without any adequate detailing and reinforcement for seismic protection. In many part of developing countries such as India, Pakistan, Nepal, Iran and china the structure made without detailing and reinforced structure mostly in rural areas. Retrofitting is provided to improve the construction quality and bearing capacity for external load capability.

3. **Requirement of Retrofitting-** Seismic retrofitting are required to improve basic error in the structure, which is arrive at any time of construction in beginning of the construction phase till end of the construction such as
   3.1 Design errors before or after construction,
   3.2 Insufficient concrete production in the construction,
   3.4 Bad execution processes,
   3.5 Due to earthquake effects,
   3.6 Due to accidental causes such as fire, explosion and collision,
   3.7 Due to lack of detailing.

4. **Failure condition in masonry structure under seismic forces-** There are following failure condition which is develop through the seismic condition. The seismic condition effects on the structural fundamental of the section. The seismic forces give then various failure conditions which is shown as below.

   4.1. Out-of-Plane failure – out-of-plane failure developed due to perpendicular loads acting on the wall section. The out of plane failure can be express by the following fundamental figure as given below. Here the,



1- Vertical crack in the corner and T walls.

2- Horizontal cracks along the facade

3- Partial collapse of an exterior wall

4-wythe separation

5- Cracks at lintel and top of slender pier

6- Cracks at the level of roof

7- Masonry ejection

Figure 1.3- out plane failure

4.2. In plane failure- in plane failure is caused by in plane seismic loads acting along in the plane of wall characterised by distributed diagonal cracking in the wall section as shown in the following figures.

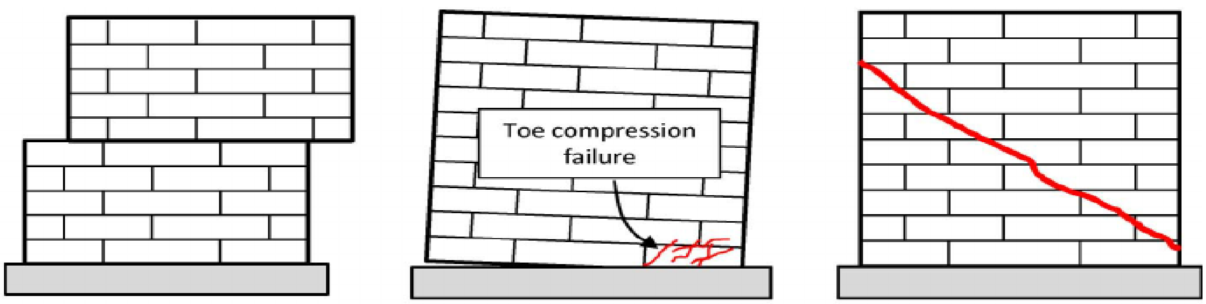


Figure 1.4- In plane failure

4.3. Diaphragm failure- Diaphragm failure is causes of low shear resisting capacity of the structure when the earth seismic motion developed then the plasticity of the structure forces the structure to revised its own position cause of these fundamental force disturbance the diaphragm failure is developed. Which is shown on the following figure as given below?

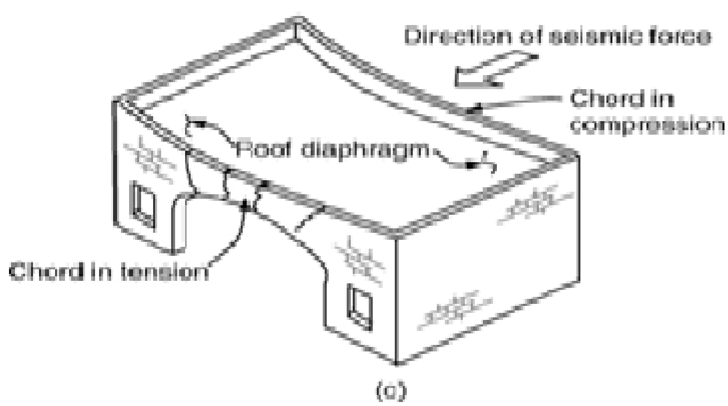


Figure 1.5- diaphragm failure

5. **Efficiency and effect of Retrofitting-** Retrofitting improve the strength of the building under lateral loading and increasing the resistant to lateral loads, improving the ductility and an association of both. Retrofitting improve the building structure through improving the fundamental aspects of the section structure with their different retrofitting techniques. In the retrofitting we mostly done two basic concept
   5.1 Addition new structural elements
   5.2.Strengthening of the existing structural elements.

6. **Basic Retrofitting Techniques-** There are following techniques are present in the local and global market which is use for retrofitting of structure these strategies is

6.1. Global techniques and strategies- Surface treatment (shotcrete), stitching and grout/ epoxy injection, re-pointing, bamboo reinforcement, post tensioning (rubber tyres), PP strip reinforcement, steel mesh cage, plastic carries bag net are the basic global techniques.

6.1.1. Surface treatment (Shotcrete)- , shotcrete is cement mortar or cement concrete(with coarse aggregate size maximum 10mm) conveyed through a house and pneumatically placed under high velocity on to prepared concrete or masonry surface. Te force of the jet impingement on the surface. The force of the jet impingement on the surface. Compact the shotcrete material and produces a dense homogeneous mass. Basically there are two methods of shotcreting.

6.1.1.1.Wet mix process- in the wet mix process all the ingredients, including water are mixed together before they enter the delivery hose.

6.1.1.2.Dry mix process- in the dry mix process, the mixture of damp sand and cement is passed through the delivery hose to the nozzle where the water is added. Dry mix process mostly used repair of concrete surface of the damage member and the layer of shotcrete is ensured with the application of suitable epoxy adhesive formulation.

Figure 1.6- Shotcrete on the site by nozzal

The shear transfer between the existing and new layer of concrete is ensured with the provision of shear keys. Addition of fibers enhances tensile strength and toughness.

6.1.2. **Stitching and reinforcing for cracks-** In the following fundamental method first we use stitching the cracks through the wire and for the beam section we provide extra reinforcement to the beam to improving the seismic condition of the building structure under the lateral loading. Stitching and reinforcing play an important role in the retrofitting techniques. The extra reinforcement provide extra strength to resist external force without cracking or deforming so we can provide the stitching to the section of masonry structure or beam section to improving it's seismic properties.

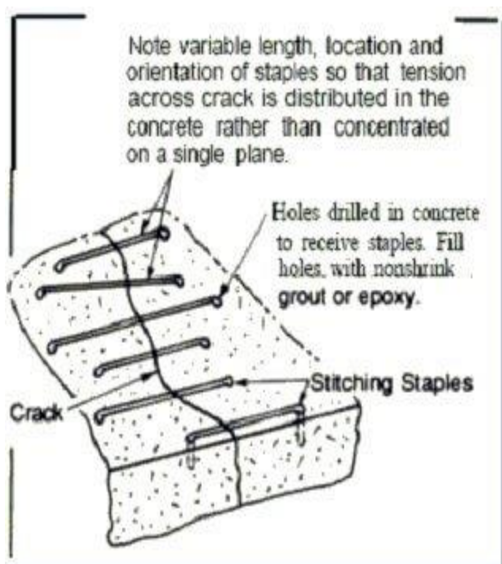


Figure 1.6-Stitching of crack section

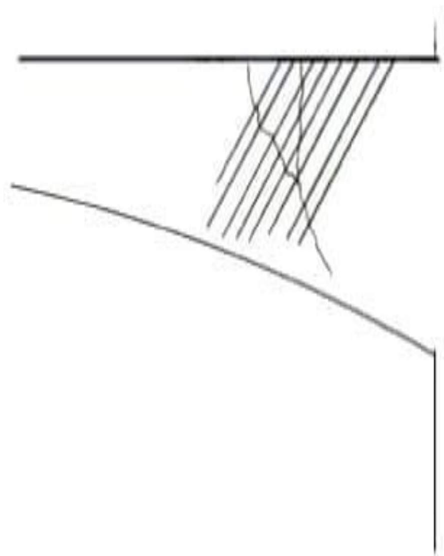


Figure 1.7- Reinforcing in cracks

6.1.3. **Re-pointing-** Re-pointing is a process in which we select a section in the masonry which is fall it's mortar in the following figure we can see the cracks in the masonry or gapping in the masonry we select these type of area and provided mortar paste for infill the cracks and provide the extra strength to the building

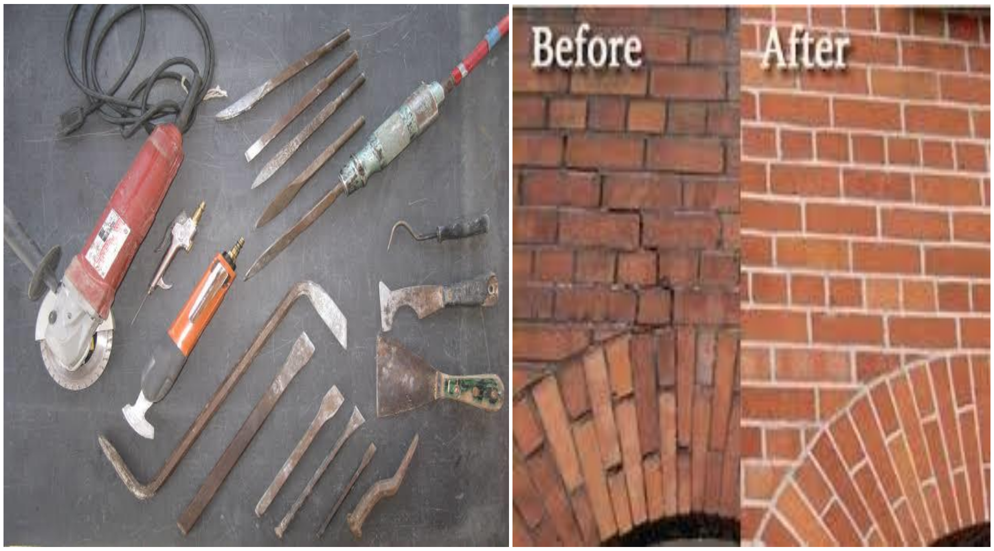


Figure 1.8- Re-pointing

Re-pointing is the process of renewing the pointing, which is the external part of mortar joints, in masonry construction. Over time, weathering and decay cause voids in the joints between masonry units, usually in bricks, allowing the undesirable entrance of water. Water entering through these voids can cause significant damage through frost weathering and from salt dissolution and deposition. Re-pointing is also called **pointing**,[1] or **pointing up**, although these terms more properly refer to the finishing step in new construction

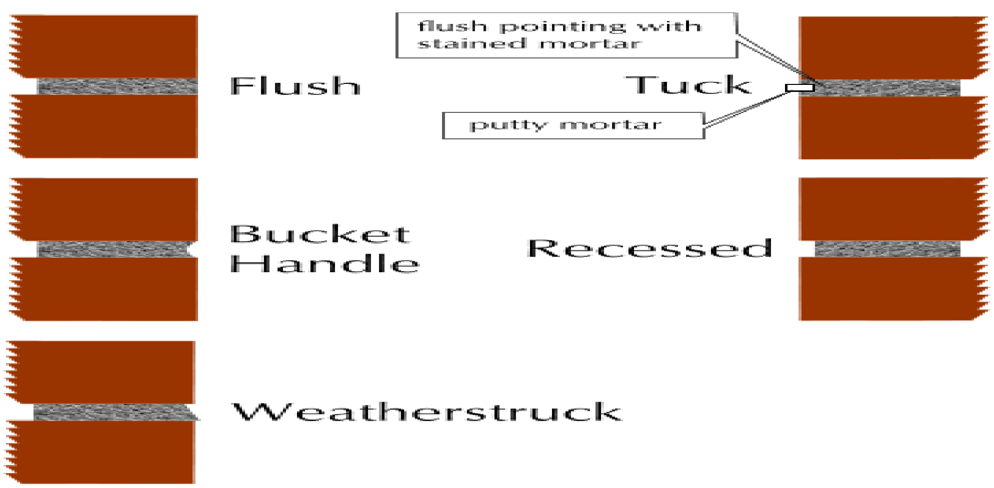


Figure 1.9- Re-pointing of brick work

If the color of the new mortar is still not similar to the old mortar after re-pointing and setting, the non-re-pointed areas of the structure can be cleaned. This may bring the colors closer together. To do this, a low pressure water jet is used to clean the old pointing. A high powered water jet is not to be used because this could damage the masonry and mortar.[2] Chemicals are also not used with the water because this could be harmful to the masonry or mortar. However, if chemicals are used, the structure is rinsed afterwards with fresh water and natural or nylon brushes. Another method to match the colors is to stain the new mortar. This is not recommended by professionals though, because it can be harmful. If stain is used, the application is tested in the test pane

6.1.4. **<u>Post tensioning (Rubber tires)-</u>** post tensioning is a process in which we provide waste tire material at the foundation level to improve the seismic quality of the structure. The tire improves the seismic ability of the structure and gives suitable strength to the section under lateral loading condition. In the following figure we can see the installation position of the waste tire materials. It is provide under the plinth level to improve the capacity of the structure through lateral load or seismic loads. Here we see the cross section of the structure, where the waste tire has been used.

