[Parmar *, 4(12): December, 2017]
ISSN 2349-6193
Impact Factor: 2.805

IJESMR

International Journal OF Engineering Sciences &Management Research

DETECTION OF WEEK ZONE IN EXISTING RCC STRUCTURE SUBJECTED LOAD IN THE FORM OF AN ADDITIONAL STOREY AND CONSIDERATION OF SEISMIC FORCES

Siddharth Parmar[*1] **& Vinay Dhakad**[2]
[*1]PG Student, Civil Engineering Department, BMCT, Indore
[2]Asst professor, Civil Engineering Department, BMCT, Indore

Keywords: *Concrete; Steel; Jacketing; Strengthening.*

ABSTRACT

All over the world there are plenty of buildings which are vulnerable to damage or damaged by earthquake. There are many buildings which are either designed without consideration of seismic forces or need to be designed with consideration of revised code of earthquake. There are many buildings with the passage of time they realize that their demands have increased and there is a need for the addition/alteration of the current structure. This demand can be fulfilled by constructing a new storey or modification of structure. However, provision for additional load due to the new construction over existing structure was not made in the structural design of the old structure. All such buildings are needed to be retrofitted for additional forces developed due to consideration of new storey and earthquake loads. It represents an opportunity to improve the overall performance of an existing building. The present study investigates the structural performance of G+3 Commercial building under the additional load in the form of new storey and seismic forces. The structure is analyzed for two load cases. In first case structure is analyzed for only gravity forces and no seismic force is considered in this analysis while in second case structure is analyzed with consideration of seismic forces along with gravity forces of G+4 building. The analysis is performed by using structural analysis software i.e. STAAD Pro. The analysis results of structure for gravity load cases STR-GR and seismic load cases STR-EQ are compared to evaluate the effect of seismic forces on the structure. The results point out that the significant increase is found in the shear force and bending moment in most of the beams. This increase of forces is more considerable in plinth beams compared to roof beams. Similarly seismic forces causes increase in bending moment mainly in the columns. The weak and deficient members are identified and strengthened for the additional forces and moments. The strengthening of beams is done by connecting steel plates in the beams with shear connectors and the columns are strengthened by steel angles section and battens.

INTRODUCTION

Retrofitting of building is the technique of modifying something in structure after building was built. Retrofitting of building includes maintenance, Rehabilitation and strengthening of building. It is improving the performance of the building. Retrofitting are needed for building whose serviceability or strength cannot meet the requirement of structural codes or buildings which are designed for earthquake forces but later on due to change in earthquake code or regulation, irregular maintenance, aging of materials or have additional stories built.

Evaluating of the retrofitting for the structure is an important, interesting, and challenging aspect of civil engineering. It is a dynamic process However; they are a major concern when those week zones would have an effect on the safety of people and property. Concerns with retrofitting have driven some of the most important advances in our understanding of the complex behavior of structure. Extensive engineering and research studies performed over the past 50 years provide a sound set of mechanical principles with which to attack practical problems of strengthen of building.

Modern software such as STAAD-Pro is making it possible to handle ever-increasing Complexity in the analysis. It is now possible to deal with complex stratigraphy, earthquake pressure conditions, additional story loads and wind load. While modern software is making it possible to analyze ever-increasingly complex problems, the same tools are also making it possible to better understand the performance of structure. Computer-assisted graphical viewing of data used in the calculations makes it possible to look beyond the factor of safety.

ISSN 2349-6193
Impact Factor: 2.805

Literature Review

Vulnerability of structure related issues in natural as well as artificial is common challenges to both Researchers and professionals. In construction areas, instability may result due to increase in wind load, earth quick, changes in geometry, external forces, loss of strength in materials and change in loading conditions.

The engineering solutions to vulnerability problems require good understanding of analytical methods, investigative tools and strengthening measures. A quantitative assessment of the safety is important when decisions are made. The primary aim of structure analyses is to contribute to the safe and economic design. Design of building should be done in such a way that they fulfils the guidelines given by IS codes and should be stable in worst condition.

Several studies have been carried out to understand the influence of additional forces on the existing structure. These forces may be due to consideration of seismic force, wind load or due to any alteration in the building. Various experimental and analytical investigations have been carried out to understand the behavior of the retrofitted structure and also to know the amount of retrofitting requires.

Gomes A. and Julio A. J. (1997) studied on strengthening of RCC beams by jointly of steel plates according to him, the members which are good quality of concrete and very less reinforcement can be retrofit with providing external reinforcement. High strength steel bolts are used at the anchorage zone, near the end of plate it is convenient .The efficiency is mostly depend on the connection behavior. Plates enhance inertia and the stiffness. Surface preparation is very essential for concrete and steel bonding. Pneumatic needle hammer used for surface preparation to increase the roughness. Extra roughness is also not suitable because it leads to increase thickness of resin which decreases the bond capacity. Additional steel can be connected to beams or columns by inject epoxy resin. If provided resins only for the connections a steel plate should be of 5mm thick and 200mm wide is used. Increases the thickness of resin leads to lower capacity of bond. At the time of retrofitting the live load must be removed.

Sakino K. and Yuping S. Y. (2000) studied on Steel jacketing of column for upgrading strength and ductility, On the basis of experiment results author and other Japanese researcher's gave some design formulae's for square reinforced concrete columns retrofitted by the steel jacket. Using the ultimate strain, ε cm and the stress block parameters, α and β, ultimate bending strength of the retrofitted RCC column sections can be precisely evaluated. The formulae to find out values of the ε cm, α and β have been calculated on the basis of the proposed stress-strain curve of concrete confined by the steel jackets. By the Arakawa's equation shear strength of the retrofitted RCC columns can be evaluated in a slightly conservative manner, on the basis of experiment results he gave an empirical equation and it was widely used for the practical design of the ordinary RCC column in Japan. Evaluating the limit rotation angle, predicted the experimental deformation capacity he also derives the design formula for of the retrofitted RCC columns with a reasonable accuracy.

Arlekar J. N. and Murty C. V. R. (2006) studied on Shear moment interaction for analysis and design of steel beam to column connections that The design of beam-to-column connections for steel Moment Resisting Frames he not consider the V-M interaction; the connections is designed for maximum probable moment and corresponding shear which is expected to be developed in the beam. This paper, examines the shear-moment interaction for AISC W-sections to analyze its effects on the connections of beam-to-column. For beams having small L/d ratios, this design procedures for beam-to-column connections will result in an over design for moment resistance and an under design for shear resistance. This can be unsafe, mostly in cases where the beam shear is very higher, i.e. in short span beams. Design procedure to calculate the shear- moment interaction in the estimation of the connection, design forces needs to be developed.

