A comprehensive experimental study of bonding behaviour of new and old concrete using high performance materials

A DISSERTATION

Submitted in partial fulfilment of the

requirements for the award of the degree

of

MASTER OF TECHNOLOGY

in

EARTHQUAKE ENGINEERING
(With specialization in Structural Dynamics)

By

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MAY, 2016

CLARIFICATION

I hereby state that my topic has been changed in accordance with the academic record, my thesis title was **"A COMPREHENSIVE STUDY OF BONDING BEHAVIOUR OF OLD AND NEW CONCRETE USING HIGH PERFORMANCE MATERIALS"**, but as per the supervisor's guidelines I have been working on **"SESMIC ANALYSIS AND RETROFITTING OF RCC BUILDING"** since June, 2015. The whole work done in the thesis is on the above mentioned topic. So please consider the thesis work as per the new title.

Candidate's Signature **Supervisor's Signature**

(ANIL KUMAR) **(DR. PANKAJ AGARWAL)**

CANDIDATE'S DECLARATION

I hereby certify that the work which is being presented in this **DISSERTATION** entitled **"SESMIC ANALYSIS AND RETROFITTING OF RCC BUILDING"**, submitted in the partial fulfilment of the requirement for the award of the degree of **Master of Technology in Earthquake Engineering** and submitted in the Department of Earthquake Engineering of the Indian Institute of Technology, Roorkee is an authentic record of my own work carried out during a period June 2015 to April 2016 under the supervision and guidance of **Dr. Pankaj Agarwal**, Professor, Earthquake Engineering Department, IIT Roorkee.

Date: **ANIL KUMAR**

Place: Roorkee **Enrolment No. 14526004**

CERTIICATE

This is to certify that the above statement made by the candidate is correct to the best of my knowledge.

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May, 2016

Place- Roorkee

ANIL KUMAR

ABSTRACT

The most of the buildings that were designed according to the earlier codes sometimes may not satisfy the requirements of the present seismic codes making them to the prone to the earthquake. This may cause the partial or complete collapse of the structure in case of any earthquake event. Thus to prevent the structure from heavy damage and to increase the seismic performance of the building we need retrofitting of old structures.

Preparedness and awareness are the key role in mitigating a disaster and thus for the protection of the structures and preventing the loss of life, Retrofitting of the seismic deficient structures is must.

The present work deals with the analysis of a G+9 storey building located in seismic Zone III. The building was designed according to the IS 456:2000 and other using Earthquake code IS 1893:2002 along with ductile detailing provided. This study shows that ductile detailing is more efficient for earthquake resistant design. Also analysis was carried out with conventional retrofitting technique like shear wall and steel bracing addition.

The work is divided into two parts: In the first step analysis of building was carried out and push over curves were plotted and seismic resistance of the building was calculated then in the second step conventional approach of retrofitting was employed and analysed. It shows that building behaves well in earthquake with shear wall and steel bracing addition to the existing structure.

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1. CHAPTER

INTRODUCTION

1.1 PRELUDE

“Seismic retrofitting is the modification of existing structures to make them more resistant to seismic activity, ground motion, or soil failure due to earthquakes”. This generally includes the process of strengthening, repairing works and sometimes also involves the remodelling of the structure. The retrofitting technique of a seismic deficit building is needed because it is more economical as compared to demolition and reconstruction. The basic concept behind retrofitting is to increase the lateral strength and ductility of the structure. Hence retrofitting is needed to make the structure damage proof and enhance its performance at the time of earthquake event.

1.2 NEED OF RETROFITTING

The retrofitting of structures is needed due to one or more than one of the following reasons:

(A). Old buildings may have been without the provision of seismic code or the seismic code have been upgraded in recent years.

(B). Structures are constructed according to modern codes but there is deficiencies in design or construction methods.

(C). Important buildings hospitals, historical buildings and architectural buildings.

(D). Sometimes the use of buildings has changed through the years.

Hence to account these above mentioned factors several seismic retrofitting techniques are used nowadays to improve the performance of the building in a particular region to make the structure seismic efficient.

1.3 AIM

Main aim of study is the dynamic analysis of a structure provided which is situated in earthquake prone area and retrofits it with different techniques and analyse its behaviour.

1.4 OBJECTIVES

- Static analysis of G+9 storey RC building by calculating capacity and demand.

- To retrofit the given building by the use of shear walls, steel bracing and jacketing at location of failure.
- To reanalyse the retrofitted building and find out the increase in its strength and ductility.

1.5 SCOPE OF THE STUDY

This study considers a RC G+9 storey building which is situated in seismic zone-III with soft soil type. Plan of building is provided with sectional details of all the beams and columns of each storey.

To analyse the behaviour of building, the nonlinear static push over analysis was carried out with the help of SAP2000. Then failure pattern was analysed with the help of location of hinges. The seismic capacity and demand of the members were studied. Then building was retrofitted with the conventional technique like shear wall, steel bracing and jacketing. Because of addition of these members seismic performance of building is enhanced. The seismic behaviour of building after retrofitting was also studied.

1.6 OVERVIEW OF THEISIS

Chapter 2- In this chapter, introduction and need of retrofitting is discussed also different terms related to retrofitting is defined. Literature reviews of retrofitting are described.

Chapter 3- In this chapter, the study of model of building is carried out and moment curvature relation is plotted. Push over analysis and demand spectrum was studied.

Chapter 4- In this chapter, the different methods of retrofitting like provision of shear wall, steel bracing and jacketing are discussed. Also seismic behaviour of building after retrofitting is analysed.

Chapter 5- In this chapter results obtained from the analysis are discussed.

Chapter 6- This chapter deals with conclusions drawn from the analysis and results.

Chapter 7- References and paper which are studied for study.

2. CHAPTER

STUDIES ON RETROFITTING

2.1 GENERAL

Due to happening of an earthquake in particular region buildings are subjected to unpredicted seismic motion that can cause the heavy damage of building components or humankind or both. This happen because of poor design of building without considering the seismic code or not meeting the ductility requirement of building for particular demand of an earthquake. By the use of different retrofitting techniques we can make the structure earthquake resistant for a particular degree. Also retrofitting of building proves to an economical task as compared to demolition and reconstruction. The basic concept behind it is to increase the stiffness of the structure to reduce its natural time period. From the experimental study it is concluded that cost of retrofitting should remain below 25% of the replacement.

The method of retrofitting chosen for a particular type of building depends upon the seismic zone, soil condition, type of building. It also depends upon the desired level of performance.

Fig-2-1:Structural repairing of RCC member

2.2 DEFINITIONS AND TERMS RELATED TO RETROFITTING:

To make the structure resistant to seismic action the method of retrofitting is used in practice. The method generally includes different process like strengthening, repairing, rehabilitation, restoration, remoulding etc. The following are few terms in relation to retrofitting:

Strengthening-

Reconstruction or renewal of any part of any existing building to provide better structural capacity i.e., higher strength and higher ductility than the original building.

Repairing-

Reconstruction or renewal of any part of a damage or deteriorated building to provide the same level of strength and or ductility when the building had prior to damage.

Remodeling-

Reconstruction or renewal of any part of any existing building owing to change of usage or occupancy.

Retrofitting-

Concept includes Strengthening, Repairing and Remodeling.

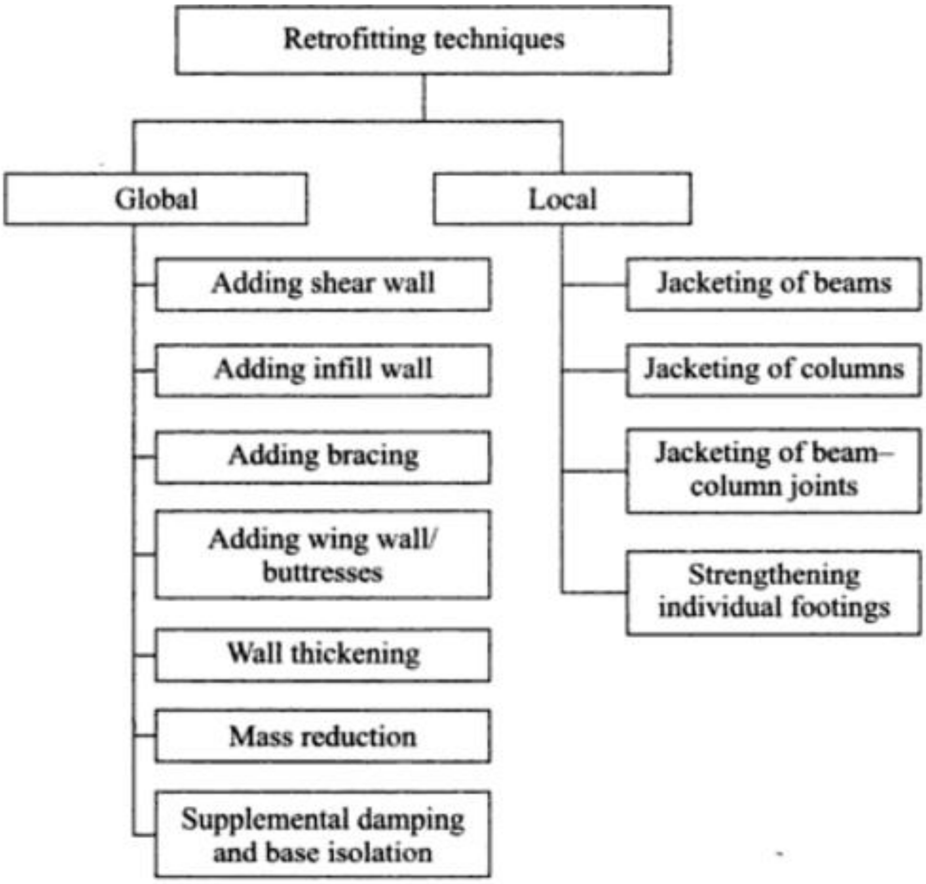
Rehabilitation-

Reconstruction or renewal of a damage building to provide the same level of function which the building had prior to the damage.

Restoring-

Rehabilitation of building of a certain area.

There are two method to increase the seismic capacity of building – Global retrofitting, Local retrofitting. Further in global method of retrofitting different techniques used are addition of shear walls, addition of steel bracing, mass reduction etc. which are conventional methods. In non-conventional methods seismic base isolation and damping devices are used.



CONVENTIONAL METHODS-

1. Addition of shear wall:

By the addition of shear wall lateral strength of building increases. Shear wall elements should be placed at the exterior of the building. It is desirable to place the shear wall adjacent to the beam between columns to minimize slab demolition. The main limitation is that overturning moment at foundation increases which requires strengthening of existing foundation.

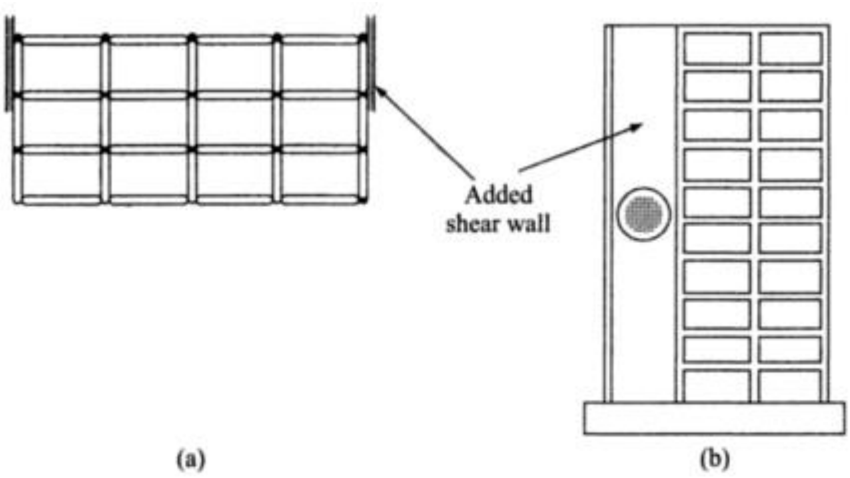


Fig-2.2 - Addition of shear wall on existing building

2. Addition of steel bracing:

By the addition of steel bracing strength and ductility of building increases. It is normally used where large openings are required. Due to less weight of steel members in this system addition of weight to existing structure is less. The effective slenderness ratio of steel braces should be kept as small as possible to make the brace effective in both compressionand tension. Hence l/r ratio should be 60 to 80 or lower.