<u>Figure 1.10- waste tire pads cross-section, Tire pads for retrofitting</u>

6.1.5. **<u>PP Strip reinforcement-</u>** PP strip reinforcement is process which is use in the seismic resistance building designing process. In the following method we use we use pp mesh around the wall surface and connected to the wall section through the spits and provide the support for PP meshing, the procedure for the PP meshing is given in above figure their are following eight step processors which is discuss above.

Figure 1.11 – PP mesh installation

6.1.6. Steel mesh cage- steel meshing is a process in which we provide steel mesh around the surface of the structure to improve the seismic ability of the structure. Steel meshing provides extra strength to the section and it is able to resist the seismic forces under a limited proportion. The steel meshing a valuable process which helps the building to become a earthquake resistant building.

Figure 1.12- steel meshing

6.1.7. **Plastic carries bag net –** in the following process we use waste plastic bags for the retrofitting of the structure. These plastic bags having capacity to improve the strength to the structure under the seismic load condition. The plastic beg have good strength and weight ratio. So we can use plastic beg as a retrofitted materials.

Figure 1.13- plastic carries bag

6.2. Local techniques- steel jacketing, concrete jacketing, use of steel plate, wrapping with fiber reinforcement polymer sheets.

6.2.1. Steel jacketing- Steel jacketing is a process which is use for the retrofitting of the structure in the following process we use steel plates for the strengthen for the structure under the seismic loads. The steel jacketing is a well define process for the retrofitting of the structure. In the following figure we can see the position of the retrofitting plats and how to install the following plats to the section there are provides ate the joints of the section.

Figure 1.14- steel jacketing

6.2.2. Concrete jacketing- concrete jacketing also a well define process which is use in the retrofitting process is use for the strengthening of the beam and column section in the structure. In the following process we provide extra reinforcement around the column and beam section to improve the seismic capacity of the section and retrofitting can be provided for strengthening of the section. In the concrete jacketing most important thing is that, that improve the grade of concrete for the retrofitting of the structure.

Figure 1.15- Concrete jacketing

6.2.3. **Use of steel plate-** Use of steel plats also a type of steel jacketing but in the following process we use steel plates and provide them across the joint of the section and use j section for the retrofitting. In the following figure we can see the use of steel plates in the retrofitting and use of j hooks in the column section for the retrofitting.

Figure 1.16- Steel jacketing

6.2.4. **Wrapping with fiber reinforcement polymer sheets-** Wrapping with fiber reinforcement polymer sheet is a good technique for the retrofitting of the section. In the following process we provide FRP around the column section to provide extra strength the gap between to polymer sheets is 150-200m approx and that provide extra strength to the section.

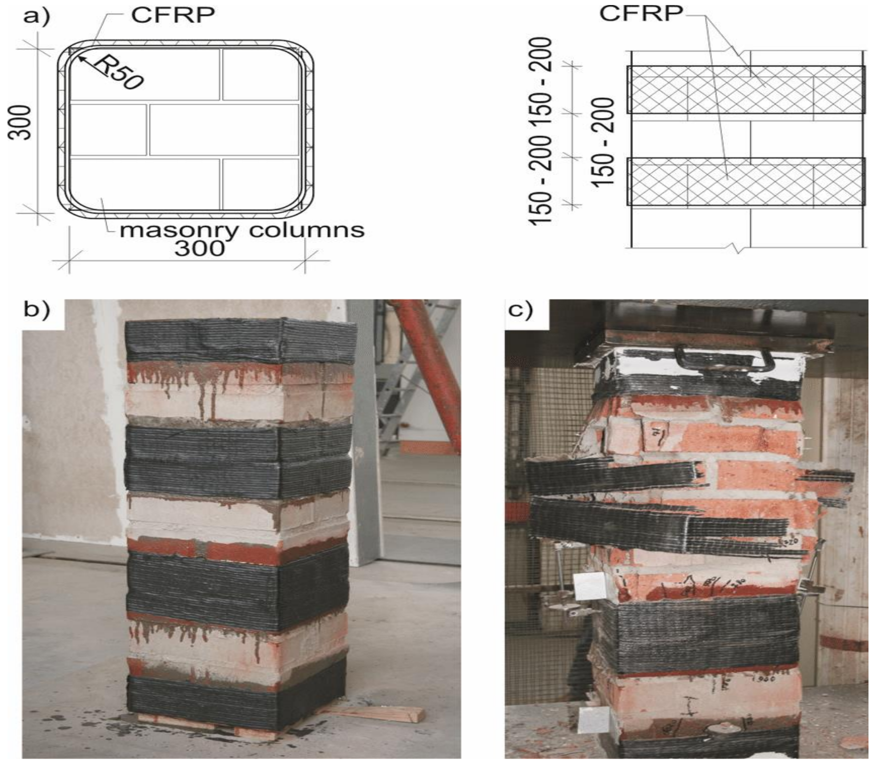


Figure 1.17- wrapping with fiber reinforcement polymer sheets

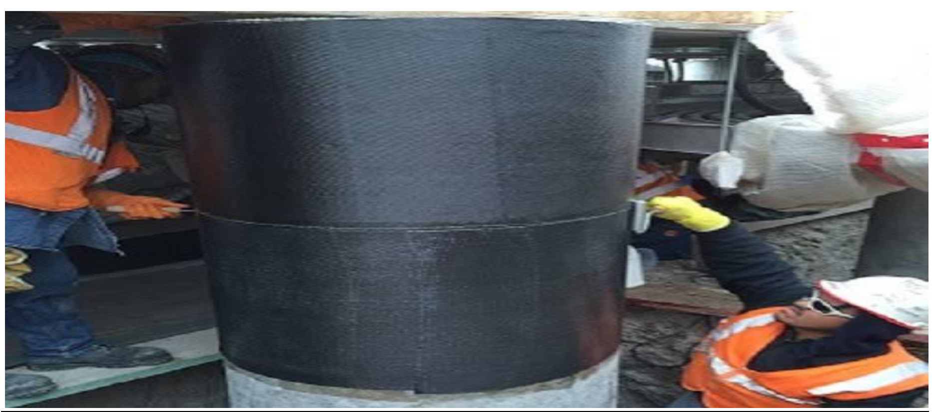
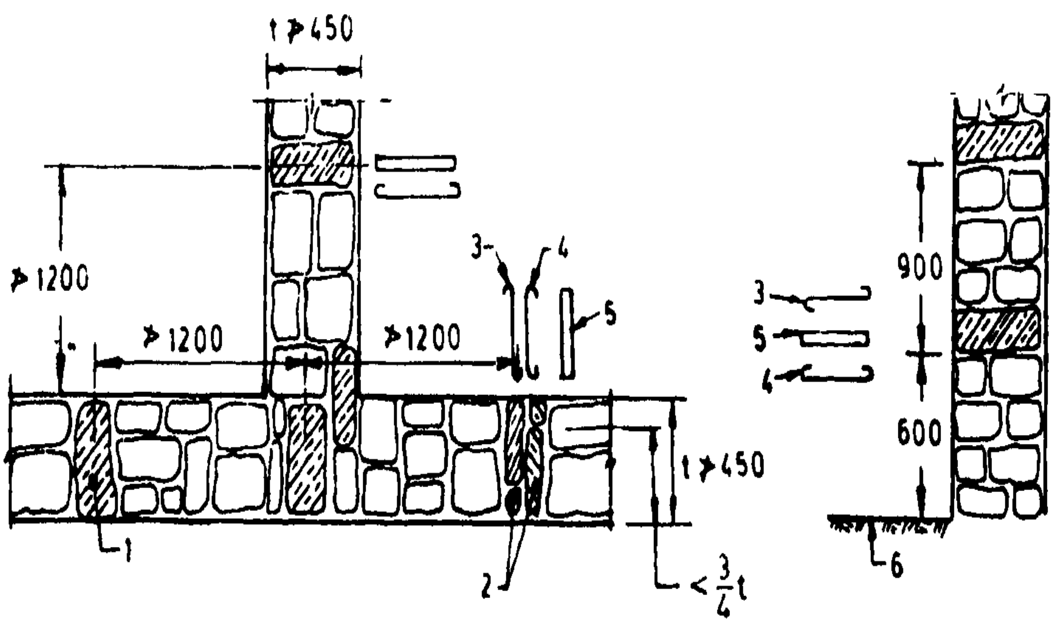


Figure 1.18- FRP installation

7. **Techniques for masonry retrofitting-** There are following techniques which is explain in the IS code 13935 And IS code 13828 which is mostly used for the masonry structure. These techniques play an important role in the retrofitting techniques. The fundamental techniques are explain as below

   7.1. **Through stone and bond element-** In the following fundamental techniques we use a stone member as a combiner for the wall structure, after adding the stone member in the section the section work like a single member. With the help of reinforcement, wooden block and other system we make it as a single member, which increase the strength of the section.



{A} Section plan of wall {B} Cross-section of the wall

1- Through stone 2-pair of over lapping stone 3-S-shape tie 4-hooked tie 5- wood plank 6- floor level

Figure 1.19- through stone and bond element

7.2. **Strengthening through reinforcement around opening-** In the following fundamental techniques we use the wire to provide the covering area of the window opening and that mesh

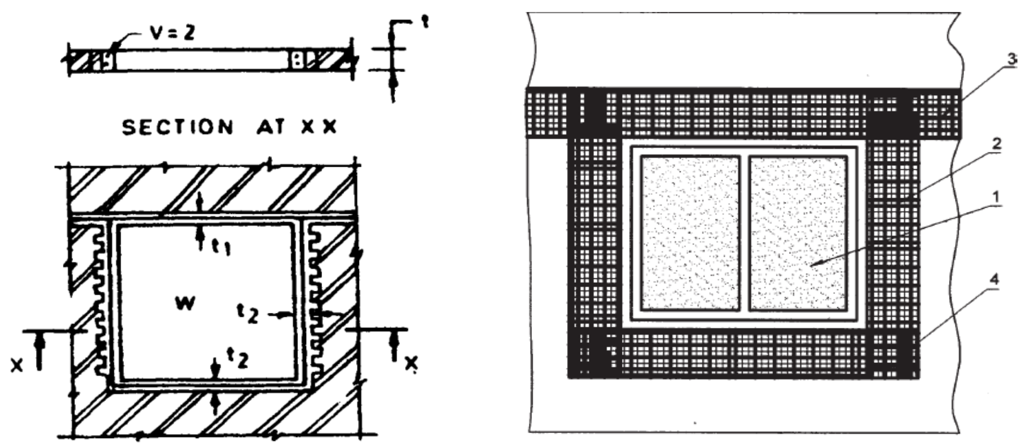
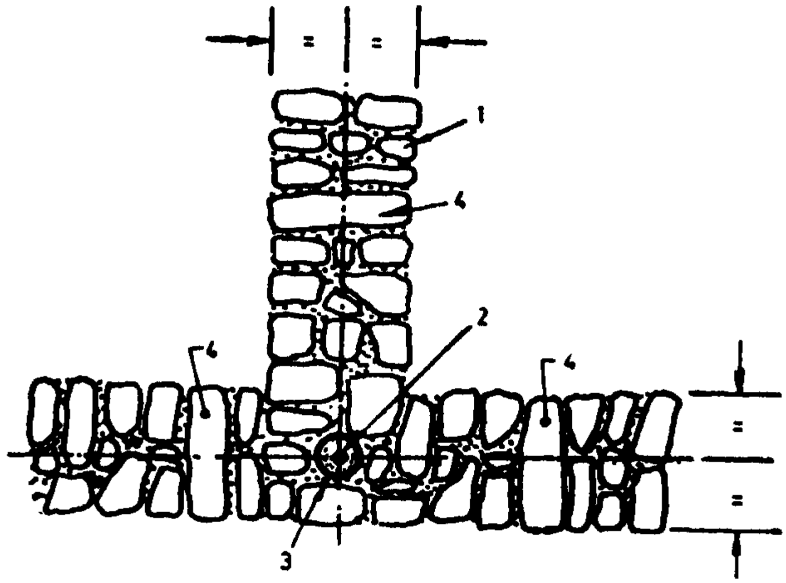


Figure 1.20- Retrofitting through wire meshing

of gauge 10 with 8 wire in the vertical direction at spacing 25mm in a belt of 200mm or a mesh of gauge 13 with wire @25mm in a belt width of 250mm which may be used.

7.3. **By Installing vertical steel bar in the stone masonry-** When we providing vertical bar in the stone masonry, first note that use a casing pipe is recommended around which masonry build to height of 600mm. The pipe will be remove after filling the cavity through M15 grade of concrete, we can use self compacting concrete in the cavity filling for the structure fundamental the self compacting concrete give the better result to the stone masonry section.



1-Stone wall 2-Vertical steel wall 3-casing pipe 4- through stone or bonding element

Figure 1.21- ***Typical construction detail for installing vertical steel bar in the random rubble stone masonry***

7.4. Through providing seismic belt- One of the most common and effective method of retrofitting is providing the seismic belt to the section to providing the extra strength to building. That seismic belt is provided just above the lintel or window or door opening, below the roof level. That seismic belt provided all around the surface wall. Seismic belt is not required at the plinth level, unless the plinth height is more then 900mm. These seismic belt provide extra strength to the section.