Kothandaraman S. and Vasudevan G. (2009) has experimental study on Flexural retrofitting of RCC beams using exterior bars at soffit level keeping the reinforcement externally at soffit level is found to be viable and the moment carrying capacity of beams increased considerably. In case of under reinforced section the capacity can be augmented up to 70%. By doing this the moment carrying capacity can be enlarged than that of the section in which the entire reinforcement is embedded. This technique is very simple to implement and it can be used for all types of beams. This technique doesn't require any costly machineries, extra accessory or skilled labour. This proposed method for strengthening of RCC beam is found to be very effective and advantageous taking into consideration of the ductile behavior, load carrying capacity, crack control, reduction of deflection and its cost-effective aspect.

Obaidat Y. T. (2011) studied on use of FRP for structural retrofitting of concrete beam. By his experiments and simulations he shows that retrofitting by FRP can increase load capacity and stiffness. The effect of retrofitting in flexure is more effective than in shear. On the other hand, these simulations showed that an increase in the amount of CFRP will in some cases decrease the maximum load capacity. This means that it is very important to understand the behaviour of a retrofitted structure since an unsuitable arrangement of CFRP can make the situation very dangerous.

Ruano G. et al (2012) has studied on Shear retrofitting of RCC beam with fibre reinforced made of steel. The reinforce technique used with self compacting concrete with steel fibre reinforced in feasible to apply at building elements. It is very appropriate to reduce the thickness of the steel jacketing, plastering can be optional in this case it provides a good surface finish. So it reduce the plaster weight or can say it reimburse the weight. FRC improves the structural properties of building.Beams strengthed by jacketing prevent the debonding, maintain the integrity of the beam. It not only increase the durability but it is also important with structural point of view because if reinforcement gets debond its contribution gets vanished.

PROPOSED WORK

The present study examine the structural behaviour of an RC frame (G+3Commercial building) under the additional load in the form of seismic forces and new story. The structure is analyzed for two load cases. In first case (Gravity load case) structure is analyzed for only gravity forces (G+3building) and no seismic force and additional store forces is considered in this analysis while in second case (Seismic load case) structure is analyzed with consideration of seismic forces along with gravity forces of (G+4 building). The analysis is performed by using software i.e. STAAD Pro. The analysis results of structure for gravity and seismic load cases are compared to assess the effect of seismic forces on the RC structure. Weak zones of building are detected by comparing the results and retrofitting technique is suggested for the weak zone. Two cases for the compare of structure are
Case 1:- Structure with gravity loads only G+3(STR-GR)
Case 2:- Structure with earthquake loads of Zone III in addition to gravity loads G+4 (STR-EQ)

Modelling

Modelling is done for the structure, the details of which is illustrated in table

Table 1 Details of structure for modelling

Structure type	RCC commercial building
Storeys	G + 3
Height of each storey	3.0m
Building plan size	20m x 20m
Building height	15.0m
Depth of foundation	2.0m below GL
Type of supports	Fixed
Slab thickness each	150mm
Column size each	400mm x 400mm
Beam size	200mm x 450mm
Live load on each floor	4 KN/m^2
Live load on terrace	2.5 KN/m^2
Seismic zone	Zone III
Live load with seismic force	50% (IS 1893:2002)
Steel grade	Fe 415
Characteristic strength of concrete (f_{ck})	25 N/mm^2
Damp	0.05
Poisson ratio	0.17