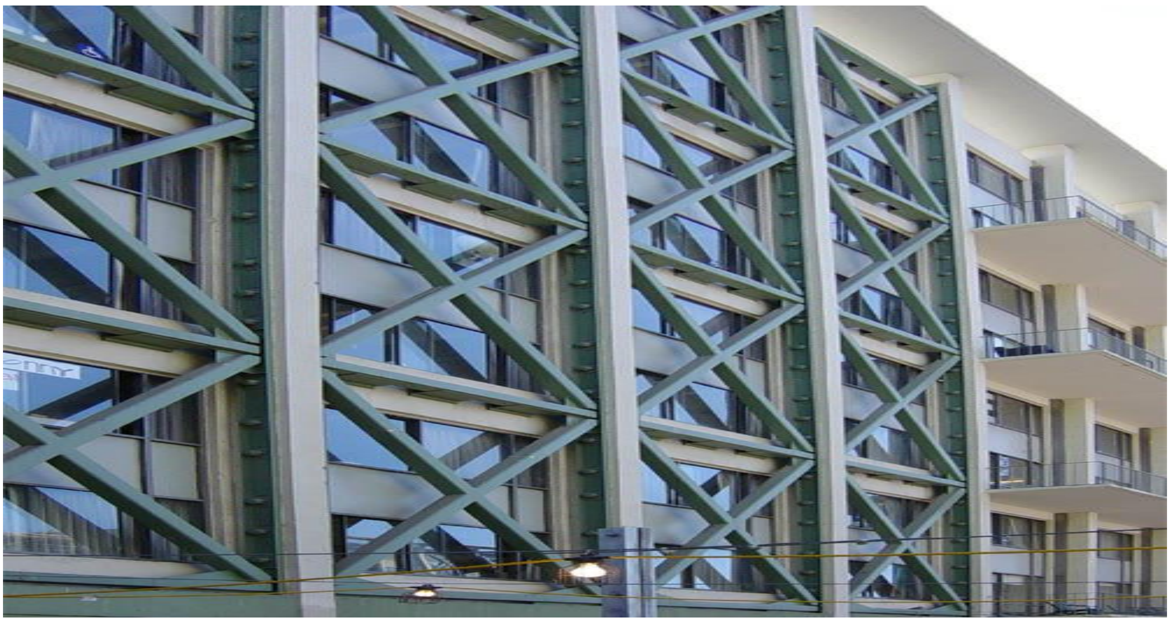


Fig.2-3: Addition of steel bracing

3. Addition of infill walls:

This method is economical to increase strength and to reduce drift of existing frames. Care must be taken of its strength because strong masonry may cause failure of existing frame.

NON-CONVENTIONAL METHODS:

1. **Seismic base isolation-**

The concept behind it is to reduce horizontal base shear due to earthquake. In this there is no need of reinforcement in super-structure. In a base isolation system rubber bearing is used at the base of the building. Rubber bearing is made of laminated layers of rubber and steel plates which are bonded tightly.

2. **Damping devices-**

These devices mostly consist of viscous-damper, frictional damper etc.

2.4 LITERATURE REVIEW:

To study the behaviour of structures during earthquake research has been done in various universities across the world by researchers. They have published their research paper of their study which were useful for further study in that area. The following research papers were used for study of this work.

K. Galal et al.: To improve the lateral strength, stiffness and energy dissipation capacity for medium to high rise buildings reinforced concrete shear walls are used. For the buildings which were not designed according to new seismic code shear wall retrofitting is used.

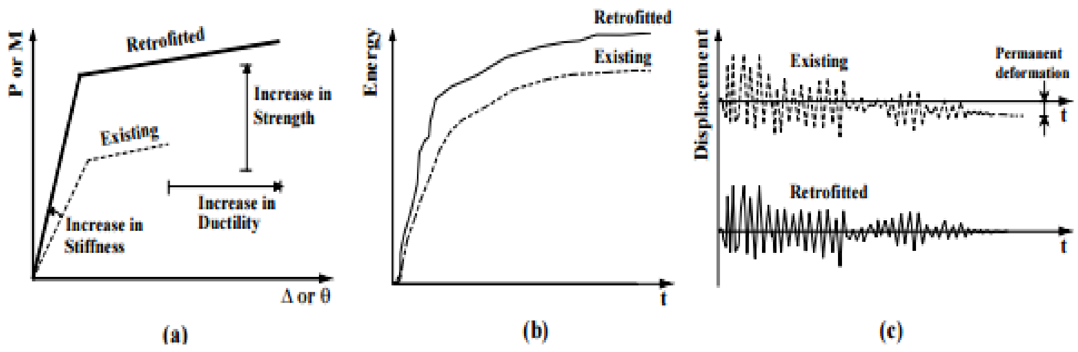


Fig.2-4: Different characteristics to be improved by retrofit (a) Stiffness, Strength, and/or ductility (b) Energy dissipation capacity (c) Permanent deformation control.

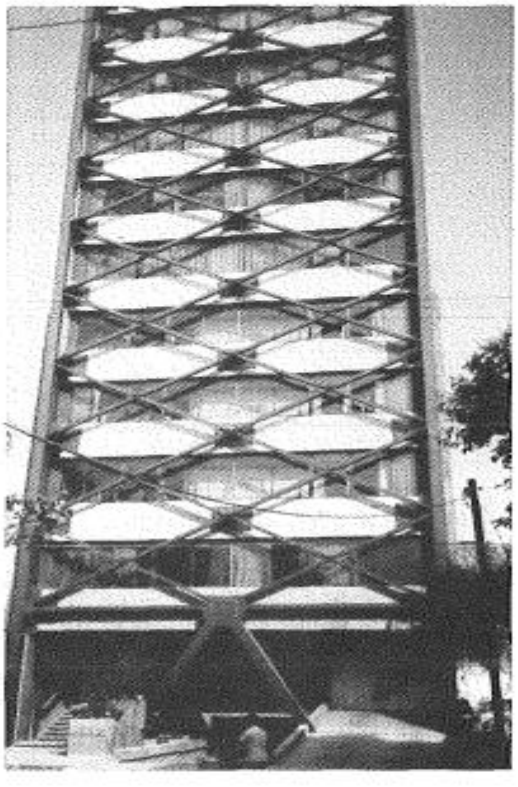
MODES OF FAILURE OF RC SHEAR WALLS-

1. Flexural failure
2. Shear failure

   There are several factors that control the choice of the retrofitting technique for RC shear walls, some of these factors are:

- • The deficiency in the existing wall and its expected mode of failure.
- • The goal of intervention (e.g. increased stiffness, strength, ductility, etc.)
- • Consequences of wall rehabilitation (e.g. increased demand on foundation, etc.).
- • The allocated budget for retrofit.

Marc Badoux et al.- Use of diagonal steel bracing is an excellent method to increase strength and ductility of buildings for lateral forces.



2. Building in Mexico City Braced Prior to 1985 Earthquake

It is desirable to brace as many bays of the frame as possible, so that increases in strength and stiffness are distributed uniformly. However, cost and functional considerations may limit the number of braced bays.

Four possible patterns are presented in Figure. X-patterns are the most common because of their simplicity. Pattern 1 tends to be superior to 2 because a smaller number of elements are needed and brace inclinations are about 45°. The diamond pattern reduces brace buckling length, but construction is more difficult because the bracing system is connected to the frame at more locations. The K-pattern has the disadvantage of generating undesirable beam shear forces if a brace buckles or fails.

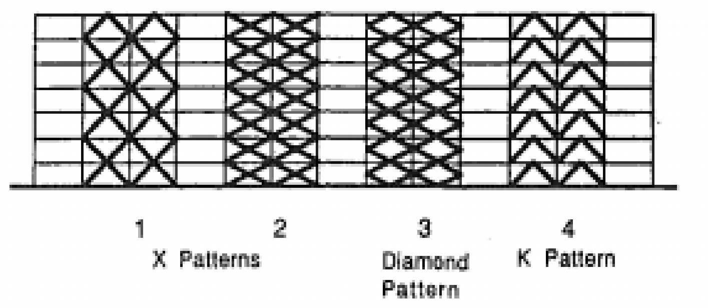


Fig.2-5: Different pattern of steel bracing

Mander et al.- For concrete subjected to uniaxial compressive loading and confined by transverse reinforcement stress strain model was developed. The effect of various type of confinement is taken into account by effective lateral confining stress which is dependent on the configuration of the transverse and longitudinal reinforcement.

For a slow strain rate and monotonic loading the longitudinal compressive stress is given by

$$f_c = \frac{f'_{cc} * x * r}{r - 1 + x^r}$$

Where f'_{cc} =compressive strength of confined concrete

$$x = \frac{\varepsilon_c}{\varepsilon_{cc}}$$

Where ε_c = longitudinal compressive concrete strain

$$\varepsilon_{cc} = \varepsilon_{c0}\left[1+5\left(\frac{f'_{cc}}{f'_{c0}}-1\right)\right]$$

Michael L. Albert et al.- Experiment shows that due to application of fibre reinforced polymers (FRPs) the load-carrying capacity of unreinforced masonry walls that are subjected to out-of-plane flexural loads increases.

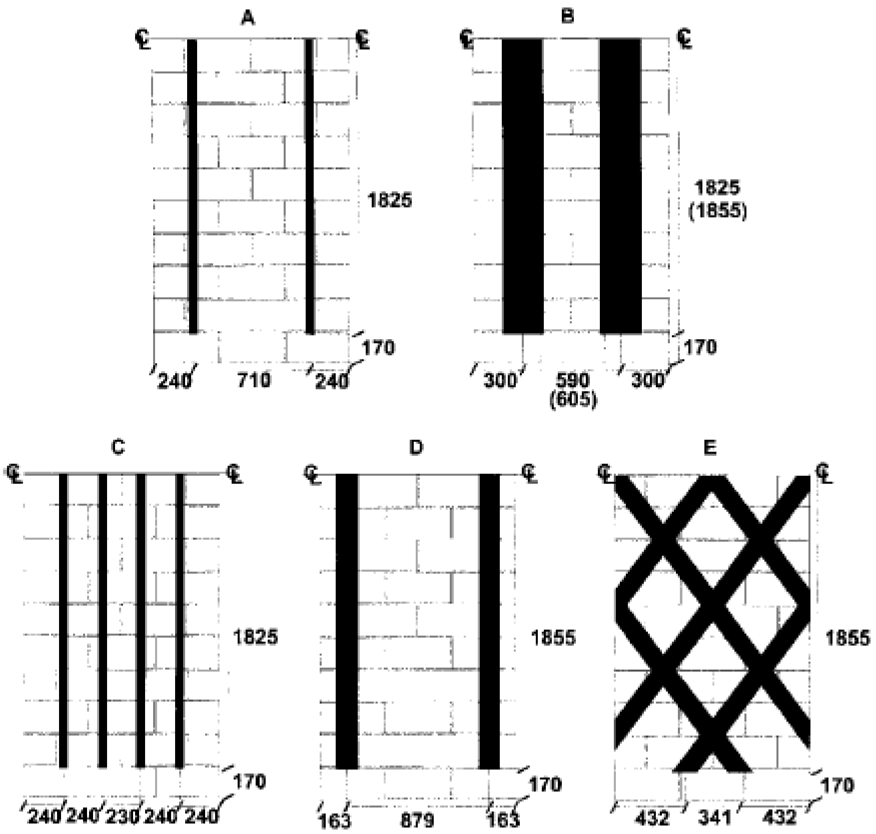


Fig.2-6 -Patterns and Placement of FRP on Specimens (Dimensions in parentheses are Series 2 Dimensions)

From the load deflection behaviour it was concluded that strength and stiffness increases due to application of FRP.

Three general modes of failure were observed:

(1) Mortar separation or mortar slip;

(2) Flexure-shear;

(3) Flexure.

Pravin B. Waghmare: It studies that jacketing is the common method to strengthen the building columns. The most common types of jackets are steel jacket, reinforced concrete jacket, fibre reinforced polymer composite jacket, jacket with high tension materials like carbon fibre, glass fibre etc. It increases concrete confinement, shear strength and flexural strength of columns. Jacketing consists of additional concrete with longitudinal and transverse reinforcement around the existing columns.

Fig.2-7- Construction Technique for Steel Jacketing

2.5 OVERVIEW OF WORK-

In seismic retrofitting of given building situated in particular seismic zone first of all static non-linear push over analysis is done from which we get the performance point of the building. From which we also get the hinge pattern in building and type of failure occurs. This will be helpful in deciding the method of retrofitting used. The method used should increase both ultimate strength and ductility.

3. CHAPTER

SEISMIC EVALUATION OF A G+9 STOREY BUILDING

3.1 GENERAL:

The considered building is situated in seismic zone III as per Indian standard IS:1893-2002(part 1). The given building is G+9 storey Reinforced concrete frame located in soft soil condition. Total height of the building is 30.75m. The plan of the building is symmetrical. The study of moment-curvature relations, Push over analysis and then conventional retrofitting method as shear wall, steel bracing and jacketing was done.

3.2 DESCRIPTION OF THE CONSIDERED BUILDING:

The given reinforced concrete building is made up of concrete of M30 grade and Steel of Fe-415 grade. The building is symmetrical in plan. It is considered as ordinary moment resisting frame (OMRF).

Table 3.1 specifications of G+9 building

Floor to floor height	3m
Grade of concrete	M-30
Grade of steel	TMT Fe-415
Seismic zone	III
Type of soil	Soft
Slab thickness	150 mm
Live load on floor	3 KN/m^2
Live load on roof	1.5 KN/m^2
Importance factor	1.5
Density of concrete	25 KN/m^3
Clear cover of beam	25mm
Clear cover of column	50mm

Type of frame	Ordinary moment resisting frame
Total height of building	30.75m

Load cases and combinations:

Dead load - The weight of the floor slabs, floor finishes, roof slabs, roof insulations, tiles, columns, beams was considered.