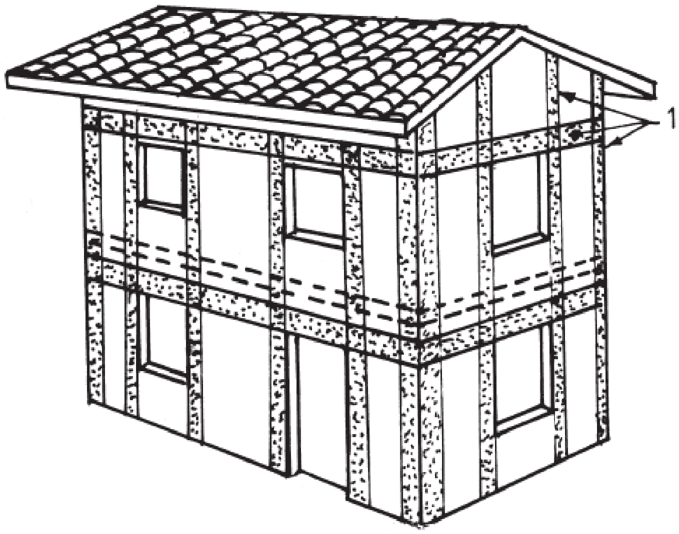


Figure 1.22- Seismic belt providing

8. **Equipment and software for analysis the retrofitted structure-** in the present time their are various software are present in the market for seismic analysis of structure and a basic equipment which is use for seismic analysis are point out as below.

8.1.Equipment for seismic analysis- Shaking table test (1D and 3D present in local market)

8.2.Software for seismic analysis – ETAAB, SAP2000, ANSYS for better result. Staad pro also good software for seismic analysis but retrofitted structure cannot be analysis by this software.

CHAPTER 2

LITRATURE SURVEY

Luca martellotta [1] et al reviewed on, "Review of seismic retrofitting strategies for residential building in an international context". In the following review paper he focused on seismic retrofitting, seismic evaluation, upgrading strategies, seismic vulnerability, international code, URM building. In the following study is belonging to improve the durability of existing housing in the Groningen area. He focused on weak aspect target of retrofitting such as overall strength, overall stiffness, mortar joint, and irregularity in plan and evaluation, wall dia for connection, deterioration of wall, diameter for deficiencies and foundation deficiency. He takes different countries seismic retrofitting guideline such as Europe, Italy, U.S.A. and New Zeland. He discussed processes for improvement of seismic building performance by reduction of element mass, local modification of component increasing building strength ductility and reduction of irregularity in plan and evaluation. He discussed various retrofitting techniques and at least he concluded that a series of parameter with lead to most technically reliable approach structural efficiency, aesthetically, scalability, repeatability, economically suitable for technical reliable.

Ratnesh kumar [2] et al reviewed on, "Review of retrofitting technique for masonry in filled RC frame building". In the following paper he focused on retrofitting strategies, retrofitting techniques and their use. He discussed various strategies of retrofitting and retrofitting techniques such as additional of shear wall additional of bracing, FRP wrapping to strengthen exiting beam and column, steel jacketing of exiting column, RC jacketing of exiting beam and column and bonding FRP to URM infill. At least he concluded that the combination of some retrofitting technique we can improve the performance of building structure.

Subhashini S. ramteke [3] et al worked on, "pushover analysis and seismic retrofitting using shear wall and bracing system of frame structure". In the following paper he focused on a non linear static push over analysis, a shear wall, bracing system, RC building, and seismic retrofitting. He performed push over analysis using the displacement coefficient method. In the following analysis he worked on the basis of IS Code 1893:2002 and zone 5^{th} for analysis. He performs pushover analysis with the help of SAP 2000. He used various bracing system and shear wall at different location. At least he concluded that the floor displacement is maximum for without retrofitting building frame as compare to retrofitted building frame and we can provide X bracing system to structure to resist the seismic force without compromising with strength and stiffness of the structure.

M.A. El gawady [4] et al worked o, "retrofitting of masonry wall using shotcrete". In the paper he retrofitted on a single side using a 40mm thick layer of shotcrete and the last one retrofitted on the double side using 20mm thick layer. In the following paper he takes two sample single side and double side sample. Provide shotcrete and concluded that retrofitting on double side had more ductile failure and energy dissipation.

Krirtika gupta [5] et al reviewed on, "review paper on seismic retrofitting of structure". In the following review paper he focused on shear wall, reinforced concrete, seismic retrofitting, retrofitting bonding and beam column, Staddpro 8i. After various literature review paper he concluded that the following method are carried out by most of researchers which are concrete jacketing of column of ground floor, brick masonry fill in the ground floor, x and v bracing, shear wall, FRP of beams and column.

M. El gawady [6] et al reviewed on, "A review of conventional seismic retrofitting techniques for URM". In the following paper he focused on the retrofitting, rehabilitation, repair and seismic fundamentals. This paper reviews of retrofitting procedures, advantage, disadvantage, limitation, effect of each retrofitting techniques. he discuss various method such as ferrocements, reinforced plaster, shotcrete, grout and epoxy injection, external reinforcement, post tensioning and centre care technique. Which is used in the retrofitting? At least he summarised all fundamental knowledge in to a table and explain all advantage and disadvantage of techniques.

S.I. khan [7] et al worked on, "Seismic retrofitting of RC building by using different bracing system". In the following paper he focused on a non linear static push over analysis using the displacement coefficient method as described in FEMA 365. He took a hostel building which is four story rectangular structures. He used SAP2000 for analysis he concluded that X and V bracing are good for retrofitting for better result.

Edvardo N.B.S. juilo [8] et al worked on "reinforced concrete jacketing interface influence on cyclic loading response". In the following paper he focused on cyclic loading, interface, jacketing, seismic response, strengthening and surface preparation. He took total seven models for analysis with different structural aspect. After providing the jacket to all the structure he declared all type of model in to a table form. After technical analysis and result he concluded that for a bending moment/ shear force ratio lower than 1.0m (3.281ft), debonding of jacketing may occur without treatment of the interface surface.

G.E. thermou [9] et al worked on, "Seismic retrofit schemes for RC structure and local global consequences". In the following paper he concentrated on retrofit, repair/ strengthening , rehabilitation, structural intervention, seismic upgrading he discuss various method of retrofitting such as injection of cracks, shotcrete, steel plant adhesion, steel jacketing, external bonded FRPs, RC jacketing, addition of walls, steel bracing, base isolation. He also discusses the effect of retrofit on global response.

E.S. juilio [10] et al worked on, "structural rehabilitation of columns with reinforced concrete jacketing". In the following paper he focused on RC jacketing, strengthening method structural rehabilitation, structural repair, retrofitting techniques. He discuss why, when and how to rehabilitate a structure and also discuss repairing techniques of RC elements. He discusses RC jacketing for the failure structure which is damage through earthquakes and other causes. In the conclusion he focused on repair method of original column, interface surface preparation, use of bonding agent, application of steel connection, temporary shoring, anchoring of the added longitudinal reinforcement, continuity between floor of the added longitudinal reinforcement, position of the steel bars of the longitudinal reinforcement, added stirrups and added concrete.

Sagar R. Padol [11] et al reviewed on, "Review paper on seismic response on multi-storeyed RCC building with mass irregularity". In the following paper he focused on seismic analysis, time history analysis, base shear, story shear and story displacement. He used IS code1893 in the following review paper, he focused on effect of mass irregularity on the different floor in

RCC building with time history and analysis is done by using ETAB software. In the following paper he focused on following methodology. Extensive literature survey referring books, selection of types of structure modelling of selecting structure, analytical work to carried out, interpretation of result and conclusion. He worked on RCC building using time history method with the help of ETAB software. At least he concluded that effect of earth quake can be minimising by shear wall, base isolation.

CHAPTER 3

METHODOLOGY

Seismic retrofitting of pure masonry structure is a fundamental comparative study between different three modal. **Model 1-** Pure Masonry Structure (P.M.S.)**, Model 2-** Reinforced concrete structure (R.C.S.)**, Model 3-** V bracing at ground level (V. B. G.)**, Model 4-** X bracing at ground level (X.B.G.), **Model 5-** V bracing at ground to first story(V.B.G+1)**, Model 6-** X bracing at ground to first story(X.B.G+1)**, Model 7-** V bracing at ground to second story(V.B.G+2)**, Model 8-** X bracing at ground to second story(X.B.G+2). With the help of different IS codes and review paper fundamental we know that retrofitting play an important role in the structural fundamental. Here we analysis different eight structure under response spectrum method. This technical paper, we focused on the basic retrofitting through the bracing system and made is seismic retrofitted as such RC frame structure. In the following paper we make different 8 model, model 1 (pure masonry structure without retrofitting), model 2 (RC frame structure), model 3(the v bracing provided at base floor), model 4 (the X bracing provide at base floor), model 5(the V bracing provided at base and first floor), model 6 (the X bracing provided at base floor and first floor), V bracing at ground to second story(V.B.G+2), X bracing at ground to second story(X.B.G+2).

3.1. Subjected load & Load combination- There are following three main loads subjected on the model these loads are

1- Live load
2- Dead load
3- Seismic load

3.1.1. Live load- Live loads are the loads that are acting on the structure through moveable things. Live loads are the weight of people, furniture, supplies, machine, and stores and so on. In the whole model analysis we use live load 3KN/m.

3.1.2. Dead load- Dead load can be defined as a constant load in a structure that is due to the weight of members, the supported structure, and permanent attachments or accessories. In the whole model analysis we use live load 1.5KN/m.

3.1.3. Seismic load- Seismic load is load which is laterally applied on the structure through the earthquake forces. The secondary waves are the main cause of seismic loading. Seismic load is one of the basic concepts of earthquake engineering which means application of an earthquake generated agitation to a building structure or its model.

Table 3.1- Seismic parameters

Serial Number	Parameter	Values
1	Soil type	2nd type (Medium soil)

2	Zone (Z)	Fifth zone(0.36)
3	Importance factor (I)	1
4	Response reduction factor (R)	5.0

These are the basic loads which is acting on the modal and various load combination are used in the following modal analysis which is explain as below

3.2. **Design load combination according to the Etabs software**-

Table 3.2- load combination

Serial Number	Load	Load combinations
1	D con 1	1.5D
2	D con 2	1.5D + 1.5L
3	D con 3	1.2D +1.2L+1.2(EQ X-)
4	D con 4	1.2+1.2L-1.2(EQ X-)
5	D con 5	1.2+1.2L+1.2(EQX)
6	D con 6	1.2+1.2L-1.2(EQX)
7	D con 7	1.2+1.2L+1.2(EQY+)
8	D con 8	1.2+1.2L-1.2(EQY+)
9	D con 9	1.2+1.2L+1.2(EQY-)
10	D con 10	1.2+1.2L-1.2(EQY-)
11	D con 11	1.5D+1.5(EQX-)
12	D con 12	1.5D-1.5(EQX-)
13	D con 13	1.5D+1.5(EQX+)
14	D con 14	1.5D-1.5(EQX+)
15	D con 15	1.5D+1.5(EQY+)
16	D con 16	1.5D-1.5(EQY+)
17	D con 17	1.5D+1.5(EQY-)
18	D con 18	1.5D-1.5(EQY-)
19	D con 19	09.D+1.5(EQX-)
20	D con 20	0.9D-1.5(EQX-)
21	D con 21	0.9D+1.5(EQX+)
22	D con 22	0.9D-1.5(EQX+)
23	D con 23	0.9D+1.5(EQY+)
24	D con 24	0.9D-1.5(EQY+)
25	D con 25	0.9D+1.5(EQY-)
26	D con 26	0.9D-1.5(EQY-)

3.3.Structural properties of different modals- There are following two models are constructed through the Etabs software, in the following software the structural data of the model can be explain as below.