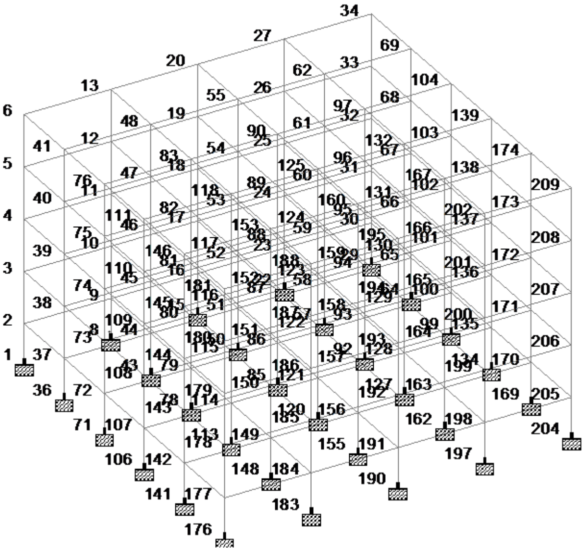

Fig 1 Isometric view of proposed structure with Node Numbering

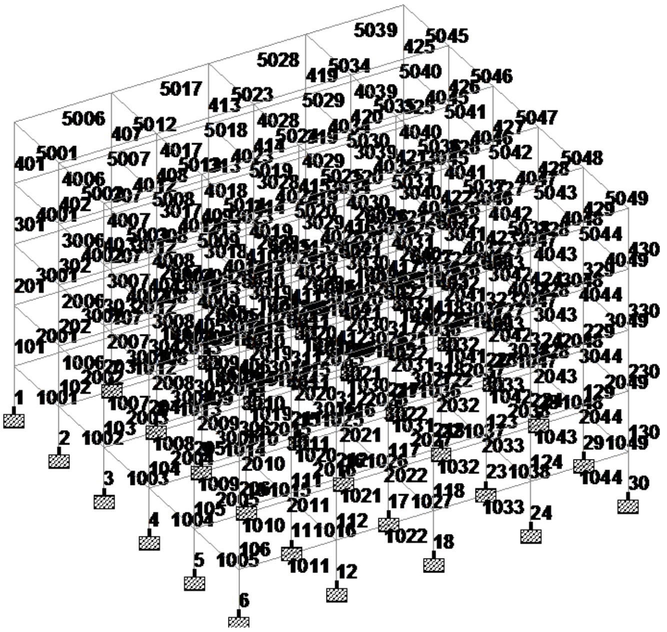

Fig 2 Isometric view of proposed structure with beam column numbering

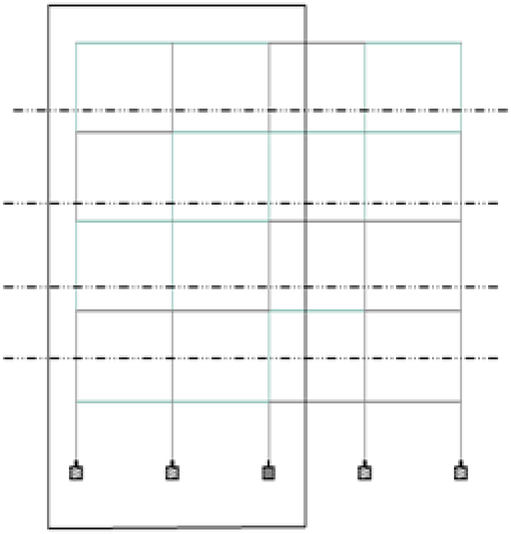

Fig 3 Region from which Beams and columns are considered for comparison

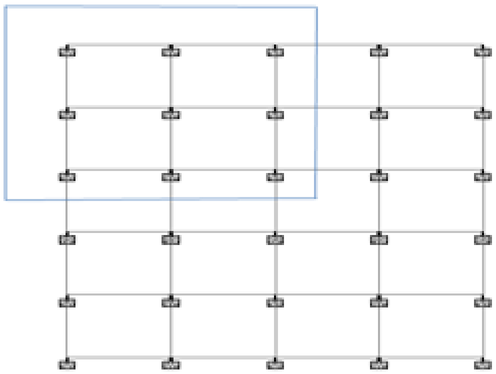

Fig 4 Region from which Beams are considered for comparison

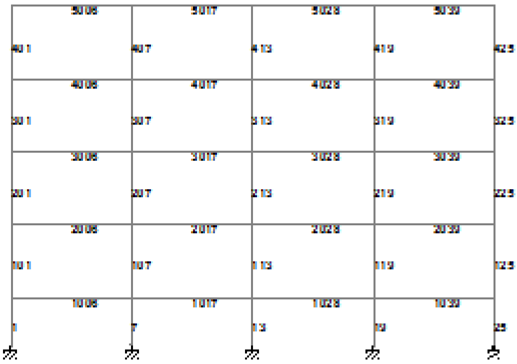

Fig 5 Section A-A in frount of node 1 showing beam and column numbering

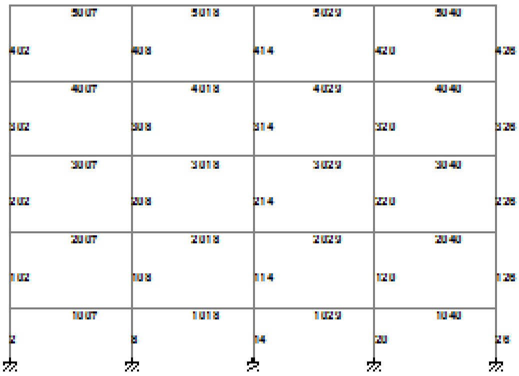

Fig 6 Section B-B in frount of node 36 showing beam and column numbering

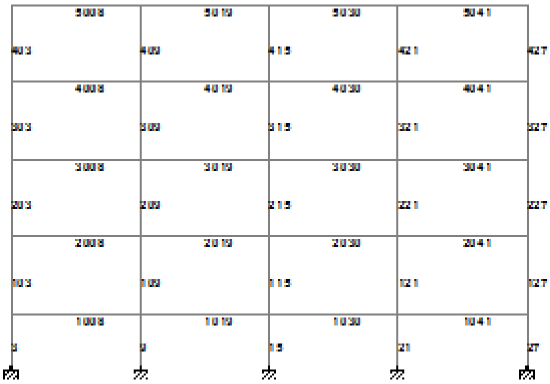

Fig 7 Section C-C in frount of node 71 showing beam and column numbering

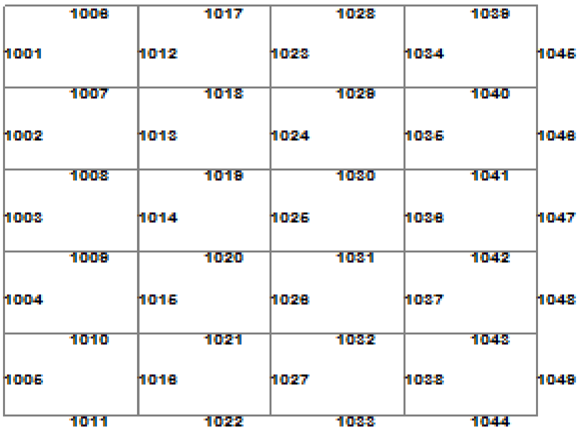

Fig 8 Sectional plan in ground floor where beams are considered

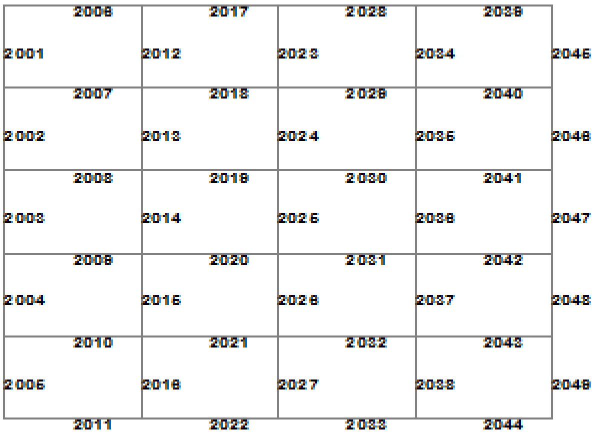

Fig 9 Sectional plan in 1st floor

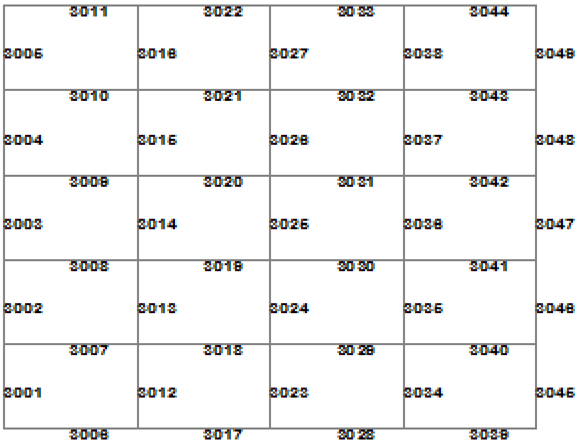

Fig 10 Sectional plan in 2nd floor

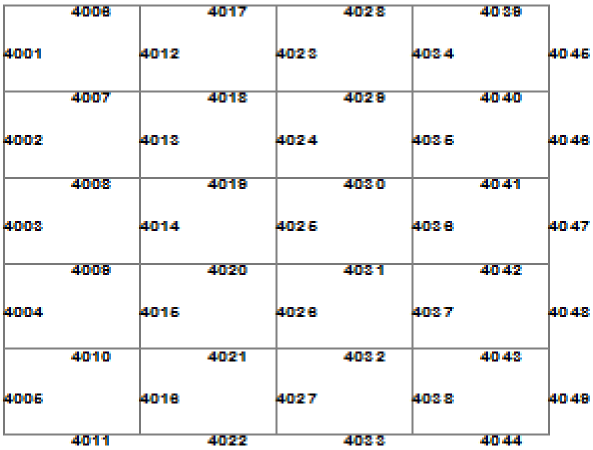

Fig 11 Sectional plan in 3rd floor

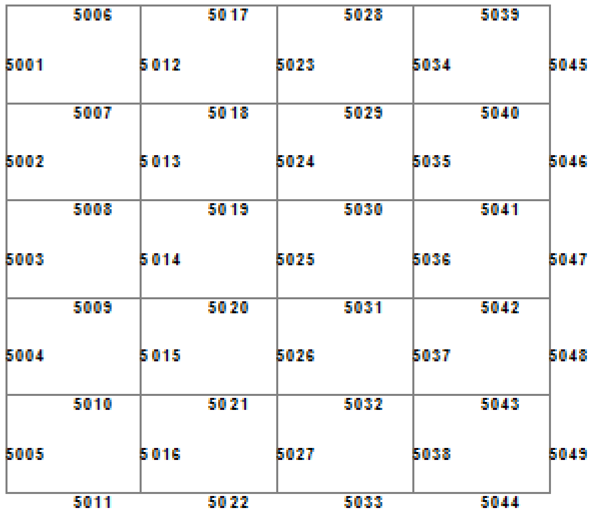

Fig 12 Sectional plan in 4th floor where beams are considered

Methodology

1 Modelling of G+ 3 structure in staad-pro software.
2 Analyze this structure for the gravity forces only and noted down forces in all the structural members.
3 An Additional one Storey introduces and modified the Forces in the Form of seismic force of Zone III and additional dead and live load at the same structure noted down forces in all the structural members.
4 Identify the weak zones in beams and columns. Retrofitting the structural members for the additional forces and moments on the structural members.