Dead load of floor finish= 1 KN/m^2

Dead load of roof treatment= 1.5 KN/m^2

Live load: These loads were considered from IS 875(Part 2):1987 and for all floors it was considered to be 3 KN/m^2 and for roof load it is taken as 1.5 KN/m^2.

Earthquake loads: These loads are to be carefully considered and majorly depend upon the importance of the building. The importance factor considered was 1.5 and seismic zone of three with a response reduction factor of 3 considering OMRF according to IS 1893(Part 1):2002.

The load combinations are taken such that all possible cases are taken, these are taken according to Indian standard IS 875:1987 and IS 1893:2002 to ensure safety of structure.

The following are some of load combinations:

1. 1.5(DL+LL)
2. 1.2(DL+LL+EQX)
3. 1.2(DL+LL- EQX)
4. 1.2(DL+LL+EQY)
5. 1.2(DL+LL-EQY)
6. 1.5(DL+EQX)
7. 1.5(DL-EQX)
8. 1.5(DL+EQY)
9. 1.5(DL-EQY)
10. .9DL+1.5EQX

11. .9DL-1.5EQX
12. .9DL+1.5EQY
13. .9DL-1.5EQY

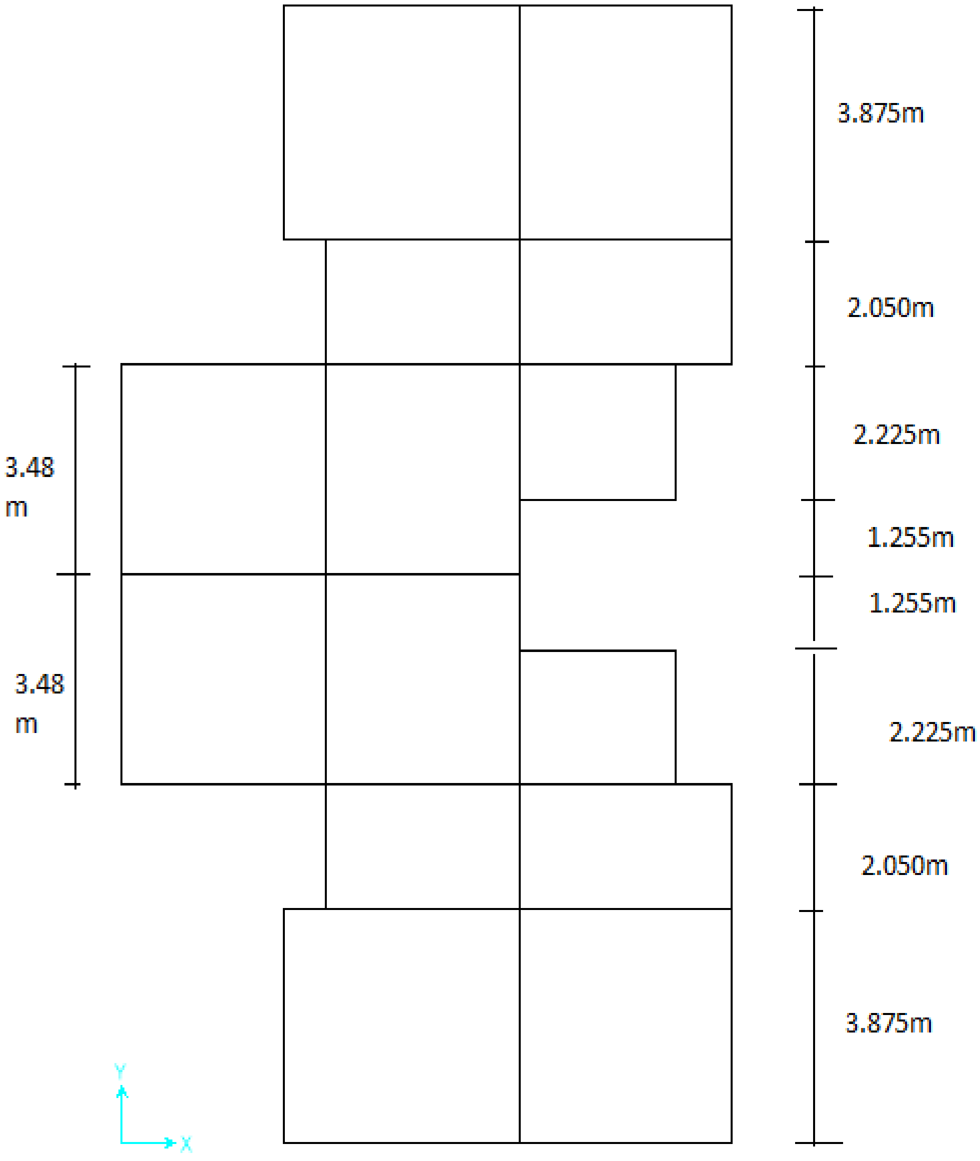


Fig.3-1: Plan of the building

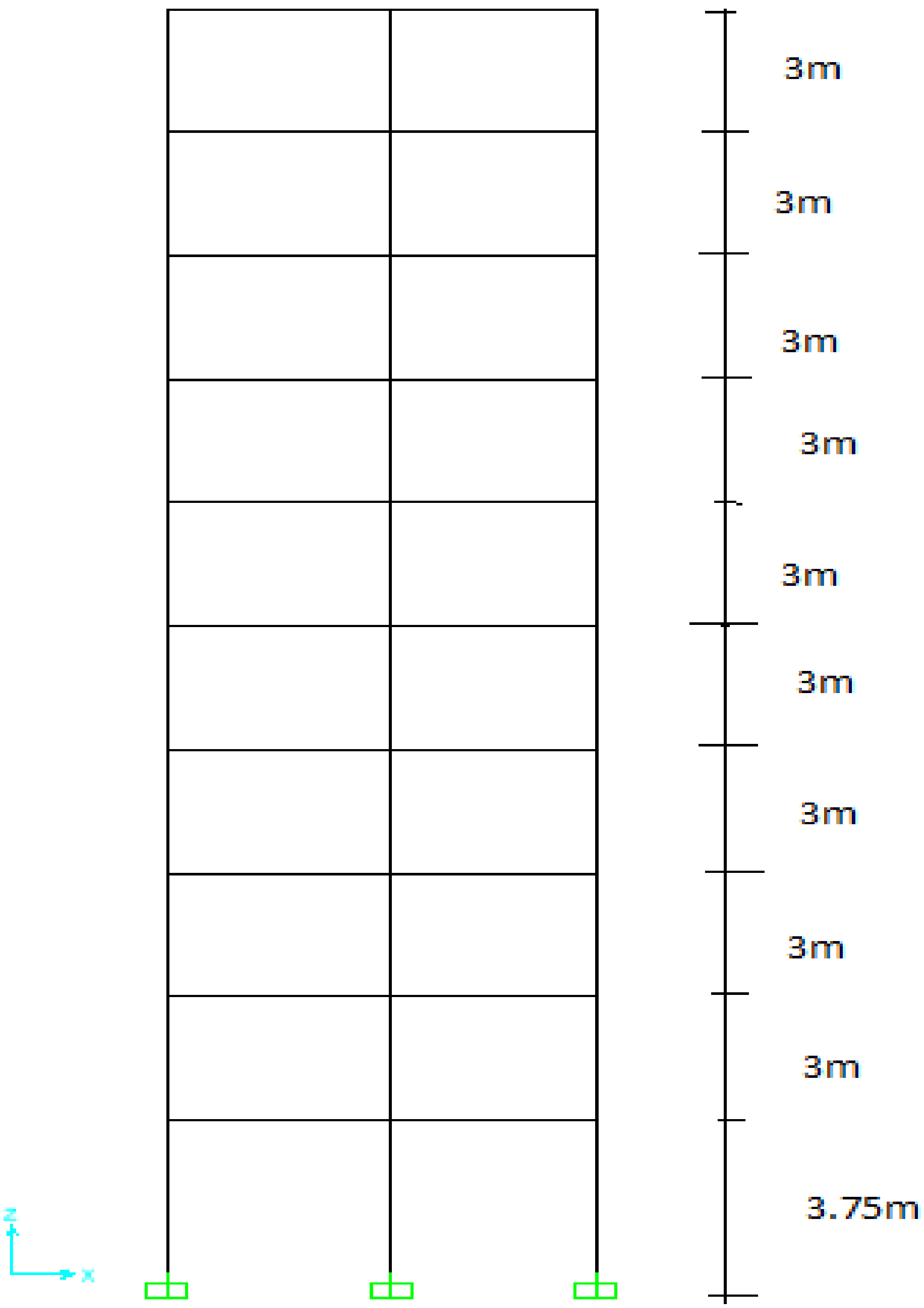


Fig.3-2- Elevation of building

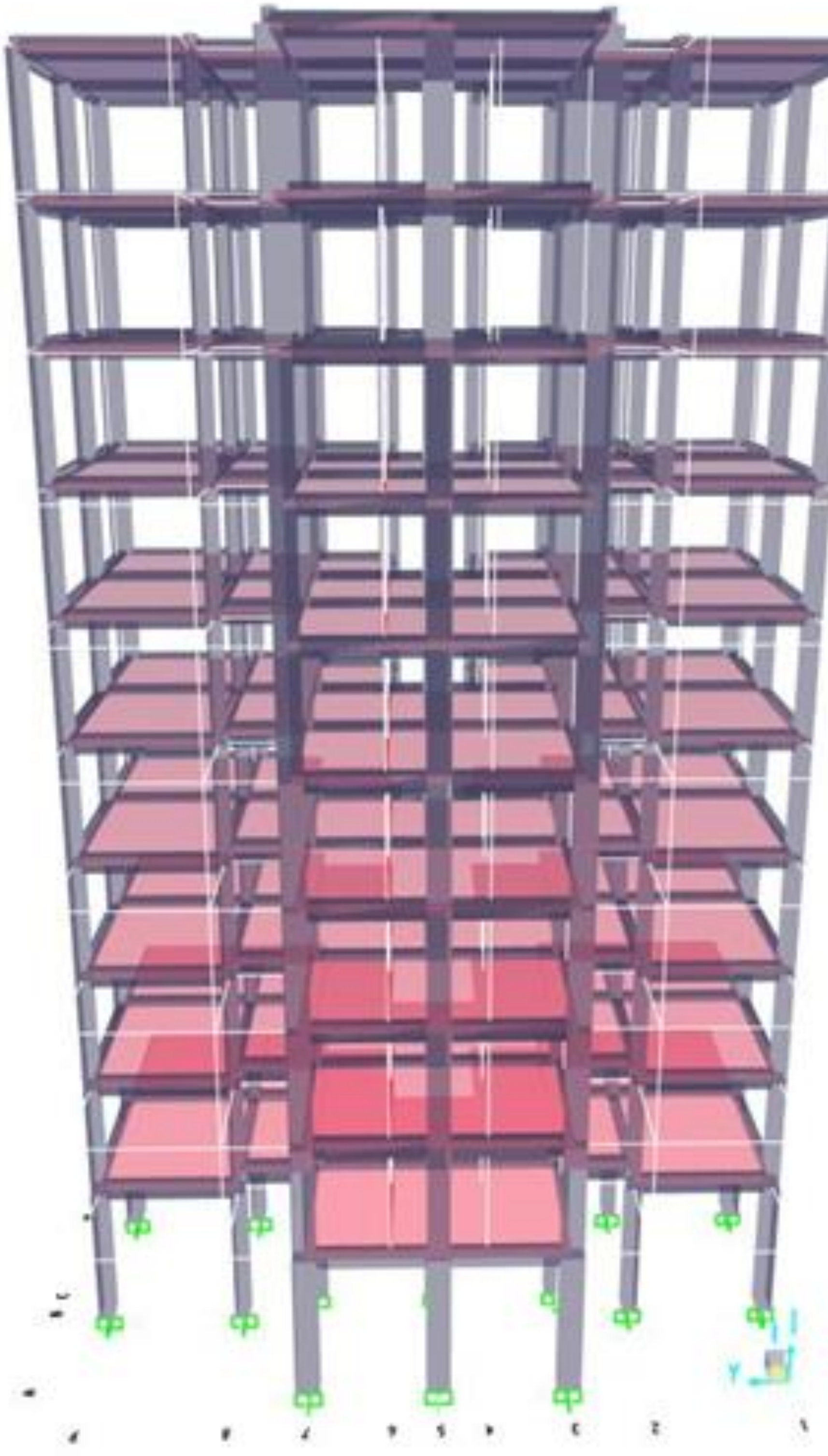


Fig.3-3- 3-D Model of building from SAP-2000

SCHEDULE OF COLUMNS-

Table 3-2: FOUNDATION TO 1ST FLOOR

SL. NO.	COLUMN NO.	OVERALL SIZE BXD (mm)	REINFORCEMNT	STRIPPUS REINF.
1.	C1,C2,C5,C6,C28,C31, C47,C50,C70,C71,C74, C75,C76,C95,C98	400 X 650	8-25 T 4-20T	8T@ 175 c/c
2.	C3,C4,C12,C16,C18,C33, C35,C39,C42,C44,C58,C60, C64,C72,C73,C82,C84,C87, C91,C93	400 X 650	8-20T 4-16T	8T@ 175 c/c
3.	C20,C21,C29,C45, C55,C56,C81,C97	400 X 650	8-16T 4-20T	8T@ 175 c/c
4.	C9,C15,C27,C49, C61,C67,C77,C99	450 X 750	16-25T	8T@ 200 c/c
5.	C10,C11,C13,C14,C30,C34, C43,C46,C62,C63,C46,C62, C63,C65,C66,C80,C83,C92, C96	400 X 650	12-25T	8T@ 175 c/c
6.	C7,C8,C17,C23,C24,C25, C32,C36,C37,C38,C40,C41,C51,C5 2,C53,C59,C68,C69,C85,C86,C88,C 89,C90,C94	400 X 650	12-16T	8T@ 175 c/c
7.	C19,C22,C26,C48,C54, C57,C78,C100	400 X 650	12-20T	8T@ 175 c/c
8.	C101,C102,C103,C104, C117,C118,C119,C120	300 X 500	12-12T	8T@ 175 c/c
9.	C105,C106,C107,C108, C110,C111,C112,C113,C114,C116	300 X 700	8-12T 8-16T	8T@ 175 c/c
10.	C109,C115	300 X 700	16-16T	8T@ 175 c/c