3.3.1. Grid system for all models-

3.3.1.1.Grid dimension-

No. Of grid line in X- direction- 4

No. Of grid line in Y-direction- 4

Spacing of grid in X-direction- 3m

Spacing of grid in Y- direction- 3m

3.3.1.2.Story dimension-

Number of stories-4

Typical story height -3m

Bottom story height -3m

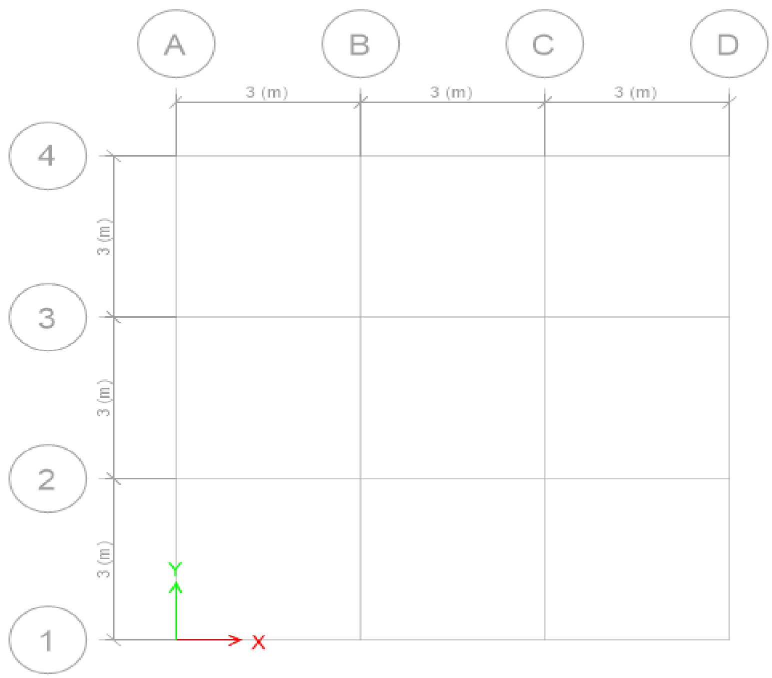


Fig 3.1- grid pattern of the modals

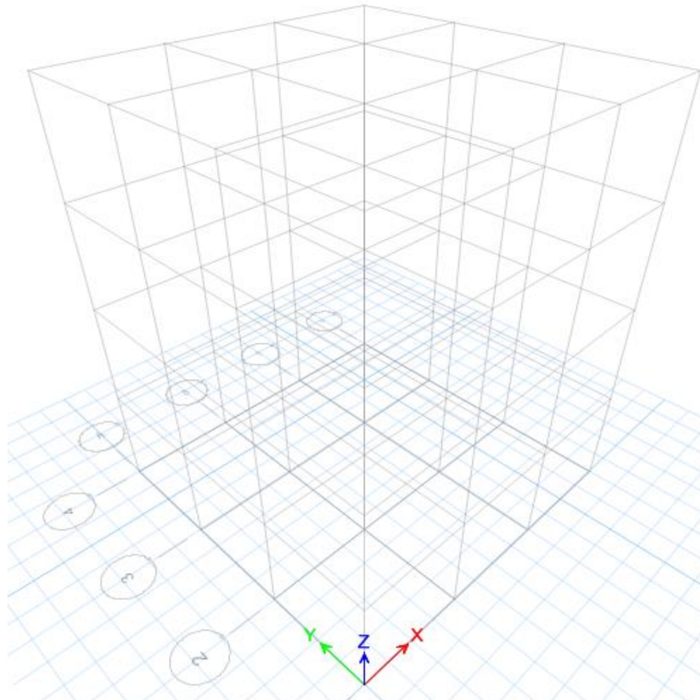


Figure 3.2- grid pattern of model in 3d

3.3.2. Model 1- (Pure masonry column without retrofitting)

3.3.2.1. Material properties-

- Rebar- Fe 250, Fe415
- Wall material – Masonry
- Grade of concrete – M25

3.3.2.2. Section properties- Frame section-

1. Column section-250mm*250mm
2. Beam section-250mm*250mm
3. Wall section –
   Thickness of wall 250mm
4. Slab section-
   Thickness of slab -150mm

3.3.3. Model 2- (Masonry structure with frame work)

3.3.3.1. Material properties-

- Rebar- Fe 250, Fe415
- Wall material – Masonry
- Grade of concrete – M25

3.3.3.2.<u>Section properties</u>- Frame section-

1. Column section-250mm*250mm
   Reinforcement in the column
   - Longitudinal reinforcement- Fe415
   - Tie up bars – Fe250
     - Diameter of longitudinal bars- 12mm
     - Diameter of tie bar- 8mm
2. Beam section-250mm*250mm
3. Wall section – Thickness of wall 250mm
4. Slab section- Thickness of slab -150mm

3.3.4. <u>Model 3, 4 - (Masonry structure with retrofitting with X,V bracing system)</u>

Model 3- Masonry structure with v bracing in base floor

Model 4- Masonry structure with x bracing in base floor

3.3.4.1.<u>Material properties-</u>

- Rebar- Fe 250, Fe415
- Wall material – Masonry
- Grade of concrete – M25
- Steel section grade – ISLB 600

3.3.4.2.<u>Section properties</u>- Frame section-

1. Column section-250mm*250mm
2. Beam section-250mm*250mm
3. Wall section –Thickness of wall 250mm
4. Slab section-
   Thickness of slab -150mm
5. bracing system- X, V bracing
   Moment releasing- continuous

CHAPTER 4

RESULT & DISCUSSION

4.1. SEISMIC ANALYSIS OF MODEL WITH LINEAR STATICS

4.1.1. Max story displacement in x direction- Story displacement is the absolute value of displacement of storey under the action of lateral forces. These following tables show fundamental value of story displacement in all eight models. In the following figure and table we can see the story displacement in the X direction.

Table 4.1. Maximum story displacement in X direction

story	Modal 1 (series 1)	Modal2 (series 2)	Modal 3 (series3)	Modal 4 (series 4)
Story 4	1.77E-05	2.44E-05	2.30E-05	2.62E-05
Story 3	5.61E-05	9.76E-05	8.24E-05	8.56E-05
Story 2	0.000104	0.000171	0.000146	0.000151
Story 1	0.00014	0.000224	0.000193	0.000198
base	0	0	0	0

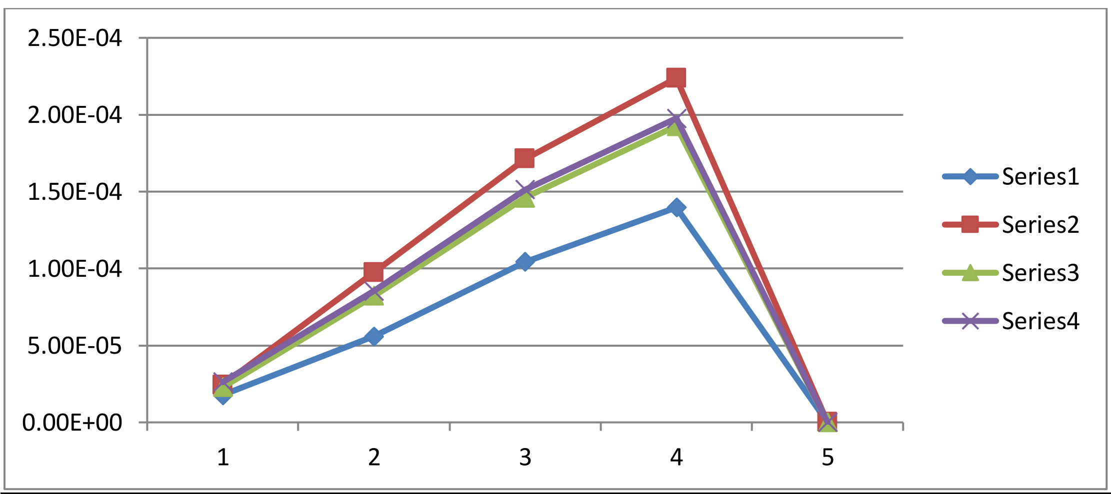


Fig 4.1.- graphical representation of story displacement

4.1.2. Max story displacement in y direction- Story displacement is the absolute value of displacement of storey under the action of lateral forces. These following tables show fundamental value of story displacement in all eight models. In the following figure and table we can see the story displacement in the Y direction.

Table 4.2. Maximum story displacement in Y direction

Story	Modal 1 (series 1)	Modal 2 (series 2)	Modal 3 (series 3)	Modal 4 (series 4)
Story 4	0.002203	0.002325	0.002217	0.002224

Story 3	0.00171	0.001831	0.001747	0.001754
Story 2	0.001127	0.001236	0.001177	0.001184
Story 1	0.000558	0.000653	0.000614	0.000622
base	0	0	0	0

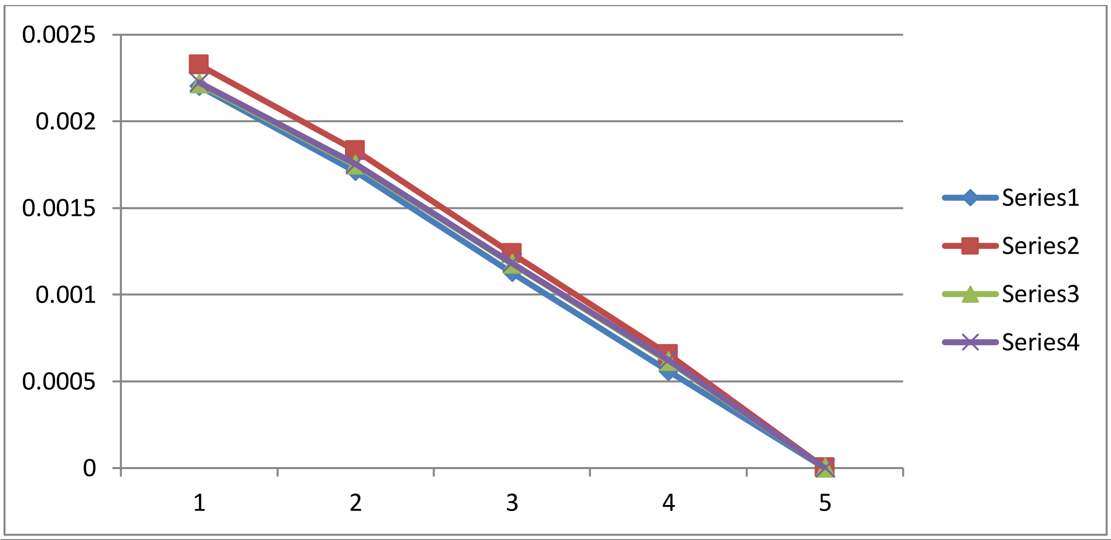


Figure 4.2.- graphical reprentation of story displacement in Y direction

4.1.3. Max story drift in x direction- story drift can be define as a lateral drift of sides way between two adjacent stories of a building due to lateral load in the following study, due to seismic load. I am also defining as the difference of displacements between two adjacent stories divided by the height of that story. In the following table and graphical representation we can see the story drift of the structure in the X direction through linear static method.

Table 4.3. - Maximum story drift at X direction

Story	**Modal 1** (series 1)	**Modal 2** (series 2)	**Modal 3** (series 3)	**Modal4** (series 4)
Story 4	1.67E-08	3.02E-08	2.72E-08	2.93E-08
Story 3	1.61E-08	2.46E-08	2.13E-08	2.19E-08
Story 2	1.18E-08	1.75E-08	1.55E-08	1.54E-08
Story 1	4.66E-08	7.46E-08	6.42E-08	6.59E-08
base	0	0	0	0

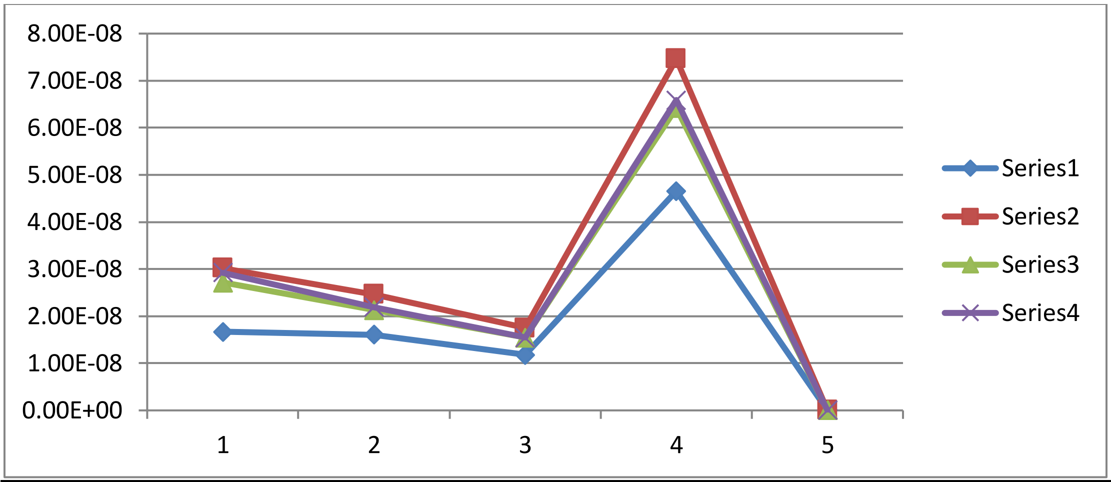


Figure 4.3.- graphical representation of story drift in X direction

4.1.4. Max story drift in y direction- story drift can be define as a lateral drift of sides way between two adjacent stories of a building due to lateral load in the following study, due to seismic load. I am also defining as the difference of displacements between two adjacent stories divided by the height of that story. In the following table and graphical representation we can see the story drift of the structure in the Y direction through linear static method.