Load cases and combinations

According to IS 1893-2002
Load cases for analysis in staad-pro
Basic loads
EQ X = EQ in +X direction
EQ-X = EQ in -X direction
EQ Z = EQ in +Z direction
EQ-Z = EQ in-Z direction
DL = Dead load
LL = Live load

Combination of loads according to IS 1893:2002
1) 1.5 DL + 1.5 LL
2) 1.2 DL + 1.2 LL + 1.2 EQ X
3) 1.2 DL + 1.2 LL + 1.2 EQ-X
4) 1.2 DL + 1.2 LL + 1.2 EQ Z
5) 1.2 DL + 1.2 LL + 1.2 EQ-Z
6) 1.5 DL + 1.5 EQ X
7) 1.5 DL + 1.5 EQ-X
8) 1.5 DL + 1.5 EQ Z
9) 1.5 DL + 1.5 EQ-Z

RESULTS AND DISCUSSION

The effects of the additional storey and earthquake forces on structure are studied in addition to gravity forces. The comparison of shear forces, axial forces and bending moments are tabulated for two cases i.e. for STR-GR and STR-EQ and their algebraic differences are tabulated for the calculation of strengthening requirement. Floor wise results are discussed for different beams and columns. Subsequently the retrofitting method is used to strengthen the weak member.

STR-GR indicates the results of structure analyzed with gravity forces only and STR-EQ indicates the results of structure analyzed with additional storey load and earthquake force in addition to gravity forces.

Effects on beam in term of shear force

The shear force and bending moment in beams and columns of different storeys are obtain and compared for STR-GR and STR-EQ cases.

Effect on shear force in beam

The shear force in both the cases as for STR-GR and STR-EQ are compared for beams at each floor. Increase in shear force with percentage are tabulated for each floor.

a) Plinth beams

The shear force in plinth beams for STR-GR and STR-EQ cases are discussed. The increase in shear forces due to application of STR-EQ cases in addition to gravity forces are shown in table 2.

Table 2 Comparison of Shear force Fy (kN) in plinth beams between STR-GR and STR-EQ case

Beam No	Shear force Fy		Increase in Shear force	% increase in shear force
	STR-GR	STR-EQ		
	1	2	(2)-(1)	% increase
1001	44.276	61.332	**17.056**	**38.52%**
1002	43.535	58.912	15.377	35.32%
1003	43.484	58.961	15.477	35.59%
1006	60.589	69.13	8.541	14.10%
1007	89.981	89.981	0	0.00%
1008	89.984	90.561	0.577	0.64%
1012	63.571	77.595	14.024	22.06%
1013	62.673	74.81	12.137	19.37%
1014	62.607	74.864	12.257	19.58%
1017	59.21	66.728	7.518	12.70%
1018	87.93	87.93	0	0.00%
1019	87.93	87.93	0	0.00%
1023	63.581	79.201	15.62	24.57%
1024	62.674	76.287	13.613	21.72%
1025	62.607	76.345	13.738	21.94%

From the above comparison it is revealed that there is an increase in shear force Fy in all the beams. The maximum increase in shear force is found to be 17.056 kN in beam no 1001 with percentage increase of 38.52%.

b) First floor beams

The shear force in first floor beams for STR-GR and STR-EQ cases are discussed. The increase in shear forces due to application of STR-EQ cases in addition to gravity forces are shown in table 3.

Table 3 Comparison of Shear force (kN) in first floor beams between STR-GR and STR-EQ case

Beam No	Shear force Fy		Increase In Shear force	% increase in shear force
	STR-GR	STR-EQ		
2001	43.741	70.1	26.359	**60.26%**
2002	43.559	66.959	23.4	53.72%
2003	43.484	67.012	23.528	54.11%
2006	59.912	76.34	16.428	27.42%
2007	88.887	97.211	8.324	9.36%
2008	88.881	98.937	10.056	11.31%
2012	63.427	88.617	25.19	39.71%
2013	62.751	84.547	21.796	34.73%
2014	62.607	84.583	21.976	35.10%
2017	59.147	73.845	14.698	24.85%
2018	87.85	94.4	6.55	7.46%
2019	87.852	96.006	8.154	9.28%
2023	63.414	90.784	**27.37**	43.16%
2024	62.751	86.54	23.789	37.91%
2025	62.607	86.58	23.973	38.29%

From the above comparison it is revealed that there is an increase in shear force Fy in all the beams. The maximum increase in shear force is found to be 27.37 kN in beam no 2023 and The maximum increase in shear force is found in percentage increase is 60.26% in beam no.2001.

c) Second floor beam

The shear force in second floor beams for STR-GR and STR-EQ cases are discussed. The increase in shear forces due to application of STR-EQ cases in addition to gravity forces are shown in table 4

Table 4 Comparison of Shear force (kN) in second floor beams between gravity and seismic load case

Beam No	Shear force Fy		Increase in Shear force	% increase in shear force
	STR-GR	STR-EQ		
3001	44.522	69.228	24.706	**55.49%**
3002	43.613	66.083	22.47	51.52%
3003	43.484	65.963	22.479	51.69%
3006	59.433	75.135	15.702	26.42%
3007	88.101	96.246	8.145	9.25%
3008	88.086	97.968	9.882	11.22%
3012	64.779	88.355	23.576	36.39%
3013	62.825	83.96	21.135	33.64%
3014	62.607	83.773	21.166	33.81%
3017	59.177	73.311	14.134	23.88%
3018	87.882	94.111	6.229	7.09%
3019	87.883	95.703	7.82	8.90%
3023	64.765	90.406	**25.641**	39.59%
3024	62.825	85.882	23.057	36.70%
3025	62.607	85.695	23.088	36.88%

From the above comparison it is revealed that there is an increase in shear force Fy in all the beams. The maximum increase in shear force is found to be 25.64 kN in beam no 3023. The maximum increase in shear force is found in percentage increase is 55.49% in beam no.3001.

d) Third floor beam

The shear force in third floor beams for STR-GR and STR-EQ cases are discussed. The increase in shear forces due to application of STR-EQ cases in addition to gravity forces are shown in table 5

Table 5 Comparison of Shear force (kN) in third floor beams between gravity and seismic load case