Table 3-3: 1ST FLOOR TO 4TH FLOOR:

SL. NO.	COLUMN NO.	OVERALL SIZE B X D (mm)	REINFORCEMNT	STRIPPUS REINF.
1.	C1,C2,C5,C6,C28,C31, C47,C50,C70,C71,C74, C75,C76,C95,C98	350 X 600	8-25T 4-20T	8T@ 175 c/c
2.	C3,C4,C12,C16,C18,C33, C35,C38,C39,C42,C44, C58,C60,C64,C72,C73,C82,C84,C 87,C91,C93	350 X 600	8-20T 4-16T	8T@ 175 c/c
3.	C20,C21,C29,C45,C55, C56,C81,C97	350 X 600	8-16T 4-20T	8T@ 175 c/c
4.	C9,C15,C27,C49,C61, C67,C77,C99	400 X 700	8-20T 8-25T	8T@ 200 c/c
5.	C10,C11,C13,C14,C30, C34,C43,C46,C62,C63, C65,C66,C80,C83,C92,C96	350 X 600	12-25T	8T@ 175 c/c
6.	C7,C8,C17,C23,C24,C25, C32,C36,C38,C40,C41,C51,C53,C 59,C68,C69,C85,C86, C88,C90,C94	350 X 600	12-16T	8T@ 175 c/c
7.	C19,C22,C26,C48,C54, C57,C78,C100	350 X 600	12-20T	8T@ 175 c/c
8.	C101,C102,C103,C104, C117,C118,C119,C120	300 X 500	12-12T	8T@ 175 c/c
9.	C105,C106,C107,C108, C110,C111,C112,C113,C114,C116	300 X 700	8-12T 8-16T	8T@ 150 c/c
10.	C109,C115	300 X 700	16-16T	8T@ 150 c/c

Table 3-4: 4^{TH} FLOOR TO 7^{TH} FLOOR

SL. NO.	COLUMN NO.	OVERALL SIZE B X D (mm)	REINFORCEMNT	STRIPPUS REINF.
1.	C1,C2,C5,C6,C10,C11,C13, C14,C28,C30,C31,C34,C43, C46,C47,C50,C62,C63,C65, C66,C70,C71,C74,C75,C76, C79,C80,C83,C92,C96,C95, C98	350 X 600	12-20T	8T@ 175 c/c
2.	C3,C4,C7,C8,C16,C17,C18, C19,C20,C21,C22,C26,C29, C33,C35,C36,C38,C40,C42, C44,C45,C48,C54,C55,C56, C57,C58,C59,C60,C68,C69, C72,C73,C78,C81,C82,C84, C86,C88,C90,C91,C93,C97, C100	350 X 600	8-16T 4-12T	8T@ 175 c/c
3.	C9,C15,C27,C49,C61, C67,C77,C99	400 X 700	16-16T	8T@ 200 c/c
4.	C12,C39,C64,C87	350 X 600	8-20T 4-16T	8T@ 175 c/c
5.	C23,C24,C25,C32,C37, C41,C51,C52,C53,C85, C89,C94	350 X 600	8-16T 4-12T	8T@ 175 c/c
6.	C101,C102,C103,C104, C117,C118,C119,C120	300 X 500	12-12T	8T@ 150 c/c
7.	C105,C106,C107,C108, C110,C111,C112,C113,C114, C116	300 X 700	8-12T 8-16T	8T@ 150 c/c
8.	C109,C115	300 X 700	16-16T	8T@ 150 c/c

Table 3-5: 7th FLOOR TO ROOF LEVEL

SL. NO.	COLUMN NO.	OVERALL SIZE B X D (mm)	REINFORCEMNT	STRIPPUS REINF.
1.	C1,C2,C5,C6,C10,C11,C13, C14,C28,C30,C31,C34,C43, C46,C47,C50,C62,C63,C65, C66,C70,C71,C74,C75,C76, C79,C80,C83,C92,C96,C95, C98	350 X 600	12-16T	8T@ 175 c/c
2.	C3,C4,C7,C8,C16,C17,C18, C19,C20,C21,C22,C26,C29, C33,C35,C36,C38,C40,C42, C44,C45,C48,C54,C55,C56, C57,C58,C59,C60,C68,C69, C72,C73,C78,C81,C82,C84, C86,C88,C90,C91,C93,C97, C100	350 X 600	8-16T 4-12T	8T@ 175 c/c
3.	C9,C15,C27,C49,C61, C67,C77,C99	400 X 700	8-12T 8-16T	8T@ 200 c/c
4.	C12,C39,C64,C87	350 X 600	8-20T 4-16T	8T@ 175 c/c
5.	C23,C24,C25,C32,C37, C41,C51,C52,C53,C85, C89,C94	350 X 600	8-16T 4-12T	8T@ 175 c/c
6.	C101,C102,C103,C104, C117,C118,C119,C120	300 X 500	12-12T	8T@ 150 c/c
7.	C105,C106,C107,C108, C110,C111,C112,C113,C114, C116	300 X 700	8-12T 8-16T	8T@ 150 c/c
8.	C109,C115	300 X 700	16-16T	8T@ 150 c/c

SCHEDULE OF BEAMS:

Table 3-6: Beams specifications

BEAM NO.	OVERALL SIZE B X D (mm)	LONGITUDINAL REINFORCEMENT			
		AT SUPPORT		AT SPAN	
		TOP	BOTTOM	TOP	BOTTOM
B1	300 X 450	3-25T	3-20T	3-25T	3-20T
B1a	300 X 575	3-25T	3-20T	3-25T	3-20T
B2	300 X 575	3-25T	2-20T+ 1-16T	3-25T	2-20T+ 1-16T
B3	300 X 450	2-16T	2-16T	2-16T	2-16T
B4	300 X 600	3-25T +2-20T	3-25T	3-25T	3-25T +2-16T
B5	300 X 575	3-20T+ 2-12T	2-20T	3-20T	2-20T
B6	300 X 450	3-20T+ 3-20T	3-20T	3-20T	3-20T
B7	300 X 450	3-20T+ 2-16T	2-20T	3-20T	2-20T
B8	300 X 450	2-16T+ 3-25T	3-20T	2-16T	3-20T
B9	300 X 575	3-16T+ 3-20T	3-16T	3-16T	3-16T
B10	300 X 650	3-20T+ 3-20T	3-20T	3-20T	3-20T
B11	300 X 575	3-20T+ 2-16T	2-16T	3-20T	2-16T
B12	300 X 450	3-20T+ 2-20T	3-20T	3-20T+ 2-16T	3-20T

3.3 Stress strain curve for the unconfined concrete:

To know the actual behaviour of unconfined concrete, stress-strain curve is needed. Bernoulli's strain compatibility method is used in Indian standard code to get the actual curve.

Table.3-7: The following values are plotted for unconfined concrete to get the stress-strain model.

Strain	0	.0001	.0002	.0003	.0004	.0005	.0006	.0007
Stress	0	4.35	6.42	7.6	8.87	10	10.93	11.8
Strain	.0008	.0009	.0010	.0011	.0012	.0013	.0014	.0015
Stress	12.58	13.4	14.1	14.85	15.45	16.1	16.75	17.3

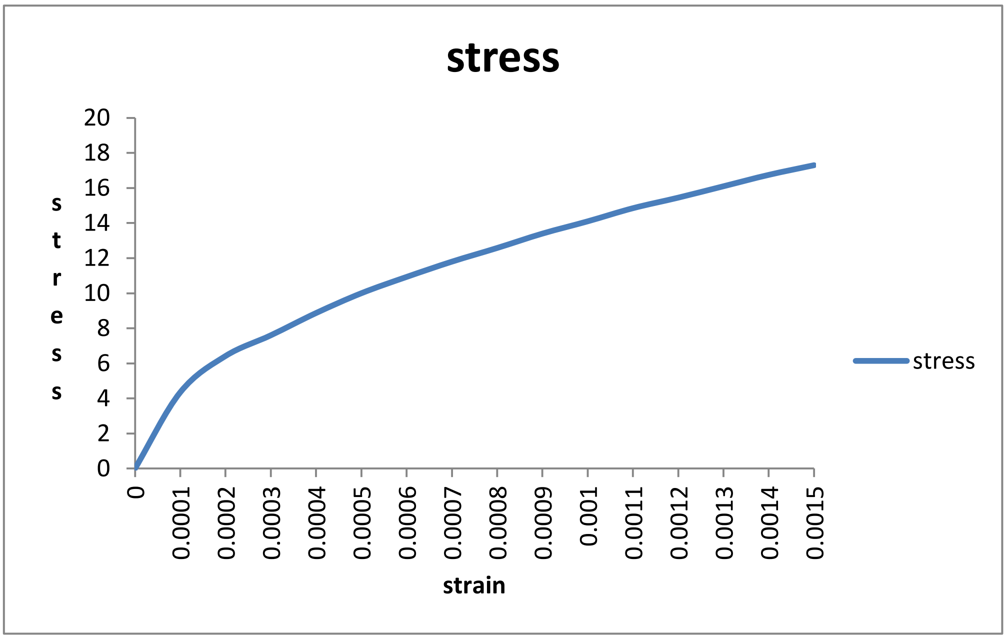


Fig.3-4- Stress-strain curve of Unconfined concrete

3.4 Stress strain curve of confined concrete model:

In earthquake resistant design ductility sufficient ductility is ensured at the places of potential hinge location so that columns will not collapse due to ground shaking. This is achieved by the application of sufficient transverse reinforcement. Experimental study shows that due to confinement there is considerable increase in strength and ductility of compressed concrete.

Mander's model is used to plot the stress-strain curve. Also this is applicable to both rectangular and circular shaped transverse reinforcement. According to this model central portion was most effective. The maximum confining transverse pressure is in core part because of arching action in that area.

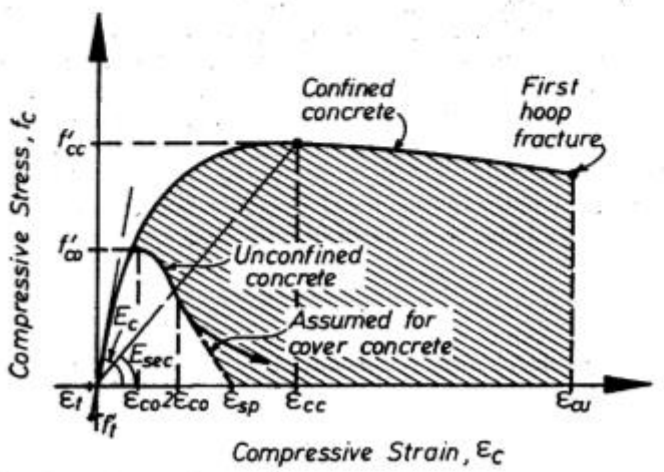


Fig.3-5: Stress-strain curve given by Mander's model

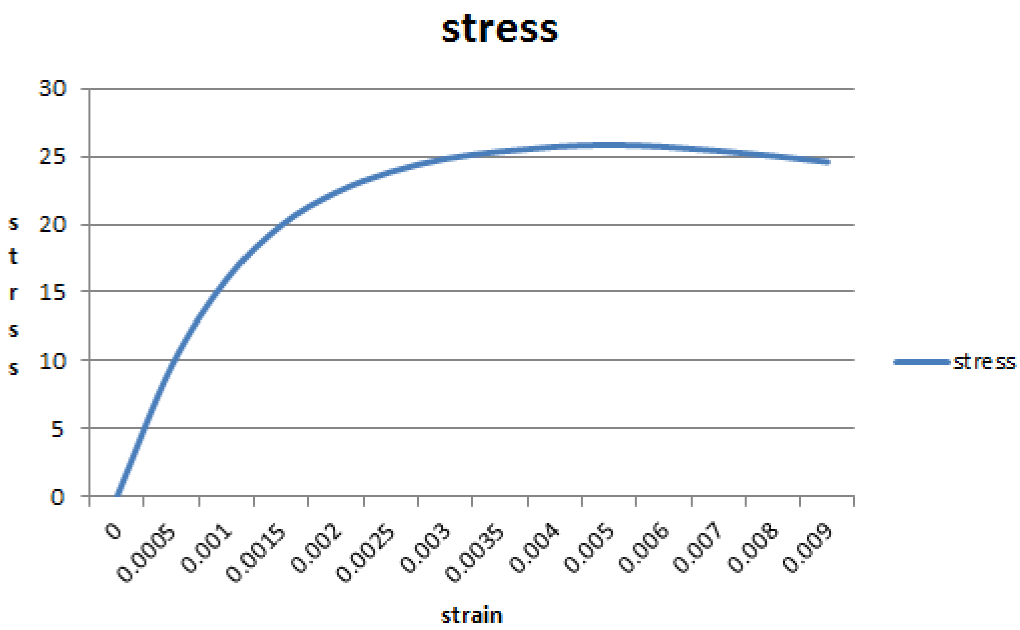


Fig.3-6:Stress Strain curve of Confined concrete

strain	0	.0005	.0010	.0015	.0020	.0025	.003
stress	0	9.61	15.92	19.93	22.34	23.84	24.82
strain	.0035	.004	.005	.006	.007	.008	.009
stress	25.35	25.7	25.85	25.71	25.41	25.03	24.59