Table 4.4. Maximum story drift in y direction

Story	Modal 1 (series 1)	Modal 2 (series 2)	Modal 3 (series 3)	Modal 4 (series 4)
Story 4	1.91E-07	2.17E-07	2.01E-07	2.04E-07
Story 3	2.14E-07	2.33E-07	2.20E-07	2.21E-07
Story 2	2.03E-07	2.17E-07	2.07E-07	2.08E-07
Story 1	1.86E-07	2.18E-07	2.05E-07	2.08E-07
base	0	0	0	0

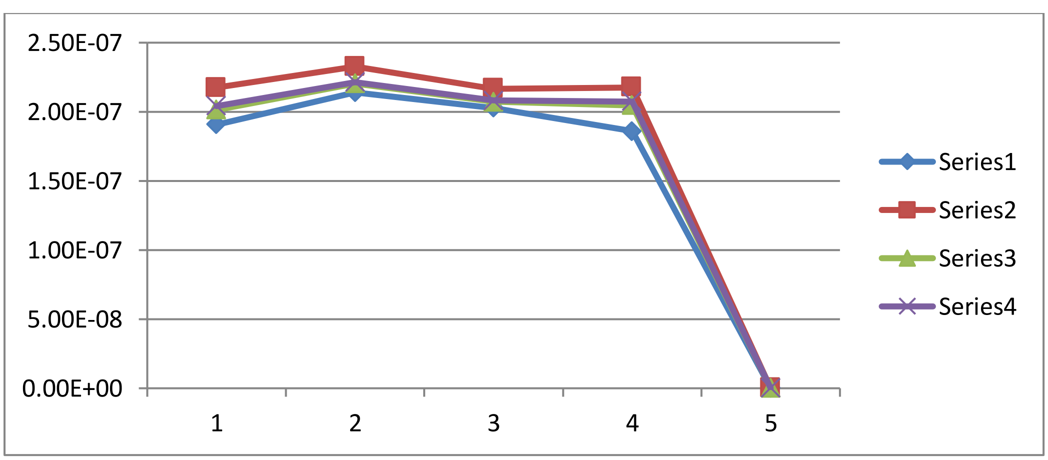
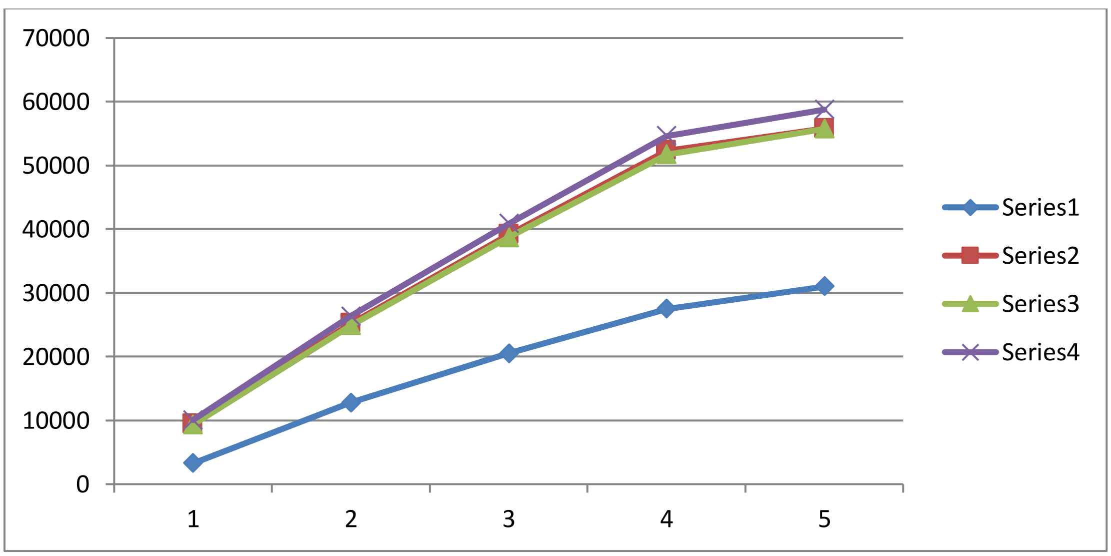


Figure 4.4. Graphical representation of max story drift in Y direction

4.1.5. <u>Story overturning moment in x direction-</u> overturning moments are those applied moments, shears and uplift forces that seek to cause the footing to become unstable and turn over. These following two tables represent the comparison between all eight models. In the following graphical representation we can see the overturning moment in the X direction through linear static method.

<u>Table4.5. Story overturning moment in x direction</u>

Story	**Modal 1** (series1)	**Modal 2** (series 2)	**Modal 3** (series 3)	**Modal 4** (series 4)
Story 4	3259.534	9461.028	9334.534	10063.53
Story 3	12756.44	25190.94	24895.28	26350.33
Story 2	20505.01	39141.82	38697.54	40875.95
Story 1	27476.56	52302.02	51718.26	54618.84
Base	30994.3	55803.51	55734.09	58766.62



<u>Figure 4.5. graphical representation Story overturning moment in x direction</u>

4.1.6. <u>Story overturning moment in y direction-</u> overturning moments are those applied moments, shears and uplift forces that seek to cause the footing to become unstable and turn over? These following two tables represent the comparison between all eight models. In the following graphical representation we can see the overturning moment in the Y direction through linear static method.

<u>Table 4.6. Story overturning moment in y direction</u>

Story	**Modal 1** (series 1)	**Modal 2** (series 2)	**Modal 3** (series 3)	**Modal 4** (series 4)
Story 4	-3259.53	-9461.03	-9334.534	-10063.5
Story 3	-14678.4	-27158	-26828.39	-28286.4

Story 2	-26097.2	-44855	-44322.24	-46509.2
Story 1	-37516.1	-62552.1	-61816.1	-64732.1
base	-45675.4	-70788	-70505.29	-73561.7

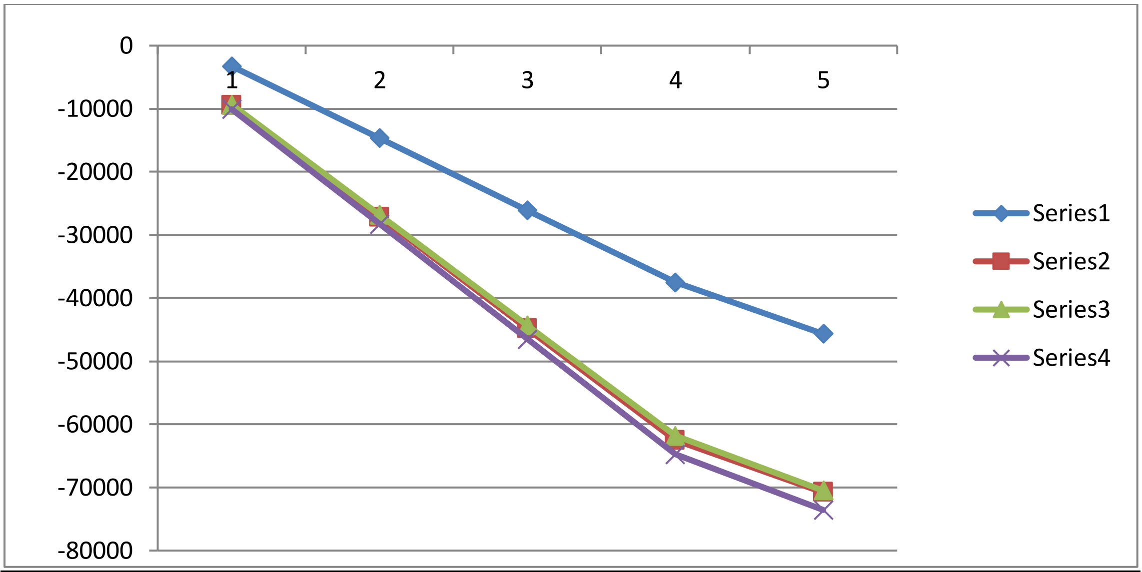


Figure 4.6. graphical representation of Story overturning moment in y direction

4.2.SEISMIC ANALYSIS OF SIX MODELS BY RESPONSE SPECTRUM

4.2.1. Response spectrum- According to the IS code 1893:2002 response spectrum can be define as, the representation of the maximum response of idealized single degree freedom system having certain period and damping, during earthquake ground motion. The maximum response is plotted against the undammed natural period and for various damping values, and can be expressed in terms of maximum absolute acceleration, maximum relative displacement.

Function damping ratio- 0.05

Seismic zone factor, Z- 0.36

Soil type- 2nd

Linear option - linear X- linear Y

Function graph -

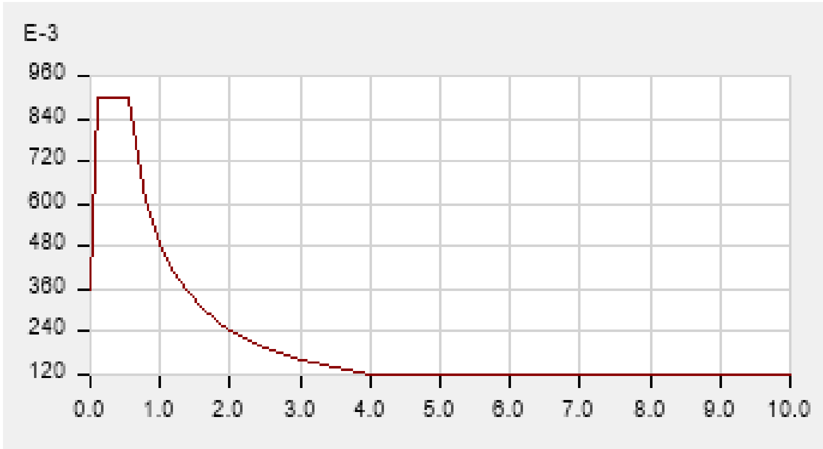


Figure 4.7. function graph of response spectrum

4.2.2. Maximum story displacement in x direction- Story displacement is the absolute value of displacement of storey under the action of lateral forces. These following tables show fundamental value of story displacement in all eight models. In the following figure and table we can see the story displacement in the X direction

Table 9 Maximum story displacement in x direction

Story	Model 1 (series1)	Model 2 (series 2)	Model 3 (series 3)	Model 4 (series 4)	Model 5 (series 5)	Model 6 (series 6)
Story 4	9.34E-05	9.55E-05	9.40E-05	9.41E-05	9.50E-05	9.54E-05
Story 3	8.09E-05	8.26E-05	8.13E-05	8.15E-05	8.23E-05	8.26E-05
Story 2	5.74E-05	5.86E-05	5.77E-05	5.78E-05	5.84E-05	5.87E-05
Story 1	2.88E-05	2.94E-05	2.90E-05	2.90E-05	2.94E-05	2.95E-05
Base	0	0	0	0	0	0

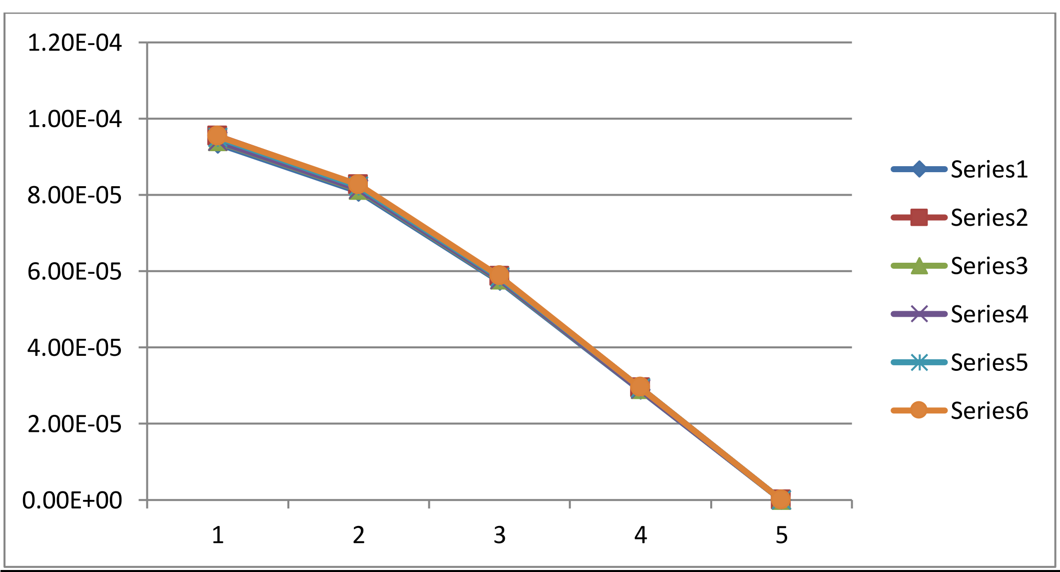
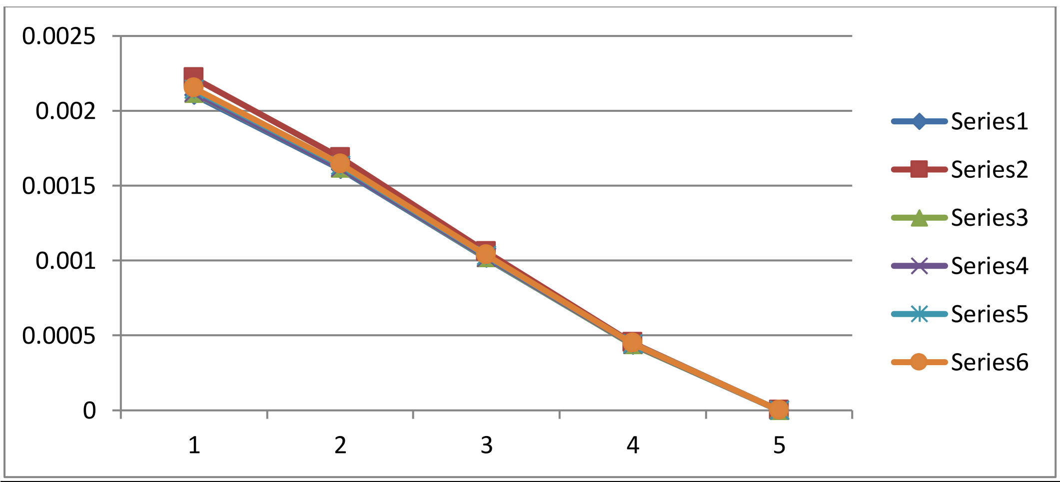


Figure9 graphical representation of Maximum story displacement in x direction

4.2.3. <u>Maximum story displacement in y direction-</u> Story displacement is the absolute value of displacement of storey under the action of lateral forces. These following tables show fundamental value of story displacement in all eight models. In the following figure and table we can see the story displacement in the Y direction.