Beam No	Shear force Fy		Increase in Shear force	% increase in shear force
	STR-GR	STR-EQ		
4001	44.987	64.584	**19.597**	**43.56%**
4002	43.745	61.541	17.796	40.68%
4003	43.484	61.381	17.897	41.16%
4006	59.146	71.256	12.11	20.47%
4007	88.166	92.416	4.25	4.82%
4008	88.195	93.902	5.707	6.47%
4012	65.734	83.555	17.821	27.11%
4013	63.077	79.027	15.95	25.29%
4014	62.607	78.796	16.189	25.86%
4017	59.294	69.472	10.178	17.17%
4018	88.112	90.161	2.049	2.33%
4019	88.119	91.531	3.412	3.87%
4023	65.723	85.259	19.536	29.72%
4024	63.081	80.642	17.561	27.84%
4025	62.607	80.411	17.804	28.44%

From the above comparison it is revealed that there is an increase in shear force Fy in all the beams. The maximum increase in shear force is found to be 19.59 kN in beam no 4001 with percentage increase of 43.56%.

e) Roof beam

The shear force in roof beams for STR-GR and STR-EQ cases are discussed. The increase in shear forces due to application of STR-EQ cases in addition to gravity forces are shown in table 6

Table 6 Comparison of Shear force (kN) in roof beams between STR-GR and STR-EQ case

Beam No	**Shear force Fy**		**Increase in Shear force**	**% increase in shear force**
	STR-GR	**STR-EQ**		
5001	26.067	56.733	**30.666**	**117.64%**
5002	25.885	54.437	28.552	110.30%
5003	25.484	53.993	28.509	111.87%
5006	37.622	64.824	27.202	72.30%
5007	67.454	90.148	22.694	33.64%
5008	67.489	90.219	22.73	33.68%
5012	45.436	74.592	29.156	64.17%
5013	45.253	70.785	25.532	56.42%
5014	44.607	70.175	25.568	57.32%
5017	36.771	63.516	26.745	72.73%
5018	65.477	88.293	22.816	34.85%
5019	65.477	88.302	22.825	34.86%
5023	45.383	75.744	30.361	66.90%
5024	45.252	71.928	26.676	58.95%
5025	44.607	71.309	26.702	59.86%

From the above comparison it is revealed that there is an increase in shear force Fy in all the beams. The maximum increase in shear force is found to be 30.67 kN in beam no 5001 with percentage increase of 117.64%.

Effect on bending moment in beam

Sagging moment and hogging moment both are compared for the both cases as for STR-GR and STR-EQ. Maximum of two hogging moments from both ends are taken for the comparison,

a) Plinth level beams

Table 7 Comparison of Sagging and hogging moment for STR-GR and STR-EQ in beams at plinth level.

Beam no	**STR-GR**		**STR-EQ (Zone III)**		**Increase in**		**% increase**	
	Max. hogging moment	**Max. Sagging moment**	**Max. hogging moment**	**Max. Sagging moment**	**Hogging moment**	**Sagging moment**	**Hogging moment**	**Sagging moment**
	1	**2**	**3**	**4**	**(3-1=5)**	**(4-2=6)**	**(5÷1=7)**	**(6÷2=8)**
1001	32.389	19.052	75.055	31.572	42.666	**12.52**	**131.73%**	**65.71%**
1002	32.33	17.629	71.562	25.844	39.232	8.215	121.35%	46.60%
1003	32.196	17.662	71.722	25.831	39.526	8.169	122.77%	46.25%
1006	56.72	31.986	93.175	35.664	36.455	3.678	64.27%	11.50%
1007	87.127	50.359	116.991	50.356	29.864	-0.003	34.28%	-0.01%
1008	87.124	50.37	119.995	50.367	32.871	-0.003	37.73%	-0.01%
1012	48.018	29.266	93.6	37.322	45.582	8.056	94.93%	27.53%
1013	48.322	27.165	89.627	30.958	41.305	3.793	85.48%	13.96%

1014	48.156	27.2	89.627	30.958	41.471	3.758	86.12%	13.82%
1017	48.322	27.165	90.164	30.659	41.842	3.494	86.59%	12.86%
1018	85.068	47.29	113.46	47.303	28.392	0.013	33.38%	0.03%
1019	85.07	47.289	116.347	47.303	31.277	0.014	36.77%	0.03%
1023	48.032	29.271	96.915	39.048	**48.883**	9.777	101.77%	33.40%
1024	48.324	27.164	92.577	32.44	44.253	5.276	91.58%	19.42%
1025	48.156	27.2	92.775	32.414	44.619	5.214	92.66%	19.17%

Table 7 shows the bending moment for STR-GR and STR-EQ load cases in plinth beams. Here the increase in hogging moment is maximum for beam no 1023 as the value of the hogging moment is increased by 48.88 kNm. Maximum increase in sagging moment is in beam no 1001 with the value is increased by 12.52 kNm The maximum increase in percentage of hogging moment at this level beams is 131.73% in beam no 1001 and maximum increase in sagging moment is in the same beam with the value is increased in percentage by 65.71%.

b) First floor beams

Table 8 Comparison of Sagging and hogging moment for STR-GR and STR-EQ.in beams at first floor

Beam no	**STR-GR**		**STR-EQ (Zone III)**		**Increase in**		**% increase**	
	Max. hogging moment	**Max. Sagging moment**	**Max. hogging moment**	**Max. Sagging moment**	**Hogging moment**	**Sagging moment**	**Hogging moment**	**Sagging moment**
	1	**2**	**3**	**4**	**(3-1=5)**	**(4-2=6)**	**(5÷1=7)**	**(6÷2=8)**
2001	31.332	19.041	95.699	44.184	64.367	**25.143**	**205.44%**	**132.05%**
2002	32.263	17.745	87.745	36.67	55.482	18.925	171.97%	106.65%
2003	32.209	17.649	87.837	36.743	55.628	19.094	172.71%	108.19%
2006	55.065	31.949	113.29	44.295	58.225	12.346	105.74%	38.64%
2007	84.452	50.299	138.738	52.806	54.286	2.507	64.28%	4.98%
2008	84.427	50.309	143.262	54.4	58.835	4.091	69.69%	8.13%
2012	47.743	29.251	119.124	49.323	71.381	20.072	149.51%	68.62%
2013	48.28	27.364	109.164	41.688	60.884	14.324	126.11%	52.35%
2014	48.176	27.18	109.164	41.688	60.988	14.508	126.59%	53.38%
2017	48.279	27.363	108.076	37.329	59.797	9.966	123.86%	36.42%
2018	84.754	47.405	133.581	47.44	48.827	0.035	57.61%	0.07%
2019	84.757	47.406	137.604	47.442	52.847	0.036	62.35%	0.08%
2023	47.713	29.256	123.63	52.582	**75.917**	23.326	159.11%	79.73%
2024	48.28	27.364	113.148	44.349	64.868	16.985	134.36%	62.07%
2025	48.176	27.179	113.253	44.355	65.077	17.176	135.08%	63.20%