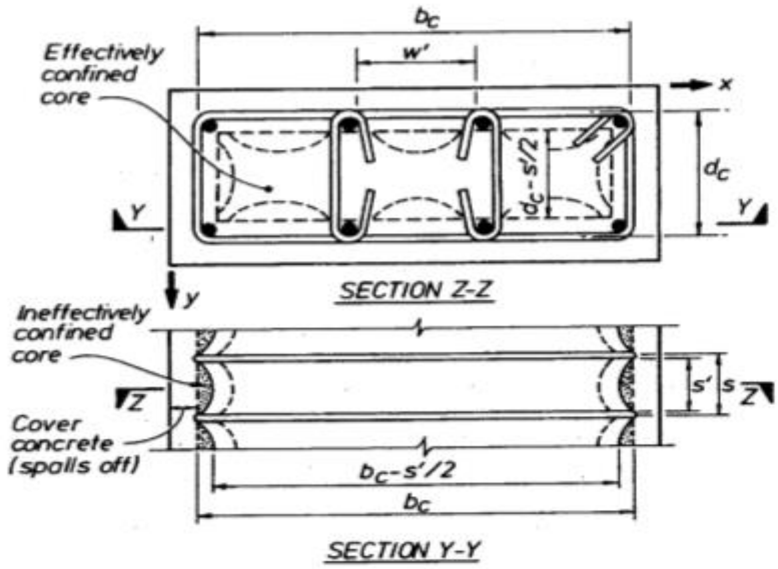


Fig3-7.- Effective confined concrete core for rectangular Hoop reinforcement

3.5 Stress strain curve for TMT of grade Fe-415:

For design purpose factor of safety of 1.15 is applied on stress. The design stress is given by-

$$f_s = \frac{f_i}{1.15}$$

The strain in steel reinforcement-

$$\varepsilon_s = \frac{f_s}{E_s} + residual\ strain$$

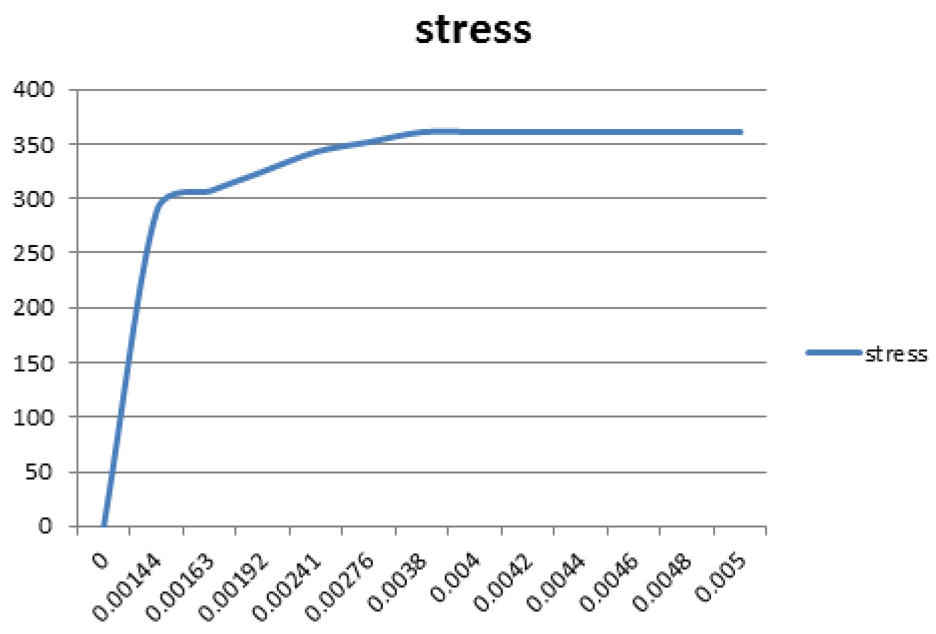


Fig.3-8: Stress strain curve of Steel

Strain X 10^{-3}	0	1.444	1.634	1.924	2.414	2.759	3.804
stress	0	288.7	306.74	324.78	342.83	351.85	360.8
Strain X 10^{-3}		4.0	4.2	4.4	4.6	4.8	5.0
stress		360.8	360.8	360.8	360.8	360.8	360.8

3.6 Moment curvature plot of beams:

Tension reinforcement ratio $\alpha = \frac{A_S}{b*d}$

Compression reinforcement ratio

$$\beta = \frac{A_S'}{b*d}$$

also $\beta_c = \frac{m_\rho'}{n_\rho}$

neutral axis coefficient

$$K=\left[\left((n\alpha^2)(1+\beta_c)^2\right)+\left(2n\alpha\left(1+\beta_c*\frac{d'}{d}\right)\right)\right]^{.5}-[n\alpha(1+\beta_c)]$$

Therefore neutral axis will be located at = K*d

Compressive strain in extreme fibre is given by-

a. yield value:

$$f_s' = \frac{E_s*\epsilon_y}{1-k}\left(k-\frac{d'}{d}\right)$$

Yield moment

$$M_y = A_s*f_y*d\left(1-\frac{k}{3}\right)+A_s'*f_s'*\left(\frac{kd}{3}-d'\right)$$

Yield curvature

$$\Phi_y = \frac{\varepsilon_y}{d(1-k)}$$

b. ultimate value:

Ultimate moment capacity

$$M = .85f'cbd\left(d-\frac{a}{2}\right)+A_s'f_s'(d-d')$$

Here $a = \frac{A_s*f_y}{.85*b*f_c'}$

Ultimate curvature

$\Phi_u = \frac{\varepsilon_u}{c}$, Here $c = \frac{a}{\beta_c}$

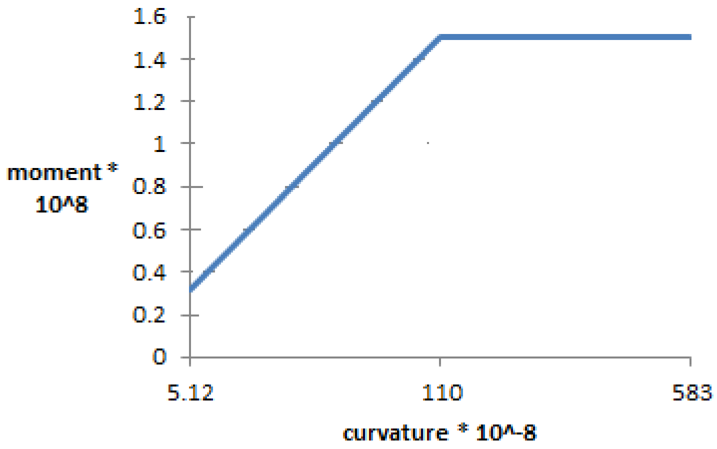


Fig.3-9-moment curvature of beams

3.7 Moment curvature of columns:

Procedure of finding the curve is same for column till yielding condition, after this for ultimate condition method of strain compatibility is used.

For ultimate condition:

a. strain compatibility (tension steel)-

$$\frac{a}{\beta_1 * d} = \frac{\varepsilon_{cu}}{\varepsilon_{cu} + \varepsilon_y}$$

Here $\beta_1 = .85$

$$\varepsilon_{cu} = .0035 \quad and \quad \varepsilon_y = .0038$$

$$f_s = E_s * \varepsilon_s$$

b. strain compatibility (compression steel)-

$$\frac{\varepsilon_s'}{\varepsilon_u} = \frac{c - d'}{c} \quad \& \quad c = \frac{a}{\beta_1}$$

Hence $f_s' = E_s * \varepsilon_s'$

3.8 CONSTRUCTION OF CAPACITY CURVE:

Pushover is a static non-linear analysis in which structure is subjected to downward gravity loading and displacement controlled lateral load which are increased continuously until failure occurs in structure. From push over curve we can determine the magnitude of the base shear which a structure can resist in earthquake prone region for a particular demand. In this base shear is plotted with respect to displacement ensuring that the maximum drift of the building will be 0.4% of the height of the building.

From the analysis by software SAP-2000 the push over curve was plotted. It is a non-linear curve which gives the value of load at which failure occurs in structure. This curve is then converted to equivalent bi-linear curve for simplification. From pushover curve we get the performance point of the structure. This is helpful in determining the technique of retrofitting to be used for make the structure safe during an earthquake.

From the software we have got the pushover curve for the entire structure. Hence it is valid as multi degree of freedom system but to simplify the analysis according to Indian standard code this is converted for single degree of freedom system.

Hence the graph was constructed between base shear and spectral displacement by Indian standard code IS 456:2000 and IS 13920:1993.