<u>Table 10 Maximum story displacement in y direction</u>

Story	Model 1 (series 1)	Model 2 (series 2)	Model 3 (series 3)	Model 4 (series 4)	Model 5 (series 5)	Model 6 (series 6)
Story 4	0.002106	0.002219	0.002119	0.002122	0.002141	0.002151
Story 3	0.00161	0.001688	0.001619	0.001622	0.001637	0.001645
Story 2	0.001014	0.001057	0.00102	0.001021	0.001032	0.001037
Story 1	0.000437	0.000452	0.000439	0.00044	0.000445	0.000447
base	0	0	0	0	0	0



<u>Figure 10 graphical representation of Maximum story displacement in y direction</u>

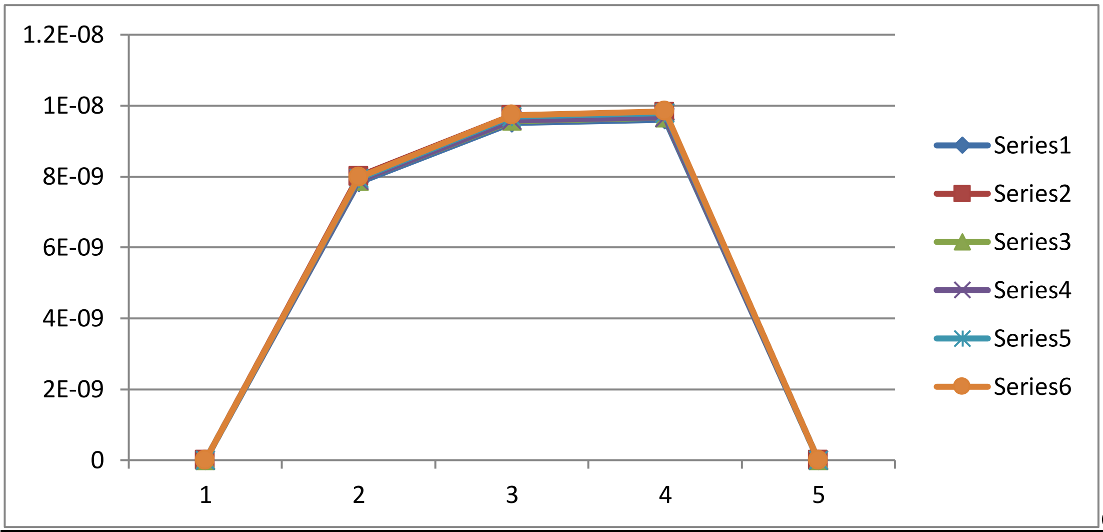
4.2.4. <u>Maximum story drift in x direction-</u> story drift can be define as a lateral drift of sides way between two adjacent stories of a building due to lateral load in the following study, due to seismic load. I am also defining as the difference of displacements between two adjacent stories divided by the height of that story. In the following table and graphical representation we can see the story drift of the structure in the X direction through response spectrum method.

5. <u>Table 11 Maximum story drift in x direction</u>

Story	Model 1 (series 1)	Model 2 (series 2)	Model 3 (series 3)	Model 4 (series 4)	Model 5 (series 5)	Model 6 (series 6)
Story 4	0	0	0	0	0	0
Story 3	7.83E-09	8.01E-09	7.88E-09	7.89E-09	7.95E-09	7.98E-09
Story 2	9.52E-09	9.72E-09	9.57E-09	9.59E-09	9.69E-09	9.73E-09
Story 1	9.60E-09	9.81E-09	9.66E-09	9.67E-09	9.79E-09	9.84E-09

base	0	0	0	0	0	0

Figure 11 graphical representation of



Maximum story drift in x direction

4.2.5. Maximum story drift in y direction- story drift can be define as a lateral drift of sides way between two adjacent stories of a building due to lateral load in the following study, due to seismic load. I am also defining as the difference of displacements between two adjacent stories divided by the height of that story. In the following table and graphical representation we can see the story drift of the structure in the Y direction through response spectrum method.

5. Table 12 Maximum story drift in y direction

Story	**Model 1** (series 1)	**Model 2** (series 2)	**Model 3** (series 3)	**Model 4** (series 4)	**Model 5** (series 5)	**Model 6** (series 6)
Story 4	1.65E-07	1.77E-07	1.66E-07	1.67E-07	1.68E-07	1.69E-07
Story 3	1.99E-07	2.10E-07	2.00E-07	2.00E-07	2.02E-07	2.03E-07
Story 2	1.92E-07	2.02E-07	1.94E-07	1.94E-07	1.96E-07	1.97E-07
Story 1	1.46E-07	1.51E-07	1.46E-07	1.47E-07	1.48E-07	1.49E-07
base	0	0	0	0	0	0

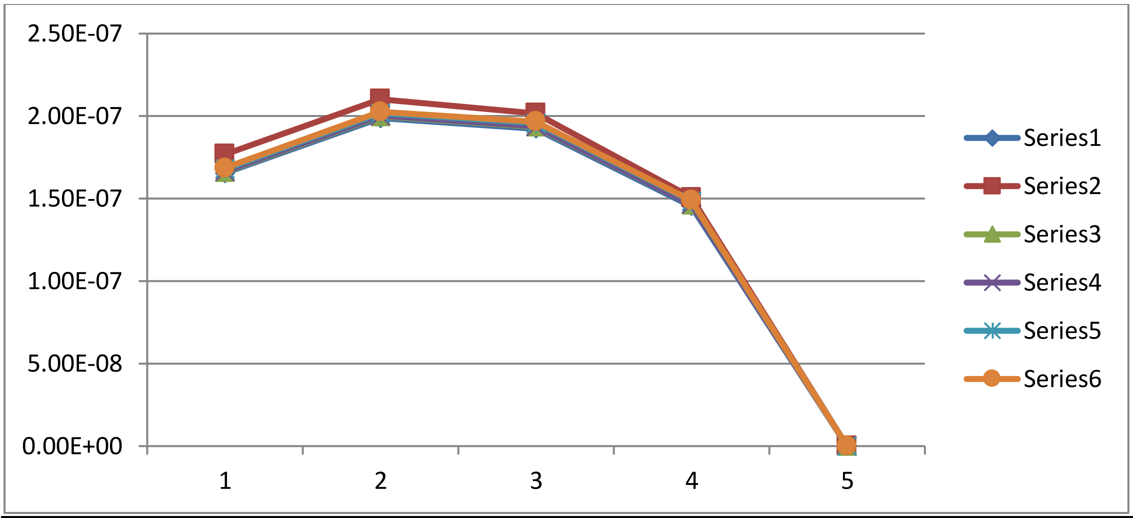


Figure 12 graphical representation of Maximum story drift in y direction

4.2.6. Overturning moment in x direction-- overturning moments are those applied moments, shears and uplift forces that seek to cause the footing to become unstable and turn over. These following two table represent the comparison between all eight models. In the following graphical representation we can see the overturning moment in the X direction through response spectrum method.

6. Table 13 Overturning moment in x direction

Story	**Model 1** (series 1)	**Model 2** (series 2)	**Model 3** (series 3)	**Model 4** (series 4)	**Model 5** (series 5)	**Model 6** (series 6)
Story 4	3259.534	9461.028	9334.534	10063.53	9334.534	10063.53
Story 3	12756.44	25190.94	24895.28	26350.33	24879.08	26329.88
Story 2	20505.01	39141.822	38697.54	40875.95	38650.4	40816.47
Story 1	27476.56	52302.017	51718.26	54618.84	52143.97	55157.51
base	30994.3	55803.514	55734.09	58766.62	56096.21	59224.85

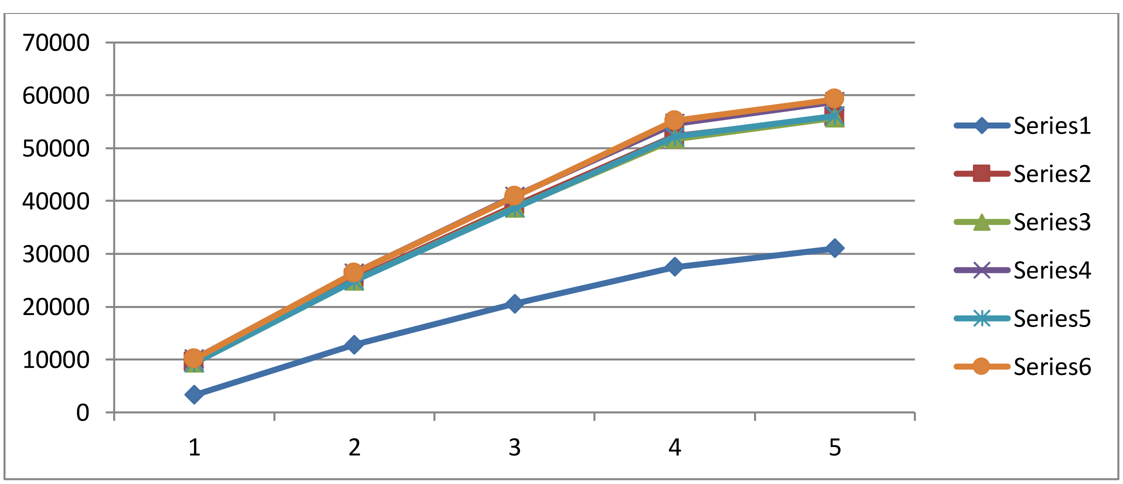
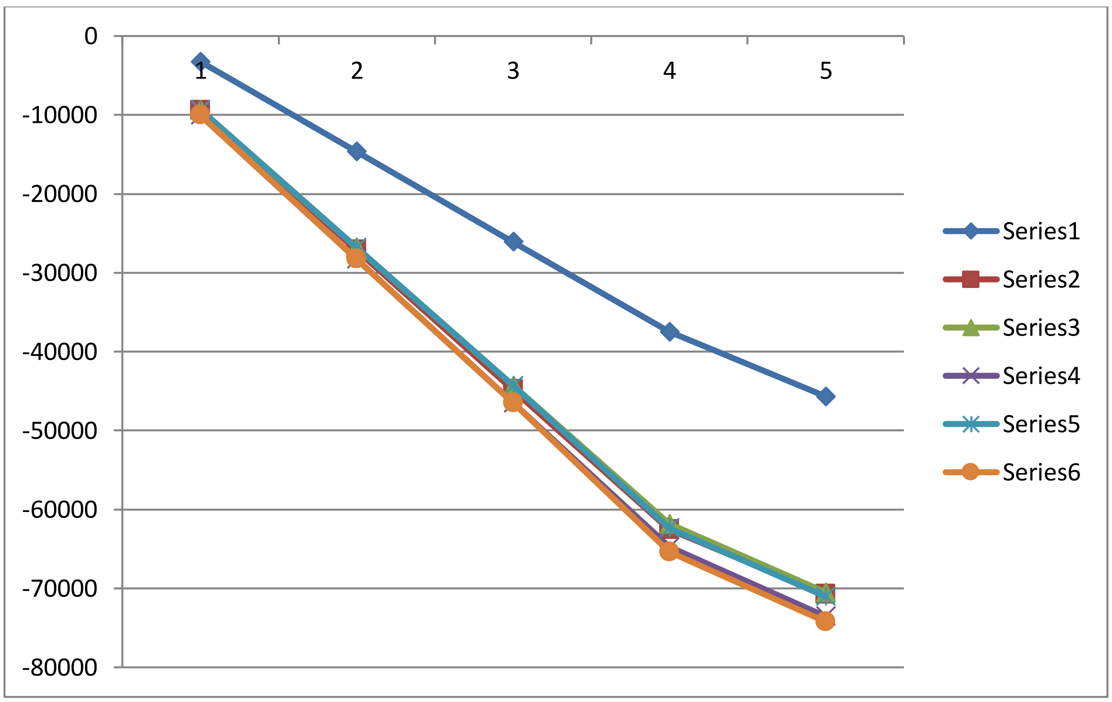


Figure 13 graphical representation of overturning moment in x direction

4.2.7. <u>Overturning moment in y direction-</u> overturning moments are those applied moments, shears and uplift forces that seek to cause the footing to become unstable and turn over. These following two table represent the comparison between all eight models. In the following graphical representation we can see the overturning moment in the Y direction through response spectrum method.