Table 8 shows the bending moment for STR-GR and STR-EQ load cases for first floor beams. Here the increase in hogging moment is maximum for beam no 2023 as the value of the hogging moment is increased by 75.91 kNm. Maximum increase in sagging moment is in beam no 2001 with the value is increased by 25.14 kNm The maximum increase in percentage of hogging moment at this level beams is 205.44% in beam no 2001 and maximum increase in sagging moment is in the same beam with the value is increased in percentage by 132.05%.

c) Second floor beam

Table 9 Comparison of Sagging and hogging moment for STR-GR and STR-EQ.in beams at second floor

Beam no	**STR-GR**		**STR-EQ (Zone III)**		**Increase in**		**% increase**	
	Max. hogging moment	**Max. Sagging moment**	**Max. hogging moment**	**Max. Sagging moment**	**Hogging moment**	**Sagging moment**	**Hogging moment**	**Sagging moment**
	1	**2**	**3**	**4**	**(3-1=5)**	**(4-2=6)**	**(5÷1=7)**	**(6÷2=8)**
3001	32.867	19.067	93.702	39.76	60.835	**20.693**	**185.09%**	**108.53%**
3002	32.31	17.806	85.848	35.315	53.538	17.509	165.70%	98.33%
3003	32.216	17.642	85.734	34.99	53.518	17.348	166.12%	98.33%
3006	53.829	31.988	111.883	42.196	58.054	10.208	107.85%	31.91%
3007	82.399	50.387	138.436	51.329	56.037	0.942	68.01%	1.87%
3008	82.349	50.401	142.874	52.87	60.525	2.469	73.50%	4.90%
3012	50.387	29.312	118.33	45.377	67.943	16.065	134.84%	54.81%
3013	48.334	27.458	107.804	41.085	59.47	13.627	123.04%	49.63%
3014	48.188	27.167	107.803	41.085	59.615	13.918	123.71%	51.23%
3017	48.333	27.458	106.637	36.583	58.304	9.125	120.63%	33.23%
3018	84.809	47.431	132.74	47.544	47.931	0.113	56.52%	0.24%
3019	84.811	47.431	136.717	47.548	51.906	0.117	61.20%	0.25%
3023	50.352	29.319	122.592	48.493	**72.24**	19.174	143.47%	65.40%
3024	48.333	27.458	111.646	43.643	63.313	16.185	130.99%	58.94%
3025	48.188	27.167	111.487	43.18	63.299	16.013	131.36%	58.94%

Table 9 shows the bending moment for STR-GR and STR-EQ load cases for second floor beams. Here the increase in hogging moment is maximum for beam no 3023 as the value of the hogging moment is increased by 72.24 kNm. Maximum increase in sagging moment is in beam no 3001 with the value is increased by 20.69 kNm The maximum increase in percentage of hogging moment at this level beams is 185.09% in beam no 3001 and maximum increase in sagging moment is in the same beam with the value is increased in percentage by 108.53%.

d) Third floor beam

Table 10 Comparison of Sagging and hogging moment for STR-GR and STR-EQ.in beams at third floor

Beam no	**STR-GR**		**STR-EQ (Zone III)**		**Increase in**		**% increase**	
	Max. hogging moment	**Max. Sagging moment**	**Max. hogging moment**	**Max. Sagging moment**	**Hogging moment**	**Sagging moment**	**Hogging moment**	**Sagging moment**
	1	**2**	**3**	**4**	**(3-1=5)**	**(4-2=6)**	**(5÷1=7)**	**(6÷2=8)**
4001	33.858	19.006	84.01	31.934	50.152	**12.928**	**148.12%**	**68.02%**
4002	32.507	17.873	76.704	29.1	44.197	11.227	135.96%	62.82%
4003	32.18	17.679	76.583	28.695	44.403	11.016	137.98%	62.31%
4006	53.242	31.858	101.817	36.962	48.575	5.104	91.23%	16.02%
4007	82.958	49.99	128.466	50.458	45.508	0.468	54.86%	0.94%
4008	83.034	49.987	132.287	50.471	49.253	0.484	59.32%	0.97%
4012	52.532	29.077	108.299	39.24	55.767	10.163	106.16%	34.95%
4013	48.696	27.599	97.849	35.381	49.153	7.782	100.94%	28.20%
4014	48.133	27.222	97.849	35.381	49.716	8.159	103.29%	29.97%

4017	48.696	27.599	97.033	32.943	48.337	5.344	99.26%	19.36%
4018	85.189	47.626	122.851	47.538	37.662	-0.088	44.21%	-0.18%
4019	85.201	47.632	126.273	47.543	41.072	-0.089	48.21%	-0.19%
4023	52.512	29.076	111.843	41.371	**59.331**	12.295	112.99%	42.29%
4024	48.701	27.601	101.084	37	52.383	9.399	107.56%	34.05%
4025	48.133	27.222	100.932	36.452	52.799	9.23	109.69%	33.91%

Table 10 shows the bending moment for STR-GR and STR-EQ load cases for third floor beams. Here the increase in hogging moment is maximum for beam no 4023 as the value of the hogging moment is increased by 59.33 kNm. Maximum increase in sagging moment is in beam no 4001 with the value is increased by 12.93 kNm The maximum increase in percentage of hogging moment at this level beams is 148.12% in beam no 4001 and maximum increase in sagging moment is in the same beam with the value is increased in percentage by 68.02%.

e) Roof beam

Table 11 Comparison of Sagging and hogging moment for STR-GR and STR-EQ.in beams at roof floo

Beam no	**STR-GR**		**STR-EQ (Zone III)**		**Increase in**		**% increase**	
	Max. hogging moment	**Max. Sagging moment**	**Max. hogging moment**	**Max. Sagging moment**	**Hogging moment**	**Sagging moment**	**Hogging moment**	**Sagging moment**
	1	**2**	**3**	**4**	**(3-1=5)**	**(4-2=6)**	**(5÷1=7)**	**(6÷2=8)**
5001	19.44	13.584	67.853	23.02	48.413	9.436	**249.04%**	69.46%
5002	20.651	12.01	62.312	21.669	41.661	9.659	201.74%	**80.42%**
5003	20.215	11.643	61.77	20.906	41.555	9.263	205.57%	79.56%
5006	35.928	23.488	85.506	31.472	49.578	7.984	137.99%	33.99%
5007	66.086	43.208	111.142	49.606	45.056	6.398	68.18%	14.81%
5008	66.108	43.275	113.876	49.602	47.768	6.327	72.26%	14.62%
5012	34.288	24.726	89.881	30.046	55.593	5.32	162.14%	21.52%
5013	36.883	21.764	81.129	28.346	44.246	6.582	119.96%	30.24%
5014	36.169	21.186	81.128	28.346	44.959	7.16	124.30%	33.80%
5017	36.519	20.769	81.927	30.327	45.408	9.558	124.34%	46.02%
5018	66.219	38.132	106.428	47.827	40.209	9.695	60.72%	25.42%
5019	66.22	38.131	108.894	47.836	42.674	**9.705**	64.44%	25.45%
5023	34.148	24.759	92.283	31.107	**58.135**	6.348	170.24%	25.64%
5024	36.884	21.761	83.406	29.115	46.522	7.354	126.13%	33.79%
5025	36.168	21.187	82.68	28.187	46.512	7	128.60%	33.04%

Table 11 shows the bending moment for STR-GR and STR-EQ load cases for roof floor beams. Here the increase in hogging moment is maximum for beam no 5023 as the value of the hogging moment is increased by 58.13 kNm. Maximum increase in sagging moment is in beam no 5019 with the value is increased by 9.70 kNm The maximum increase in percentage of hogging moment at this level beams is 249.04% in beam no 5001 and maximum increase in sagging moment in beam no 5002 by 80.42%

Strengthening of beams

Beams are failed in shear and flexure due to STR-EQ. Strengthening of beams is done for the flexure and shear, to reach the strength of the structural member up to the require strength.