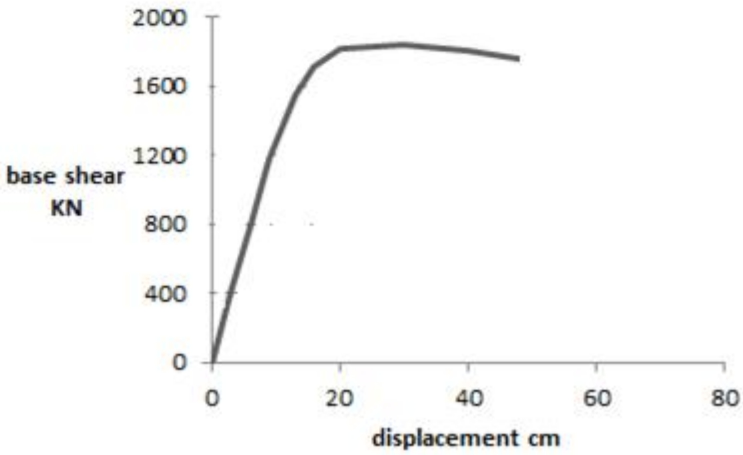


Fig.3-10- pushover curve as IS 456:2000

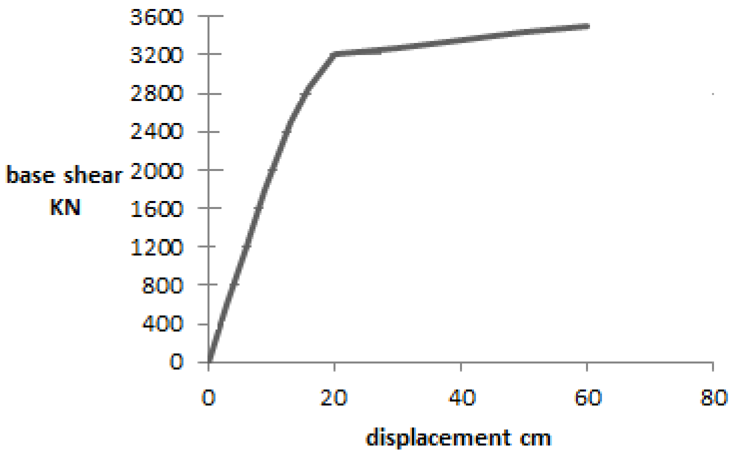


Fig.3-11- pushover curve as IS 13920:1993

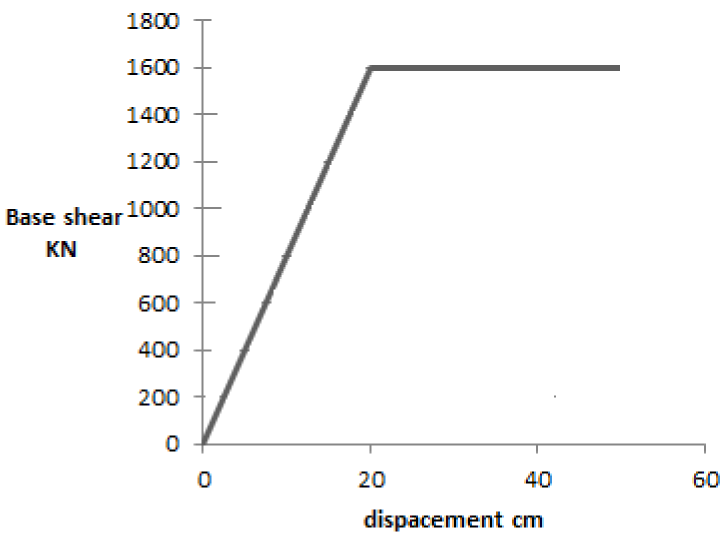


Fig.3-12- bilinear push over curve as IS 456:2000

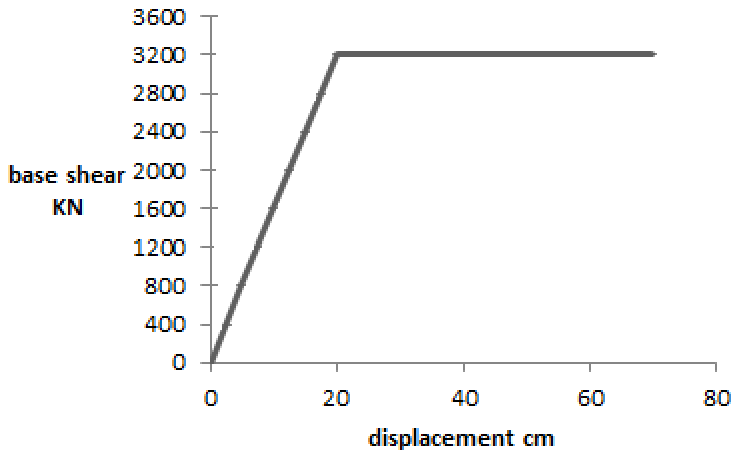


Fig.3-13- bilinear push over curve IS13920:1993

From the above plot it can be easily seen that by the application of ductile detailing as per IS 13920:1993 capacity of building is enhanced. Hence this should be applied in earthquake prone region to increase the performance of the building.

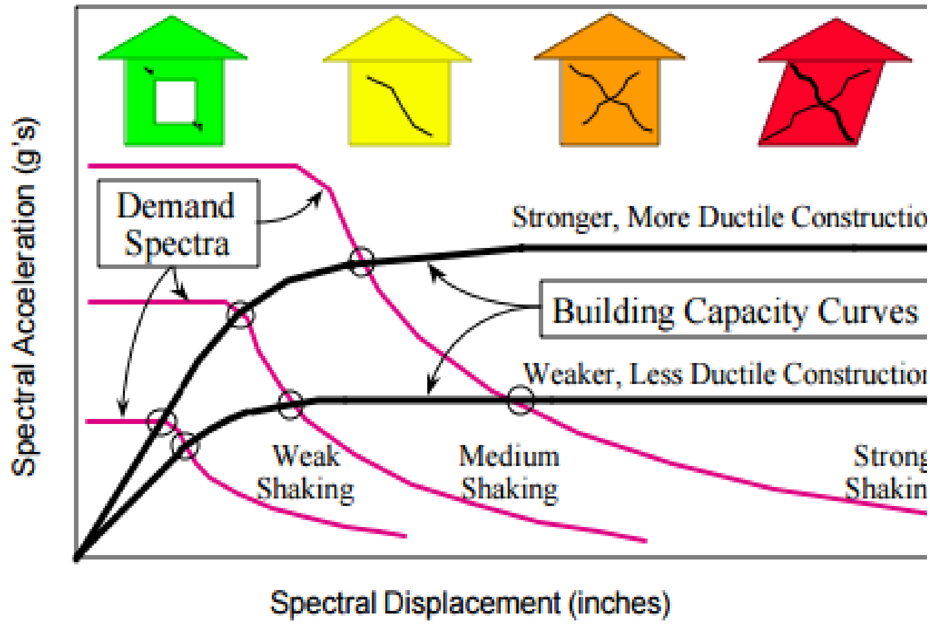


Fig.3-14:Performance point evaluation

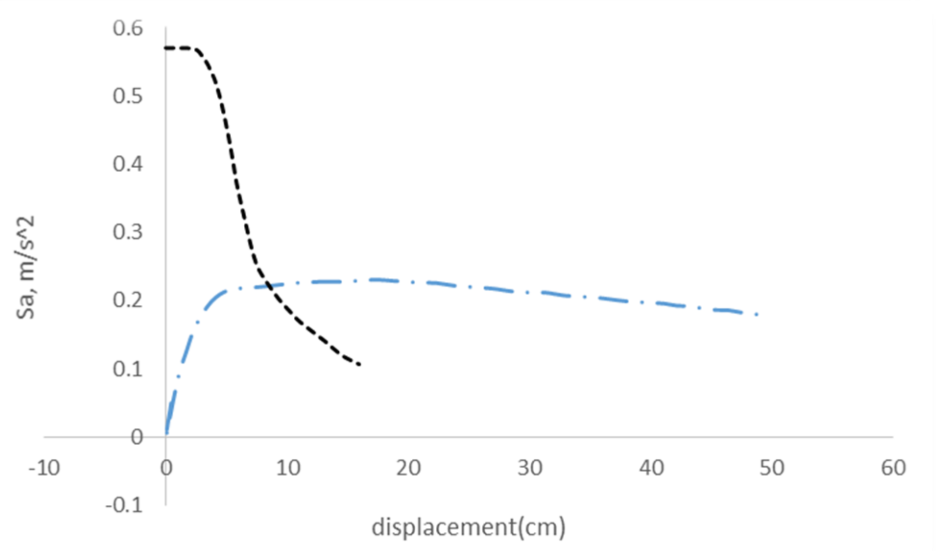


Fig.3-15- performance point curve as per IS 456:2000

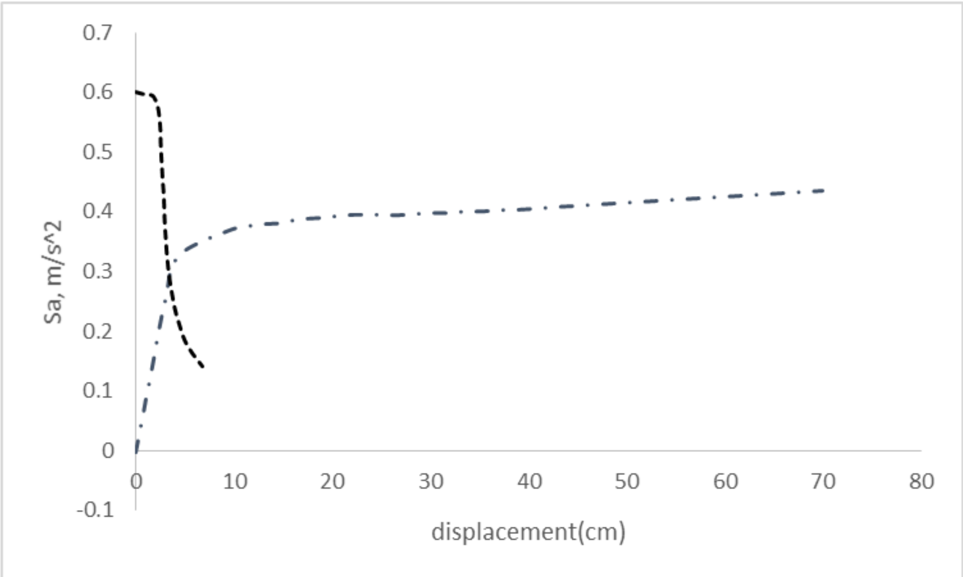


Fig.3-16-Performance point curve as per IS 13920:1993

3.9 Fragility curves:

These curves are the most important tool to determine the seismic risk of a particular area of the building stock which is useful in determining the damage state and to predict the human and economic losses after the earthquake event. These curves are mostly used for high rise structures. Building fragility curves are plotted as lognormal function that describes the probability of exceeding of particular damage state with respect to spectral response i.e. spectral displacement or spectral acceleration.

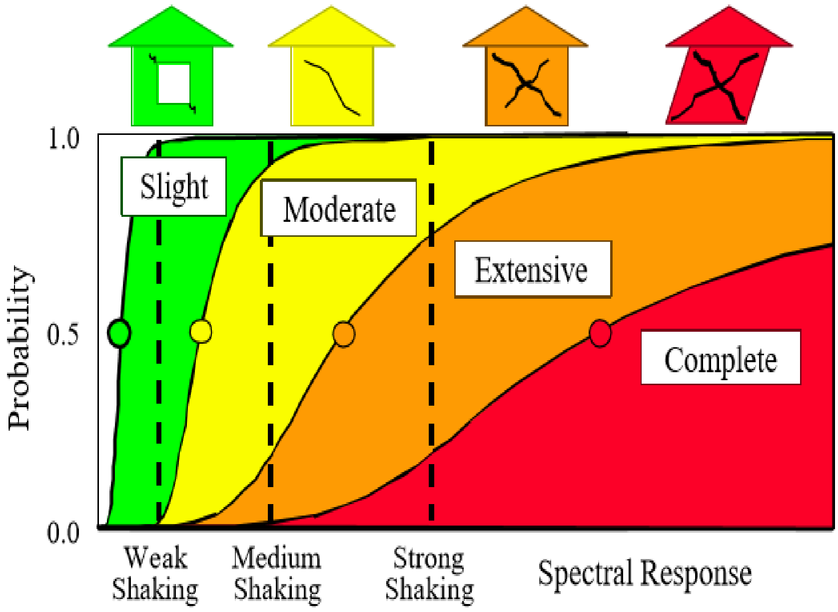


Fig.3-17: Fragility curves for slight, moderate, extensive and complete damage

Each fragility curve is defined by a median value of demand parameter that also depends upon variability associated with that parameter. Hence fragility curve depends upon two parameters – spectral displacement and the median value which again depend upon the type of building and ground motion parameter. We define the probability of being exceeding the damage state for that level of ground shaking or a particular damage state, ds, for a spectral displacement, Sd, defined by function:

$$P\left[{}^{d_s}/_{S_d}\right] = \emptyset\left[\frac{1}{\beta_{ds}} ln \frac{S_d}{S_{d,sds}}\right]$$

Where

$S_{d,sds} =$ Median value of spectral displacement at which the building reaches the threshold of the damage state, ds

β_{ds} = Standard deviation of the natural logarithm of spectral displacement of damage state, ds and

$\emptyset$ = Standard normal cumulative distributive function

For calculation purposes the value of β_{ds} for different damage state are taken as follows:

Table.3-10 : standard deviation of different damage states

Damage state	$\boldsymbol{\beta_{ds}}$
Slight	0.65
Moderate	0.75
Extensive	0.85
Complete collapse	0.95

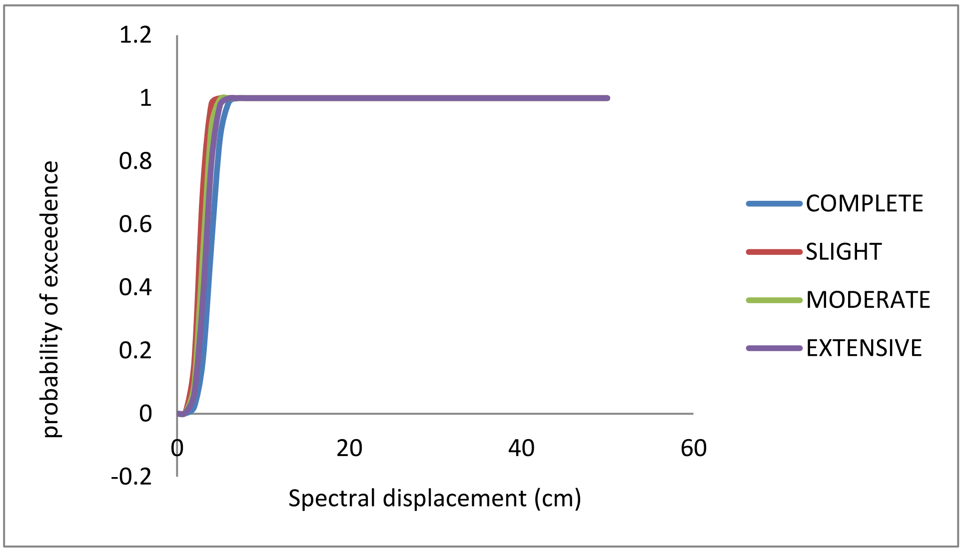


Fig.3-18: Fragility curve as per IS 456:2000

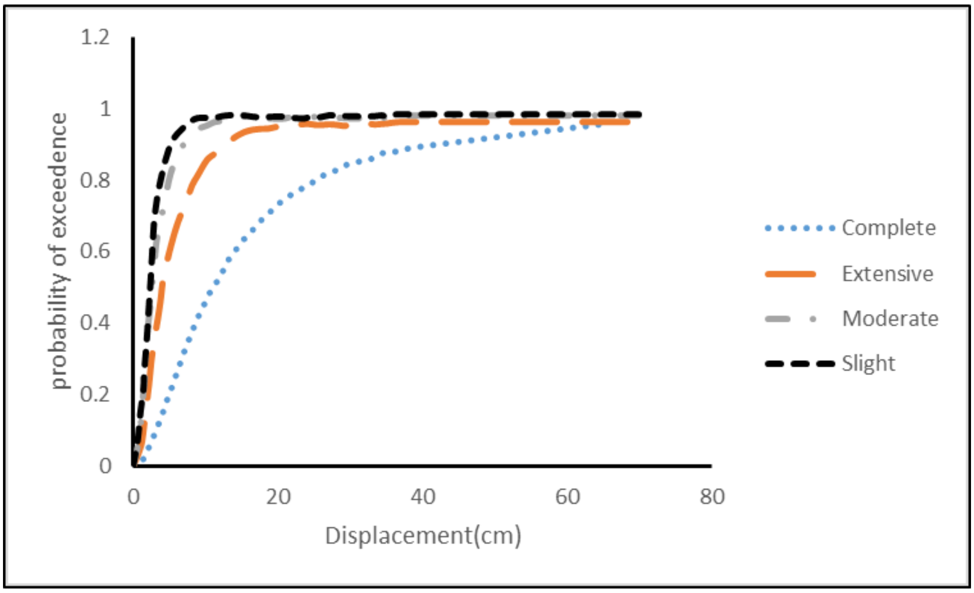


Fig.3-19: Fragility curve as per IS 13920 :1993

4. CHAPTER

SEISMIC RETROFITTING BY CONVENTIONAL METHODS

In earthquake prone region it is essential to retrofit the seismic deficit structures to improve the performance of the building at the time of earthquake incident. There are two techniques named as global and local retrofitting. In global method of retrofitting whole structural members are modified and performance is improved while in local retrofitting only few members which are deficient are improved. The method to be used depends upon the type of building, soil type and failure pattern. The different curves for the building are to be analysed and then most economical and suitable method is selected to retrofit it.