7. <u>Table 14 Overturning moment in y direction</u>

Story	**Model 1** (series 1)	**Model 2** (series 2)	**Model 3** (series 3)	**Model 4** (series 4)	**Model 5** (series 5)	**Model 6** (series 6)
Story 4	-3259.53	-9461.03	-9334.534	-10063.5	-9334.53	-10063.5
Story 3	-14678.4	-27158	-26828.39	-28286.4	-26828.4	-28286.4
Story 2	-26097.2	-44855	-44322.24	-46509.2	-44322.2	-46509.2
Story 1	-37516.1	-62552.1	-61816.1	-64732.1	-62346	-65402.3
base	-45675.4	-70788	-70505.2	-73561.7	-71035.2	-74231.9



<u>Figure 14 graphical representation of Overturning moment in y direction</u>

4.2.8. <u>Story shear in y direction-</u>

8. <u>Table 15 Story shear in y direction-</u>

<u>Story</u>	**Model 1**(series1)	**Model 2** (series 2)	**Model 3** (series3)	**Model 4** (series4)	**Model 5** (series5)	**Model 6** (series6)	**locatio n**
Story 4	640.6506	655.6981	644.370	645.354	649.771	652.168	**Top**
	640.6506	655.6981	644.370	645.354	649.771	652.168	**Bottom**
Story 3	1223.426	1248.710	1230.53	1232.40	1240.84	1245.42	**Top**

	1223.426	1248.710	1230.53	1232.40	1240.84	1245.42	**Bottom**
Story 2	1482.437	1512.271	1491.04	1493.32	1510.05	1517.35	**Top**
	1482.437	1512.271	1491.04	1493.32	1510.05	1517.35	**Bottom**
Story 1	1547.190	1578.162	1557.78	1560.59	1578.98	1587.40	**Top**
	1547.190	1578.162	1557.78	1560.59	1578.98	1587.40	**Bottom**
base	0	0	0	0	0	0	**Top**
	0	0	0	0	0	0	**bottom**

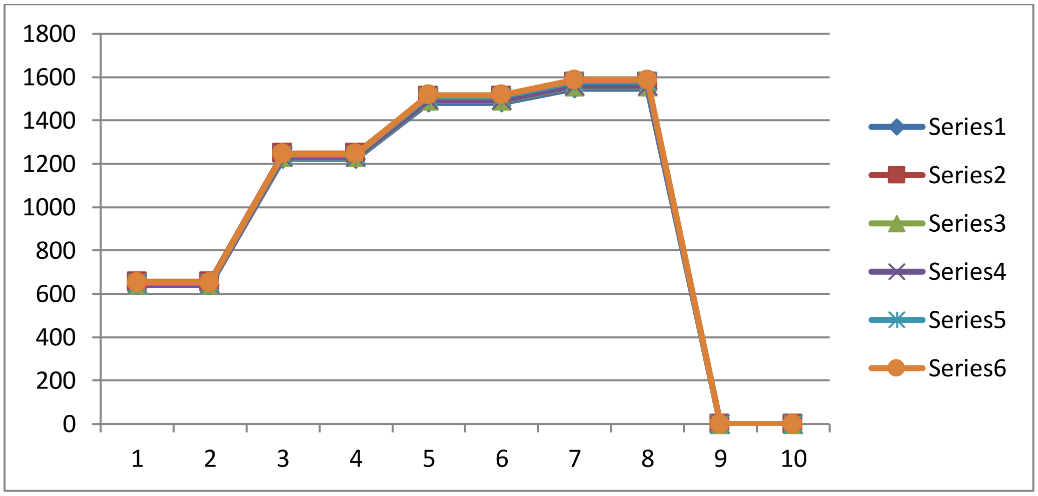


Figure 15 graphical representation of Story shear in y direction

4.3. SEISMIC ANALYSIS OF EIGHT MODELS BY RESPONSE SPECTRUM

4.3.1. Models detail- For phase two of research by response spectrum.

1. **Model 1-** Pure Masonry Structure (P.M.S.)
2. **Model 2-** Reinforced concrete structure (R.C.S.)
3. **Model 3-** V bracing at ground level (V. B. G.)
4. **Model 4-** X bracing at ground level (X.B.G.)
5. **Model 5-** V bracing at ground to first story(V.B.G+1)
6. **Model 6-** X bracing at ground to first story(X.B.G+1)
7. **Model 7-** V bracing at ground to second story(V.B.G+2)
8. **Model 8-** X bracing at ground to second story (X.B.G+2)

4.3.2. Maximum story displacement- Story displacement is the absolute value of displacement of storey under the action of lateral forces. These following tables show fundamental value of story displacement in all eight models.

5. Table 16- Maximum story displacement in X direction

	Story 4	**Story 3**	**Story 2**	**Story 1**	**base**
P.M.S.	9.34E-05	8.09E-05	5.74E-05	2.88E-05	0
R.C.S.	9.55E-05	8.26E-05	5.86E-05	2.94E-05	0

V.B.G.	9.40E-05	8.13E-05	5.77E-05	2.90E-05	0
X.B.G.	9.41E-05	8.15E-05	5.78E-05	2.90E-05	0
V.B.G+1	9.50E-05	8.23E-05	5.84E-05	2.94E-05	0
X.B.G+1	9.54E-05	8.26E-05	5.87E-05	2.95E-05	0
V.B.G+2	9.61E-05	8.33E-05	5.92E-05	2.98E-05	0
X.B.G+2	9.68E-05	8.40E-05	5.97E-05	3.00E-05	0

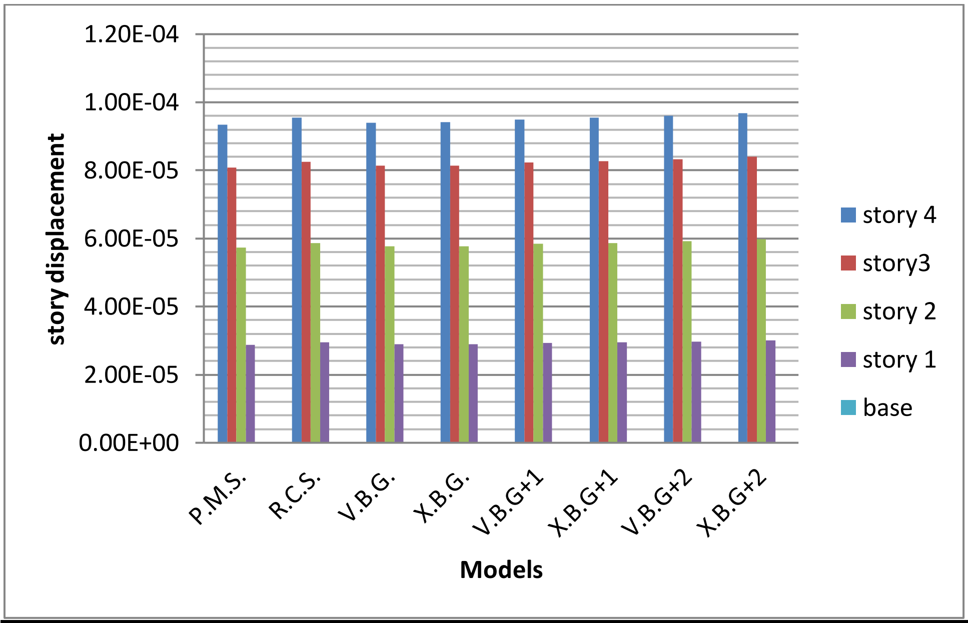
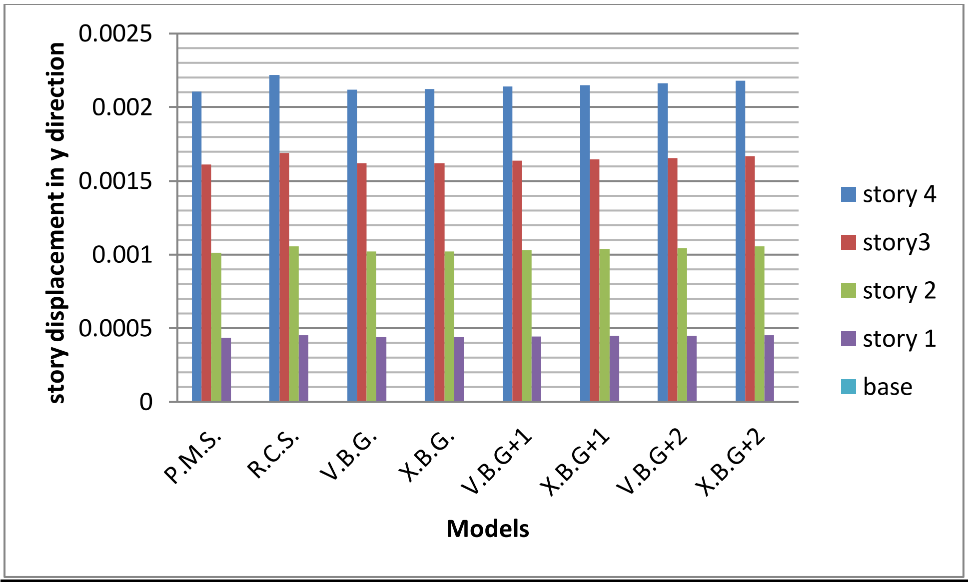


Table 17- Maximum story displacement in Y direction

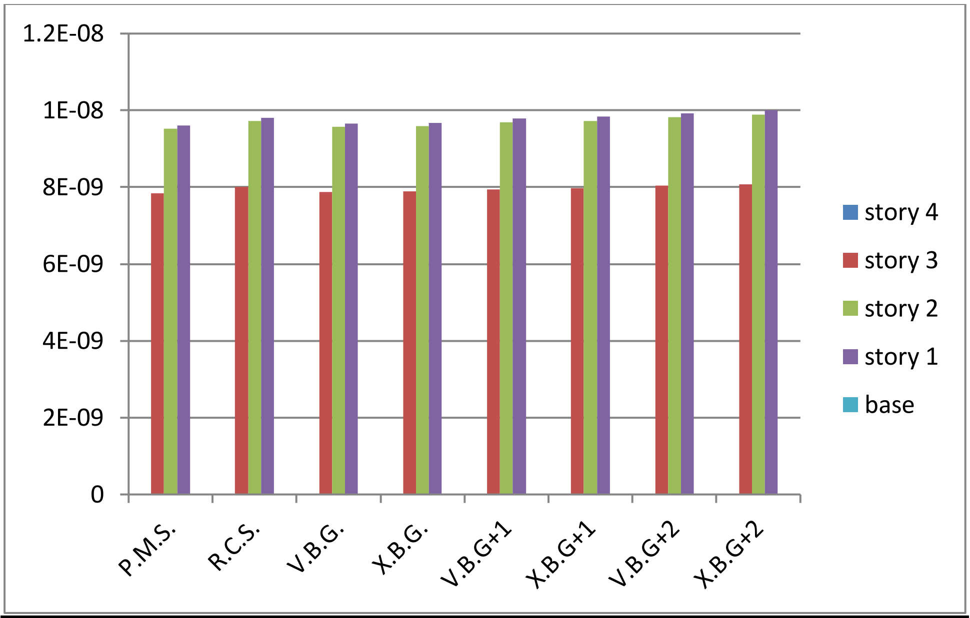
	Story 4	**Story 3**	**Story 2**	**Story 1**	**base**
P.M.S.	0.002106	0.00161	0.001014	0.000437	0
R.C.S.	0.002219	0.001688	0.001057	0.000452	0
V.B.G.	0.002119	0.001619	0.00102	0.000439	0
X.B.G.	0.002122	0.001622	0.001021	0.00044	0
V.B.G+1	0.002141	0.001637	0.001032	0.000445	0
X.B.G+1	0.002151	0.001645	0.001037	0.000447	0
V.B.G+2	0.002164	0.001657	0.001045	0.00045	0
X.B.G+2	0.00218	0.00167	0.001054	0.000454	0



4.3.3. **Maximum story drift-** story drift can be define as a lateral drift of sides way between two adjacent stories of a building due to lateral load in the following study, due to seismic load. I am also defining as the difference of displacements between two adjacent stories divided by the height of that story.