Strengthening of beams for flexure

Strengthening of beams is done by adding steel plate of equivalent area of reinforced bars. Plate is designed for the additional area of steel required for STR-EQ case.

Equivalent mild steel area:-

The additional area of reinforcement bars are found by the comparison of analysis of STR-GR and STR-EQ cases, the obtained additional required steel is of tor steel. But for the retrofitting mild steel plate is available in market, the area of equivalent mild steel plate can be found by force equilibrium.

For tor steel (Fe 415 N/mm^2) area for 1200 mm^2
$A_{st_1} = 1200\ mm^2$, $f_{y_1} = 415\ N/mm^2$
$f_{y_2} = 250\ N/mm^2$, A_{st_2} = Area of Mild steel
So $A_{st_2} = (\frac{415}{250}) \times 1200 = 664\ mm^2$

Similarly equivalent area of mild steel, as given in table below

Design of steel plate for required additional reinforcement

Select different range from the tables for additional Ast (mm^2) of $f_y = 250\ N/mm^2$

Table 12 Plate sizes showing for different range of equivalent mild steel area

Serial Number	Additional reinforcement area required (Fe 415)	Corresponding mild steel area required (Fe 250)	Plate size used
1	Up to 400	664	120 x 8
2	400-600	996	120 x 10
3	600 -800	1328	120 x 12
4	800 -1000	1660	120 x 14
5	1000 -1200	1992	150 x 14

Design of shear connector for flexure

Shear connector has to be design for every beam column joints for the maximum moment in that beam. Shear connector will transfer the additional force coming at existing reinforcement level to the outer plate which is designed for different beams. So the force which is to be transfer to the outer plate is to be calculated. These connectors are used for either top plate for hogging moment or bottom plate for sagging moment. As every beam will have different additional moment, the force for which shear connector will design will be different. Here shear connector is designed for the maximum moment developed among all the beams of the structure.

So for this, we have
Force = $\frac{\text{moment}}{\text{Lever arm}}$ …………………………….……….eq^n 1
Here lever arm L.A. = (d-0.42x_u) ………………….eq^n 2
But for x_u ,
M = 0.36 f_{ck} x b x_u x (d-0.42x_u) ………………..…..eq^n 3

Maximum additional moment = 75.91 kNm
Calculation of force for this maximum additional moment is given below,
Finding x_u for max of sagging and hogging moment by eq^n 3
Max hogging moment = -75.91 kNm

Therefore we have,
$75.91 \times 10^6 = 0.36 \times 25 \times 200\, x_u \times (367 - 0.42x_u)$
$75.91 \times 10^6 = 660600x_u - 756\, x_u^2$
x_u = 136.11mm
Put this x_u in eq^n 2
L.A. = 367 – 0.42 x 136.11mm
L.A. = 309.83 mm

Now additional force which is to be carried by stud
$F = \frac{M}{L.A.} = \frac{75.91 \times 10^6}{309.83}$

F = 245005.32 N= 245.00 kN

Now designing the shear connector for the above force using IS 11384:1985 code
From table 1, we have
For 22 mm diameter of stud, 100 mm height and for M25 concrete
Strength of Shear connector F = 77.5 kN
Provide 4 shear connectors to resist the design shear force.

Strengthening of beams for shear

Steel plates are used at side face of the beams for resist additional shear force. Side face steel plates used one side or both side of beams.

The maximum force is taken among from all the floors and all the beams as 30.67 kN.

Take mild steel plate as Fe 250 for practical purpose. Permissible stress for mild steel plate in shear is 140 N/mm^2
So for this,
Area of steel plate = $\frac{\text{Force}}{\text{Permissible stress in plate}}$
So As = $\frac{30670}{140}$ = 219.07 mm^2
Assume depth of the plate is 200 mm
So thickness of plate will be $\frac{235.79}{200}$ = 1.09 mm≈ 2 mm
But for the practical purpose take plate of size 200mm x 4mm.

Design of shear connector for shear

To transfer the shear stresses from existing shear reinforcement to outer plate, Shear connectors are used according to IS: 11384-1985.

As the maximum additional shear force among all the floors and all the beams is 30.67 kN. So for this,

By table 1 of IS: 11384-1985 gives the Design strength of shear connectors for different concrete strengths.

Strength of shear connector for 12mm dia. and 62mm height used in M25 is 25.50 kN. So, two shear connectors are needed to resist shear force of 30.67 kN.

Effects of additional seismic forces on beams

The results point out that the significant increase found in the shear force and bending moment in most of the beams. The comparison of critical value of shear force, hogging moments and sagging moments at each floor level is depicted in table 13

Table 13 Effects of Seismic load case on beams

Comparison of maximum shear force (kN) in beam			
Floor	Max shear force		
	STR-GR	STR-EQ	% increase
Plinth beam	44.276 (LC STR-GR 101)	61.332(LC STR-EQ 108)	38.52%
First floor beam	43.741 (LC STR-GR 101)	70.1(LC STR-EQ 109)	60.26%
Second floor beam	44.522 (LC STR-GR 101)	69.228(LC STR-EQ 109)	55.49%

Third floor beam	44.987 (LC STR-GR 101)	64.584(LC STR-EQ 109)	43.56%
Fourth floor beam	26.067 (LC STR-GR 101)	56.733(LC STR-EQ 109)	117.64%
Comparison of maximum hogging moment (kNm) beam			
Floor	Max hogging Moment		
	STR-GR	STR-EQ	% increase
Plinth beam	32.39 (LC STR-GR 101)	75.05 (LC STR-EQ 109)	131.73
First floor beam	31.33 (LC STR-GR 101)	95.69 (LC STR-EQ 109)	44.18
Second floor beam	32.87 LC STR-GR 101	93.70 (LC STR-EQ 109)	39.76
Third floor beam	33.86 (LC STR-GR 101	84.01 (LC STR-EQ 109)	31.93
Fourth floor beam	19.44 LC STR-GR 101	67.85(LC STR-EQ 109)	249.04
Comparison of maximum sagging moment (kNm) in beam			
Floor	**Max sagging moment**		
	STR-GR	**STR-EQ**	**% increase**
Plinth beam	19.05 (LC STR-GR 101)	31.57(LC STR-EQ 108)	65.71
First floor beam	19.04 (LC STR-GR 101)	205.44(LC STR-EQ 108)	132.05
Second floor beam	19.07 (LC STR-GR 101)	185.09(LC STR-EQ 108)	108.53
Third floor beam	19.01 (LC STR-GR 101)	148.12(LC STR-EQ 109)	68.02
Fourth floor beam	12.01 (LC STR-GR 101)	21.669(LC STR-EQ 108)	80.42

CONCLUSION

The analysis conclusions of a G+3Commercial building under constrained site conditions are as follows.