Most widely used methods in normal building are shear wall addition and steel bracing to enhance seismic performance of the building. Their use also proves to be economical.

4.1 Shear wall addition:

By the addition of shear wall lateral strength of building increases. Shear wall elements should be placed at the exterior of the building. It is desirable to place the shear wall adjacent to the beam between columns to minimize slab demolition. The shear wall method proves to be most economical method among all. Due to ability of taking lateral load coming on them hence they are very effective in controlling the drift and lateral deflections. Shear wall increases strength hence capacity of members like slabs, floor, columns etc. increases while increase in ductility improve the energy absorption capacity of the structure.

4.1.1 Location of shear wall:

To get the maximum advantage Of addition of shear wall they should be placed symmetrically at the exterior of the building. It should make box like structure and length of elements should be almost equal. To hold shear wall effectively of different storey hold down devices are used.

4.1.2 Forces on shear wall:

There are two types of forces acting on the shear wall- uplift force and shear force. Uplift forces tend to one end up and other end down. Shear forces occurs due to horizontal forces that are transferred from ground to structure. Amount of force acting on them also depends on length and width of the member.

4.2 Steel bracing:

By the addition of steel bracing strength and ductility of building increases. It is normally used where large openings are required. Due to less weight of steel members in this system addition of weight to existing structure is less. Steel bracing member acts as axial member hence take the axial load effectively. By the use of steel bracing advantage of natural light also can be taken. Also less work has to done as foundation needs not to be modified. The effective slenderness ratio of steel braces should be kept as small as possible to make the brace effective in both compression and tension. Hence l/r ratio should be 60 to 80 or lower.

X–shaped pattern is commonly used because of simplicity. In K- pattern main disadvantage is that extra shear forces will induces which is not desirable. Sometime local reinforcement of the columns may also need to account the increased load acting in them. Calculation of dead load is also required to calculate the number of bays of steel bracing to be provided in structure. For light and simple building care should be taken that there is no tension in braces. There may be some inconvenience in steel bracing due to lack of information about the seismic behaviour of bracing. Failure of one section can critically affect the performance of the building.

4.3 MODELLING OF SHEAR WALL AND STEEL BRACING:

Shear wall modelling has been done by the software SAP: 2000. While steel bracing are provided as X shaped due to efficient section. They should be provided such that they do not cause disturbance to other member and provided such that there is no torsion comes in the members.

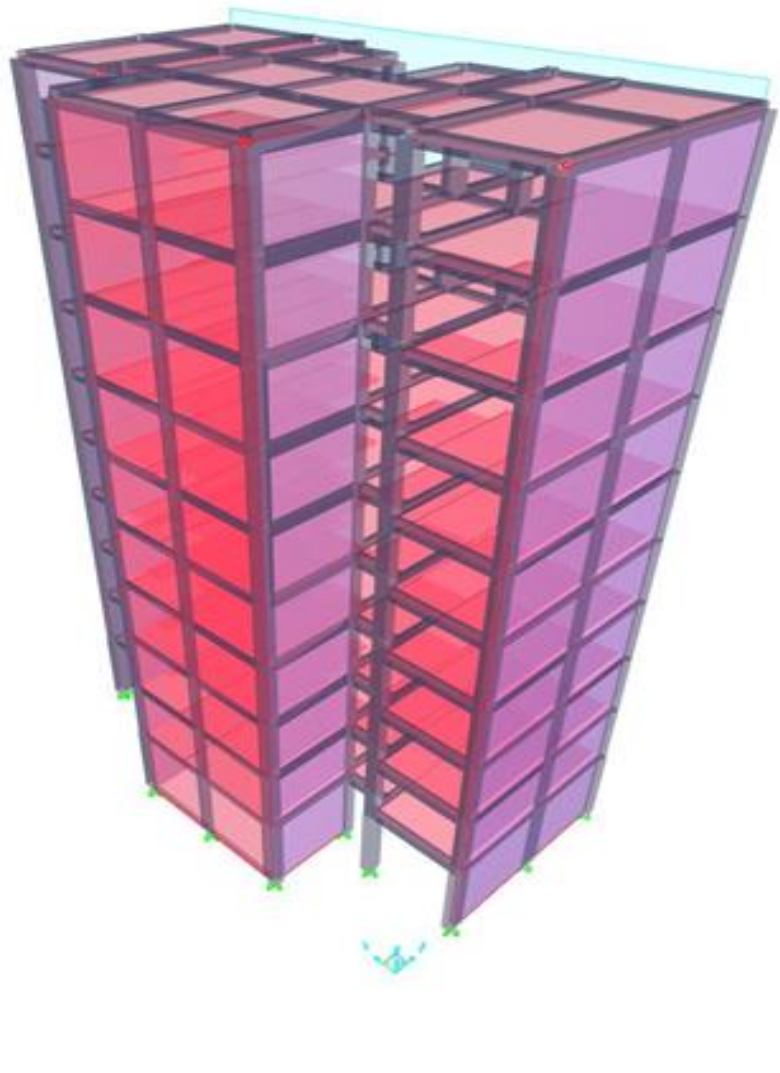


Fig.4-1-Model of building with shear wall addition

Fig.4-2-Model of building with steel bracing addition

5. CHAPTER

ANALYSIS AND RESULTS

5.1 EFFECT OF SHEAR WALL AND STEEL BRACING ADDITION:

The analysis was carried out after the application of shear wall at different location and results was studied. It was shown that capacity of the structure to take the seismic load increases 4 to 5 times then original normal structure without any shear wall.

Here graphs are shown which are the pushover curves of the structure before and after the addition of shear wall which clearly reflects the effect on load carrying capacity of the building.