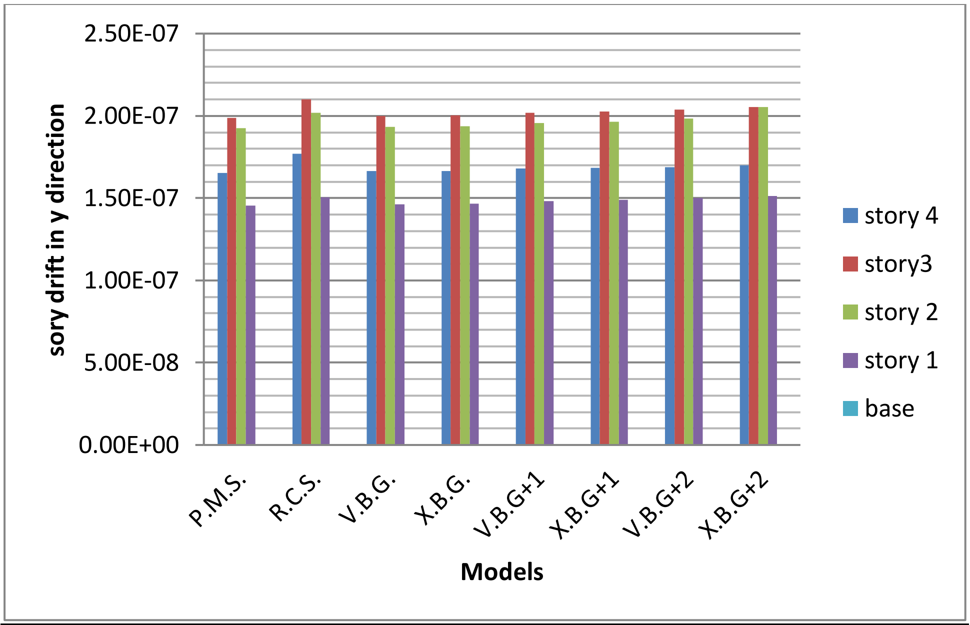
	Story 4	Story 3	Story 2	Story 1	base
P.M.S.	0	7.83E-09	9.52E-09	9.60E-09	0
R.C.S.	0	8.01E-09	9.72E-09	9.81E-09	0
V.B.G.	0	7.88E-09	9.57E-09	9.66E-09	0
X.B.G.	0	7.89E-09	9.59E-09	9.67E-09	0
V.B.G+1	0	7.95E-09	9.69E-09	9.79E-09	0
X.B.G+1	0	7.98E-09	9.73E-09	9.84E-09	0
V.B.G+2	0	8.03E-09	9.82E-09	9.92E-09	0
X.B.G+2	0	8.08E-09	9.90E-09	1.00E-08	0

Table 18 – maximum story drift in X direction



	Story 4	Story 3	Story 2	Story 1	base
P.M.S.	1.65E-07	1.99E-07	1.92E-07	1.46E-07	0
R.C.S.	1.77E-07	2.10E-07	2.02E-07	1.51E-07	0
V.B.G.	1.66E-07	2.00E-07	1.94E-07	1.46E-07	0
X.B.G.	1.67E-07	2.00E-07	1.94E-07	1.47E-07	0
V.B.G+1	1.68E-07	2.02E-07	1.96E-07	1.48E-07	0
X.B.G+1	1.69E-07	2.03E-07	1.97E-07	1.49E-07	0
V.B.G+2	1.69E-07	2.04E-07	1.98E-07	1.50E-07	0
X.B.G+2	1.70E-07	2.05E-07	2.05E-07	1.52E-07	0

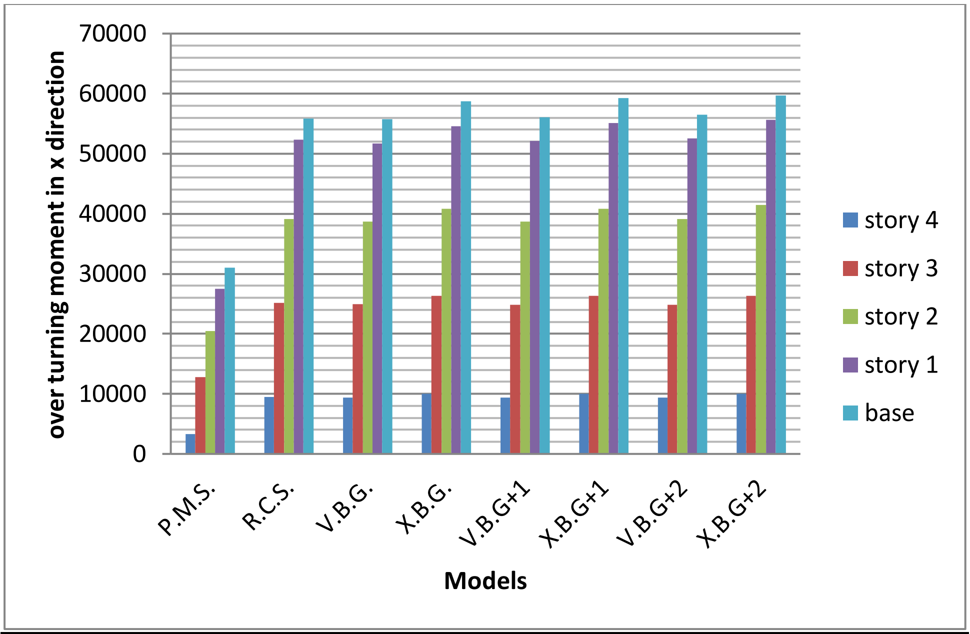
Table 19- maximum story drift in Y direction



4.3.4. Overturning moment- overturning moments are those applied moments, shears and uplift forces that seek to cause the footing to become unstable and turn over. These following two tables represent the comparison between all eight models.

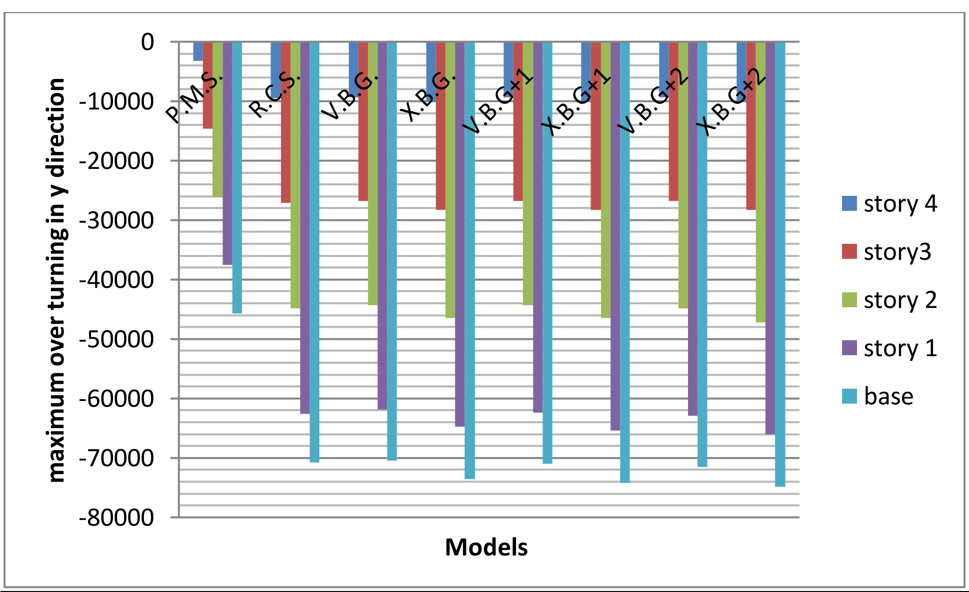
	Story 4	Story 3	Story 2	Story 1	base
P.M.S.	3259.534	12756.44	20505.01	27476.56	30994.3
R.C.S.	9461.028	25190.94	39141.82	52302.02	55803.51
V.B.G.	9334.534	24895.28	38697.54	51718.26	55734.09
X.B.G.	10063.53	26350.33	40875.95	54618.84	58766.62
V.B.G+1	9334.534	24879.08	38650.4	52143.97	56096.21
X.B.G+1	10063.53	26329.88	40816.47	55157.51	59224.85
V.B.G+2	9334.534	24879.03	39136.2	52566.19	56454.85
X.B.G+2	10063.53	26329.95	41431.12	55691.71	59678.63

Table 20 maximum overturning moment in x direction



	Story 4	Story 3	Story 2	Story 1	base
P.M.S.	-3259.53	-14678.4	-26097.2	-37516.1	-45675.4
R.C.S.	-9461.03	-27158	-44855	-62552.1	-70788
V.B.G.	-9334.53	-26828.4	-44322.2	-61816.1	-70505.3
X.B.G.	-10063.534	-28286.389	-46509.243	-64732.097	-73561.659
V.B.G+1	-9334.5343	-26828.389	-44322.243	-62345.97	-71035.162
X.B.G+1	-10063.5	-28286.4	-46509.2	-65402.3	-74231.9
V.B.G+2	-9334.5343	-26828.389	-44852.115	-62875.842	-71565.034
X.B.G+2	-10063.5	-28286.4	-47179.5	-66072.6	-74902.1

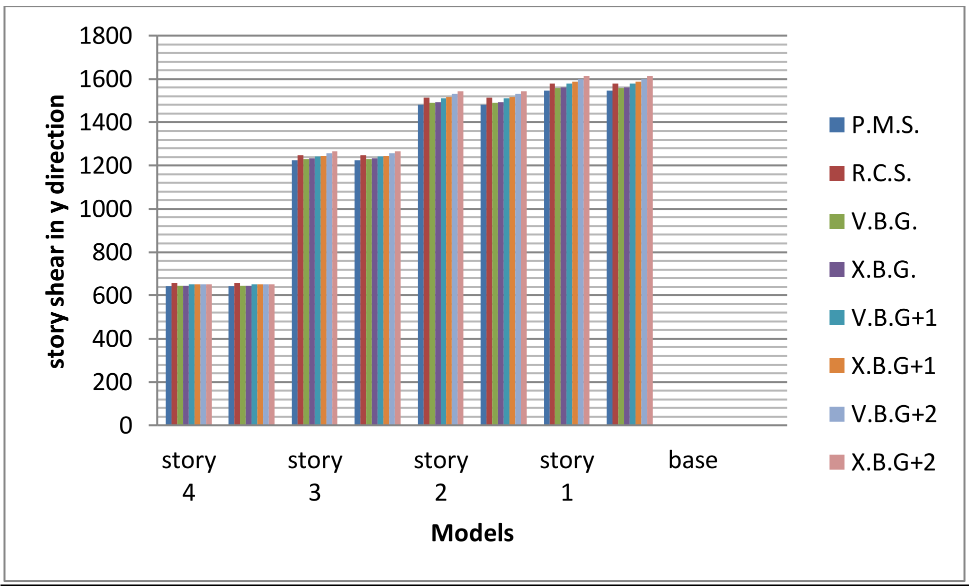
Table 21 maximum overturning moment in Y direction



4.3.5. Story shear-

Top / Bottom	Story 4	Story 3	Story 2	Story 1	base
P.M.S.	640.6506	1223.426	1482.437	1547.19	0
R.C.S.	655.6981	1248.711	1512.272	1578.162	0
V.B.G.	644.3703	1230.53	1491.045	1557.788	0
X.B.G.	645.3544	1232.409	1493.322	1560.595	0
V.B.G+1	649.7711	1240.843	1510.053	1578.9826	0
X.B.G+1	652.1683	1245.421	1517.355	1587.405	0
V.B.G+2	649.7853	1255.52	1531.246	1600.178	0
X.B.G+2	652.1464	1263.977	1544.167	1614.214	0

Table 22- story shear in Y direction



CHAPTER 5

CONCLUSION

According to the graphical comparative study between eight modal, modal with retrofitting and modal without retrofitting can be analyzed by the Etabs 2015 software and concluded that the retrofitted structure having more stable and more seismic resisted compression with pure masonry structure.

1. V bracing retrofitted system model gives better strength compression to pure masonry structure. On the basis of story drift, story displacement and story shear. Story drift without retrofitting is 7.83E-09 mm and retrofitting with V bracing 8.03E-09 mm. Story displacement without retrofitting 9.34E-05 mm and with retrofitting with v bracing is 9.61E-05 mm. Story shear without retrofitting is 640.6506 mm and with retrofitting with V bracing is 649.7853 mm. to seen all fundamental values we can say that retrofitted structure is better than masonry structure.
2. X bracing retrofitted system model gives better strength compression to V bracing system model. On the basis of story drift, story displacement and story shear. Story drift of Retrofitting with X bracing is 8.08E-09 mm and retrofitting with v bracing is 8.03E-09 mm. Story shear with retrofitting with X bracing 652.1464 mm and retrofitting with V bracing is 649.7853 mm. so we say that retrofitting with X bracing is better than V bracing retrofitting.
3. X bracing is better than V bracing system for retrofitting of a masonry structure. When we provide X bracing to a masonry structure to first two floor (base floor, first floor) it's give better story drift and story shear compare to a RC frame structure.
4. In the following research paper, when we retrofitted structure through X, V bracing the seismic properties of structure should be improved and it is better to RC structure. Story displacement increases 9.34E-05 mm (P.M.S.) to 9.68E-05 mm (X.V.G+2) which is better than RC structure story displacement (9.55E-05mm) at 4^{th} floor.
5. Retrofitted structure with X bracing can provided better story drift as compare to RC frame structure. It is increases 9.52E-09(P.M.S.) to 9.90E-09(X.B.G+2) which is better the RC structure (9.72E-09).
6. Retrofitting provide extra seismic resistance quality to the structure under the seismic loads.

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