1) If G+3Commercial building has design only for Gravity load and effect of earthquake analysis on same building, structure is unstable for such type of loading. Hence earthquake load analysis is plays an important role in stability of structure.
2) If G+3Commercial building has design only for Gravity load and effect of additional story analysis on same building, structure is unstable for such type of loading. Hence additional story load analysis also plays an important role in stability of structure.

3) From table 13 it is concluded that as load increases, percentage of shear force and bending moment also increases in all beam. From increasing the load STR-GR to STR-EQ shear force & bending moment increases mainly due to earth quick. Hence evaluation of earthquake load is very important for retrofitting.
4) If the fund availability is limited then provision of retrofitting is a better option as compared to providing a new construction.

SCOPE FOR FUTURE WORK

- The effect of earthquake and additional load only analysis in this thesis, wind load, snow load, hydrostatic pressure from water, effect of tropical cyclones, tornadoes etc. also needs to be studied in details for finding optimum option of retrofitting.
- In this thesis it is assumed that all the column supports are fixed. Further the structure can be analyzed considering the effect of soil-structure interaction.
- The structure can be analyzed for different seismic zones and different type of foundation.

REFERENCES

1. *Belal M.F., Mohamed H.M. and Morad S.A. (2014), "Behaviour of reinforced concrete columns strengthened by steel jacket" in HBRC journal.*
2. *Singh V., bansal P. P., Kumar M. and Kaushik S.S (2014), "Experimental studies on strength and ductility of CFRP jacketed reinforced concrete-beam joint" in construction and building materials volume 55, page no. 194 – 201.*
3. *Ruano G., Facundo I, Pedraza R. I., Sfer D. and Luccioni B. (2013), "Shear retrofitting of reinforced concrete beams with steel fibre reinforced concrete" in construction and building materials volume 54, page no. 646 – 658.*
4. *Su R. and lingzhi L.I. (2013), "Strengthening of Reinforced Concrete Structures by Bolting of Steel Plates" in Hong Kong Concrete Institute.*
5. *S. Kothandaraman and G. Vasudevan (2010), "Flexural retrofitting of RC beams using external bars at soffit level- An experimental study" in construction and building materials volume 24, page no. 2208–2216.*
6. *Obaidat Y. T. (2011), "structural retrofitting of concrete beams using frp - Debonding Issues" in department of construction science structural mechanics, ISSN 0281-6679.*
7. *Obaidat Y.T., Heyden S., Dahlblom O., Abu-Farsakh G. and Yahia A.J. (2011), "Retrofitting of Reinforced Concrete Beams Using Composite Laminates", in Construction & Building Materials, volume 25, page no. 591-597.*
8. *Sabu D.J., Pajgade P.S.(2012),"Seismic Evaluation of Existing Reinforced Concrete Building" in International Journal of Scientific & Engineering Research Volume 3, ISSN 2229-5518.*
9. *Obaidat Y. T., Dahlblom O., Heyden S. (2010), "Nonlinear FE Modelling of Shear Behaviour in RC Beam Retrofitted with CFRP", in proceedings of Computational Modelling of Concrete Structures (EURO-C), ISBN 978-0-415-5879-1.*
10. *Vijayakumar A. and Venkatesh B. (2011), "A survey of methods and techniques used for Seismic retrofitting of RC buildings" in international journal of civil and structural engineering, ISSN 0976 – 4399, volume 2, page no. 56-66.*
11. *Duggal S.K. (2010) "Limit state Design of steel structures" in Tata McGraw hill education private limited New Delhi, ISBN no. 978-0-07-070023-9.*
12. *Bhavikatti S.S. (2010) "Design of steel structures" in I.K. International Publishing House Pvt. Limited, ISBN no 938057813X, 9789380578132.*
13. *Shrestha H.D. and Krishna S., Pribadi (2009), "Retrofitting of existing vulnerable school buildings – assessment to retrofitting" in construction Quality &*
14. *Technical Assistance (CQTA) Center for Disaster Mitigation - Institute of Technology Bandung (CDM –ITB).*
15. *Williams R.J., Gardoni P. and Bracci J. M. (2009), "Decision analysis for seismic retrofit of structures" in Zachry Department of Civil Engineering, Texas A&M University, College Station, USA volume 31, page no. 188-196.*
16. *Shrestha H. And Dixit A.M. (2008) "Identifying seismic retrofitting measures for common reinforced concrete frame buildings in Nepal" in The 14th World Conference on Earthquake Engineering, Beijing, China.*

17. *Agarwal P. and Shrikhande M. (2006) "Earthquake resistant design of structure" in prentice hall, of India private limited, New Delhi, ISBN no. 81-203-2892-2.*
18. *Arlekar J.N. and Murty C. V. R. (2004), "Shear moment interaction for design of steel beam-to-column connections" in 13th World Conference on Earthquake Engineering Vancouver, B.C., Canada, Page no. 635.*
19. *Richard D., Sheikh S.A. and Bayrak O. (2003) "Retrofit of Square Concrete Columns with Carbon Fibre-Reinforced Polymer for Seismic Resistance" in ACI structural journal, title no. 100-S81.*
20. *Riyadh A.A. and Riyadh A.M. (2006), "Coupled flexural – shear interaction of RC beams using CFRP straps" in 13th International Conference of Composite Structures, Melbourne, Australia volume 75, page no. 457 – 464.*
21. *Lakshmanan N. (2006), "Seismic evaluation and retrofitting of buildings and structures" in ISET Journal of Earthquake Technology, Volume 43, Paper No. 469.*
22. *Sakino K. and Sun Y. (2000), "Steel jacketing for improvement of column strength and ductility" in 12th world Conferences on Earthquake Engineering (WCEE).*
23. *Geng Z.J., Chajes M.J., Chou T.W. and Pan D.Y.C. (1998), "The retrofitting of reinforced concrete" in composite sciences and technology, volume 58, page no. 1298-1305.*
24. *Gomes A. and Appleton J. (1997), "Strengthening design of Concrete beam by addition of steel plates" Department of civil engineering, IST, Technical university of Lisbon, Portugal.*
25. *Parretti R. and Nanni A. (2000), "Axial testing of concrete columns confined with carbon FRP" effect of fibre orientation*