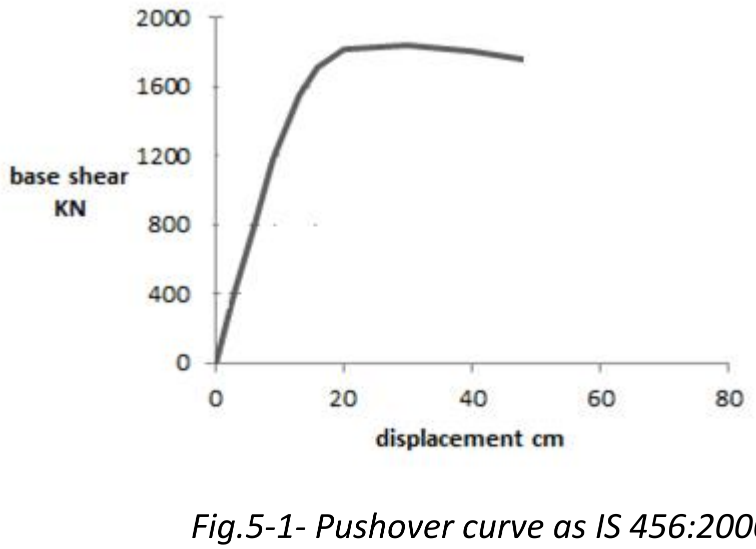


Fig.5-1- Pushover curve as IS 456:2000

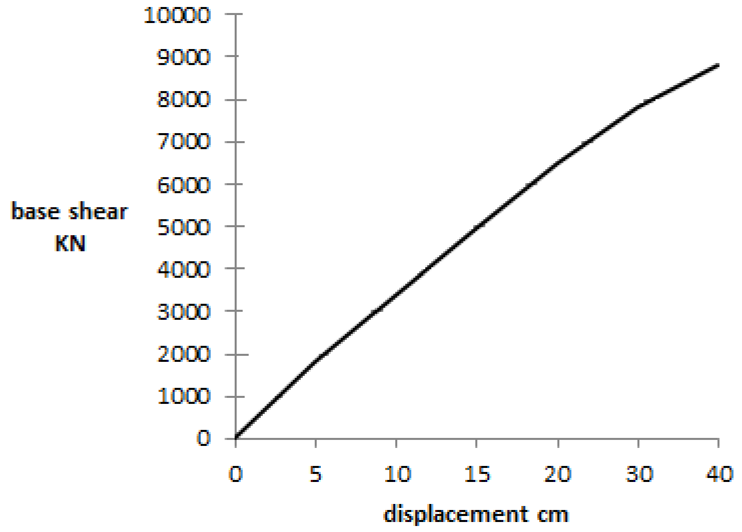


Fig5-2.-Pushover curve after the addition of shear wall as IS 456:2000

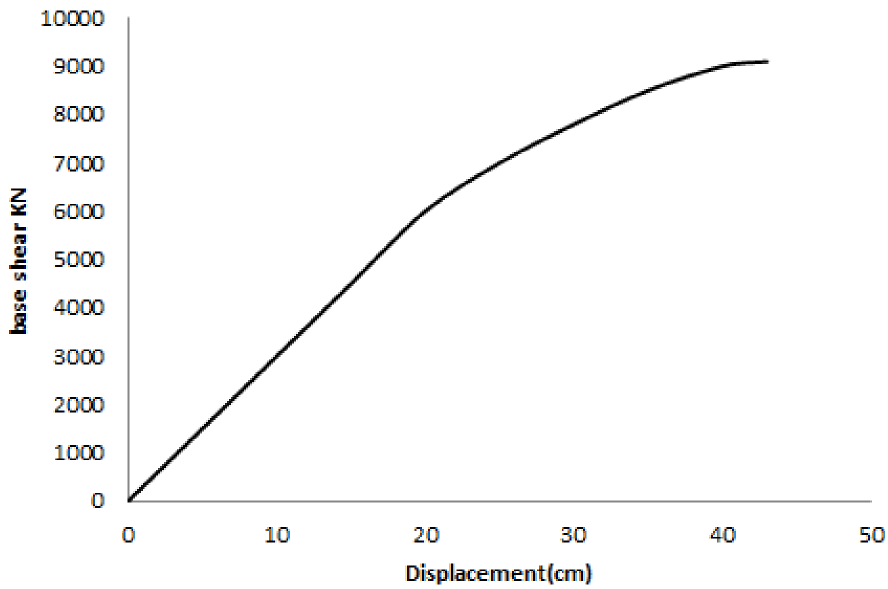


Fig.5-3-Pushover curve after the addition of steel bracing as IS 456:2000

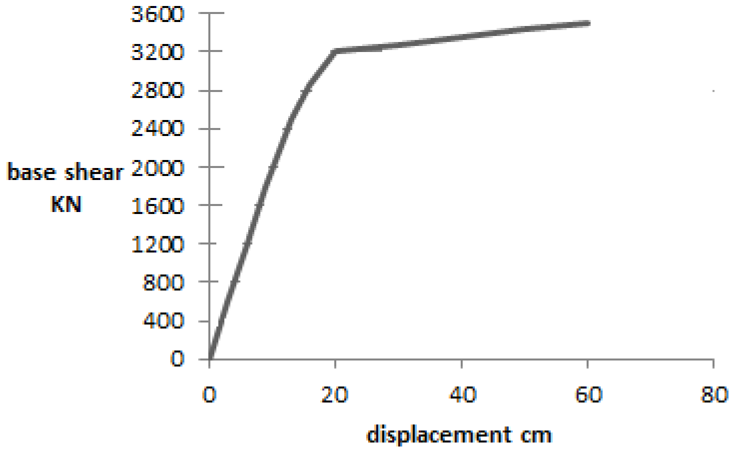


Fig.5-4-Pushover curve as IS 13920:1993

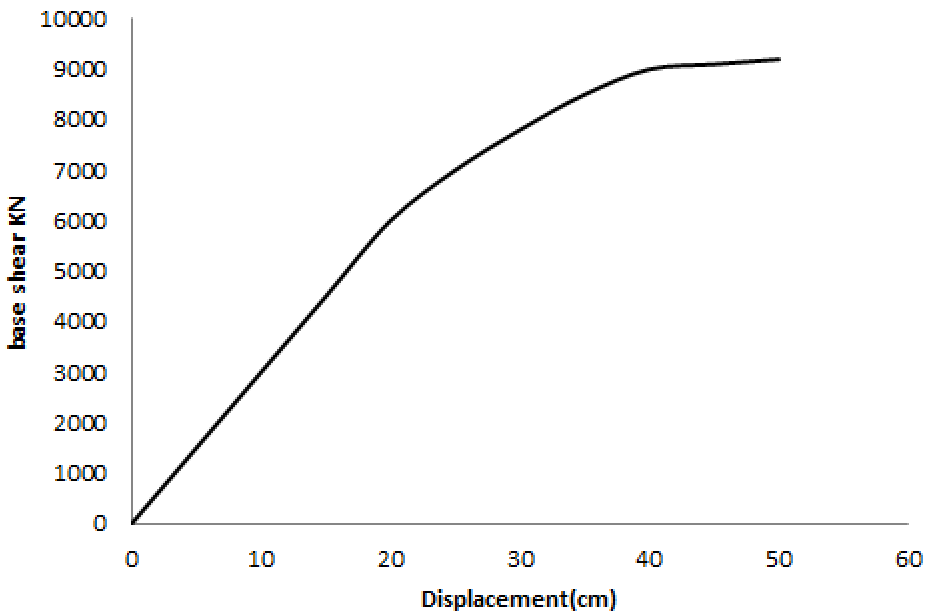


Fig-5-5:Pushover curve after addition of shear wall as IS 13920:1993

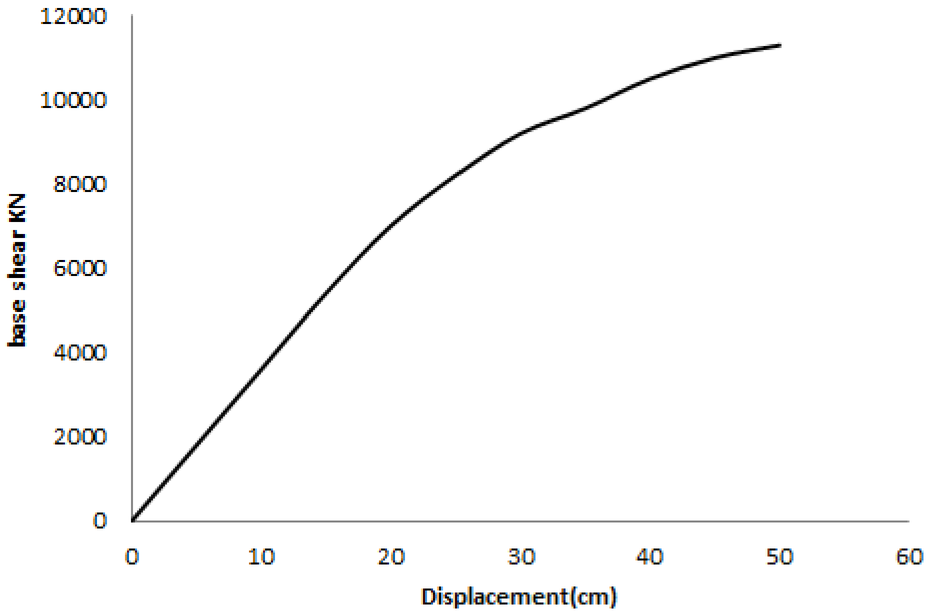


Fig.5-6-Pushover curve after addition of steel bracing as IS 13920:1993

From the above graphs it is concluded that base shear capacity of the structure is enhanced by the application of different retrofitting schemes.

5.2 Fragility curves after the retrofitting:

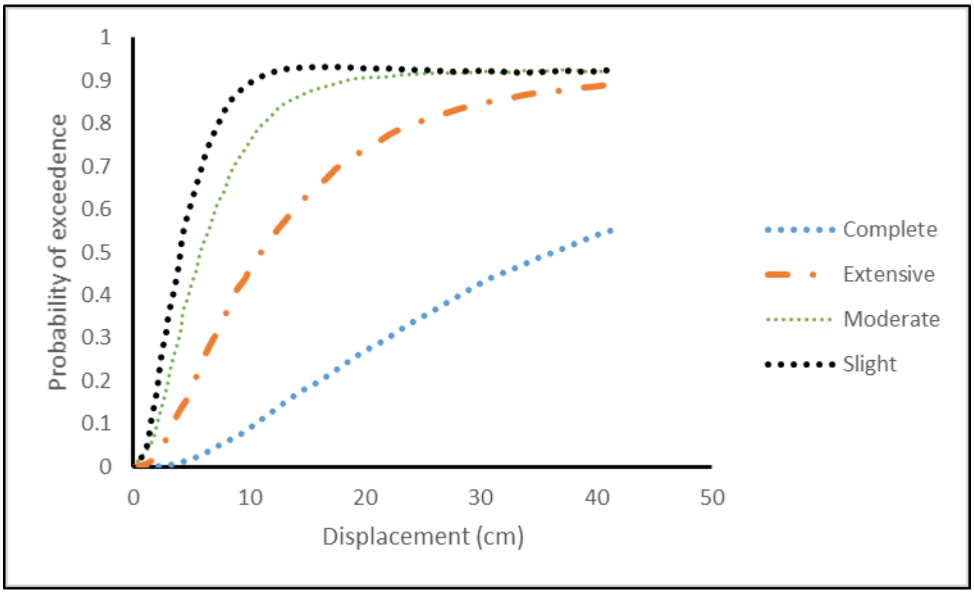


Fig.5-7: Fragility curve after the addition of shear wall as per IS 456:2000

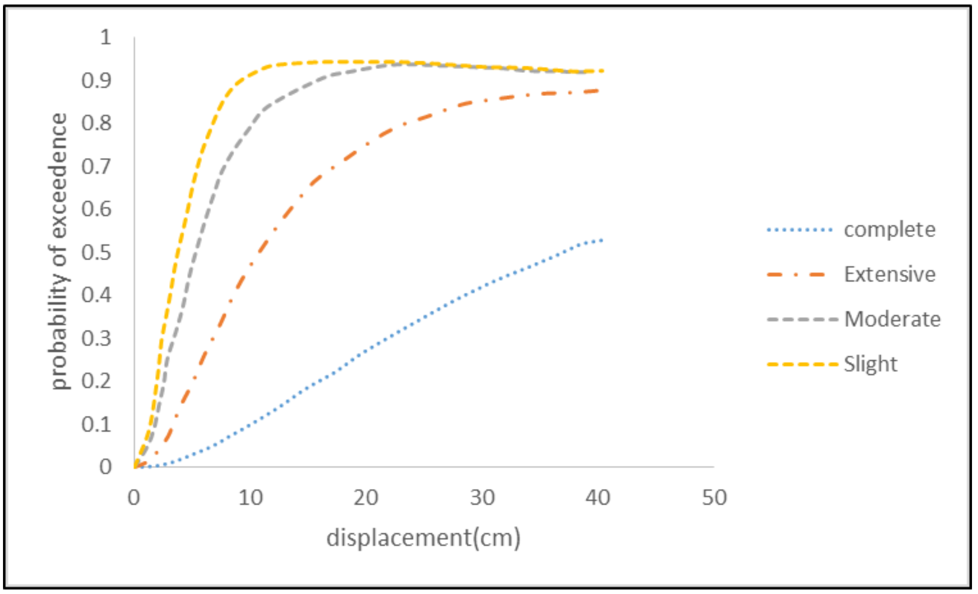


Fig.5-8: Fragility curve after the addition of steel bracing as per IS 456:2000

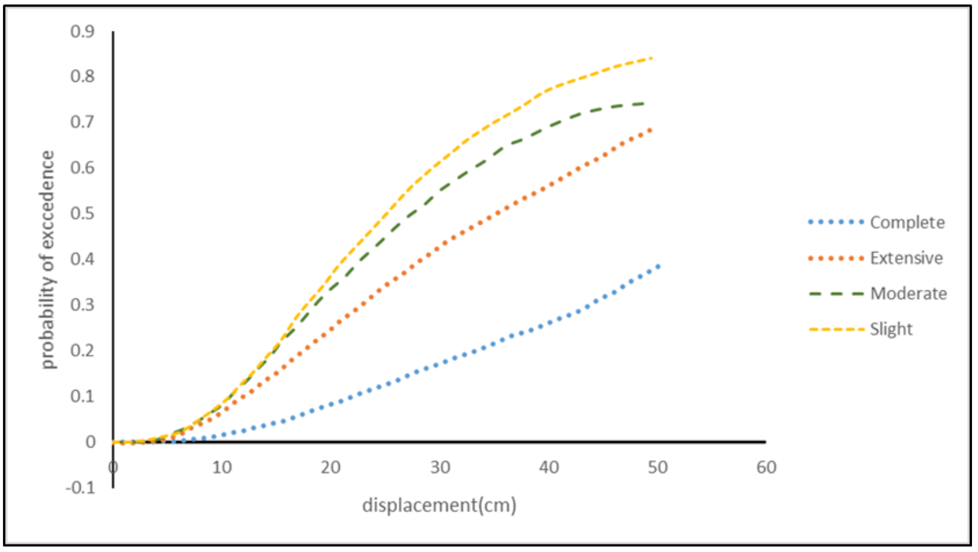


Fig.5-9: Fragility curve after the addition of shear wall as per IS 13920:1993

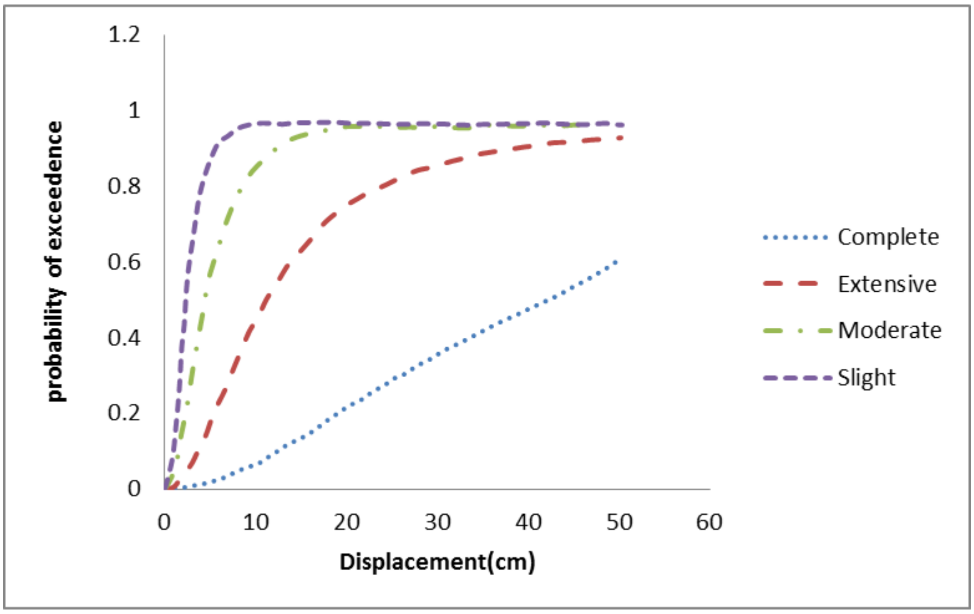


Fig.5-10: Fragility curve after the addition of steel bracing as per IS 13920:1993

From the above figures it is concluded that probability of exceedence of particular damage state is reduced after the addition of new components. Hence after the retrofitting probability of failure is reduced at lower displacements.

6. CHAPTER

CONCLUSIONS

From all the analysis which has done on the structure is can be concluded that design of a building must be in accordance with ductility detailing as per IS 13920:1993 in the earthquake prone region. Because due to this ductility and strength of structure is enhanced this increases the energy absorption capacity of the structure. As old structures are constructed according to non-ductile detailing there will be severe loss if any earthquake event occurs in that area. So all these structures must be retrofitted to enhance the performance of the structure in case of seismic loading. As retrofitting proves to be most economical solution to make the structure safe. The method of retrofitting to be used depends upon type of structure and other specifications like type of soil, seismic zone etc. It needs a complete analysis which will better give the effect due to addition of different elements to improve seismic capacity.

The following conclusion are drawn from analysis:

1. The ductile detailing is more efficient than as designed by IS 456:2000 in case of seismic loading.
2. The base shear capacity is enhanced due to ductility of the structure as compared to ordinary RC framed structure.
3. Conventional retrofitting technique provide the economic solution for better performance of structure however this additional construction can also be constructed during the construction.
4. Push over curve shows that addition of shear wall and steel bracing results in increased lateral load carrying capacity.

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