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# Irregularity in the RC construction practices in hilly region Shimla & different Retrofitting Schemes

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**Abstract:** *Due to lack of plain terrain in Shimla, it offers sloppy terrain for construction site. Behaviour of buildings on sloppy terrain behaves different than the building on the plain terrain. Past construction practices in Shimla includes common irregularity such as soft storey, mass irregularity, torsional irregularity, unsymmetrical layout of plan, vertical irregularity and pounding. Over the past earthquakes and research papers have shown that RC buildings in sloppy terrain affects more. The present study investigates the irregularities (Table 4&5 of IS 1893 (Part-1): 2002) in the RC construction practices in hilly region (Shimla). The behaviour of (G+3) storey building with regular and irregular configurations is checked for the linear and non linear analysis based on studies that had done.*

**Keywords:** *Sloppy terrain, Regular building, Irregular building, Equivalent lateral static method, Push over analysis and Time history method, FRP, Retrofitting schemes.*

## I. Inrtroduction

### a) Irregularities:

Most of the past constructions in Shimla have faulty construction practices. A number of buildings have constructed from 1990's to up to now. Most of the buildings are irregular as per the Table-4 and Table-5 (IS 1893 (Part-1) : 2002)[18]. Irregularity like ***soft storey*** is a common practice in construction at basement level or in the first floor level for the parking purpose. Buildings have soft storey failed in a number during the past earthquakes e.g. a) Apollo Apartment at Ahmadabad, ground floor was completely collapsed; b) G+6 RC framed building at Bhuj, (Pankaj Agarwal and Manish Shrikhande, 2006) [17]. Generally buildings in sloppy terrain have ***vertical configurations*** like step back building, step back setback building and setback building. The Step back set back configuration is found to be more suitable for sloppy terrain (B.G. Birajdar, S.S. Nalawade, 2004) [7]. Due to the unequal height of columns at basement level and above storey columns, generally ***short columns*** problem exist which finally leads to the torsional failure (Keyvan Ramin, Foroud Mehrabpour,2014) [6].

### b) Methods of design, linear and non linear analysis are:

- Design of a RC building as per IS 456:2000 and IS 1893(part-1):2002.
- Lateral static analysis.
  - Modal analysis (Equivalent Lateral Force Method).
  - Linear static dynamic analysis (Response Spectrum Method).
  - Linear static dynamic analysis (Time History Method).
  - Non linear static analysis (Push over Analysis).

### c) Retrofitting:

To improve the performance of the structure and to make it seismically strong is called retrofitting. Also the addition of new structural members and many other techniques to improve the structural strength come under retrofitting. Achieving proper retrofitting may lead to better structural function, structural survivability and the safety of the occupants in a building. Retrofitting techniques are of two types i.e. global and local. Global technique is adopted for the structure level works and local technique is adopted for the member level works. Bureau of Indian Standards also provides IS 15988:2013 for seismic evaluation and strengthening of existing reinforced concrete buildings.

Most of the existing buildings constructed in last two decade in Shimla do not fulfil the current seismic requirements i.e. consists many irregularities, may suffer extensive damage or even collapse if shaken by a severe ground motion due to lack of structural design. By the modification of structure to make it stand well during earthquake ground motions sounds good and reduces the losses in terms of life, money and socially. Mostly past construction have not concerned IS 1893 (part 1); 2002 and ductile detailing IS 13920:1993.

**Review-Papers**

- Mahesh, Mr S., and Mr Dr B. Panduranga Rao [1] (2014) worked on the topic "Comparison of analysis and design of regular and irregular configuration of multi story building in various seismic zones and various types of soils using ETABS and STAAD". They draw regular and irregular configurations. They studied seismic response of the building with height G+11; including number of bays in the x direction and y direction are 8 and 5 respectively. Perform equivalent static lateral force method analytically. Draw graphs for the base shear and storey drifts for regular and irregular configurations for different conditions in ETAB and STAAD. From the worst combination of load case they find out story drift for all seismic zone and all types of soil. Thus they concluded that the base shear value is more in the regular configuration, because of the structure have more symmetrical dimensions than irregular configuration. They also concluded that the storey drift is more in the regular configuration because of the structure have more dimensions. Finally when compared both the software's result, steel provided is 5-10% more by the STAAD PRO v8i.
- Nagarjuna and Shivakumar B. Patil [2] (2015) studied on the topic "Lateral stability of multi-storey building on sloping ground". Three building configurations are considered, which include step back building, step back setback and setback buildings. Number of storey considered for each type of configurations is 10 storeys. Plan layout of each configuration includes 4 bays across the slope direction and 6 bays are considered along the slope direction. Slope of the ground considered are 10°, 20°, 30°, and 40° with the horizontal with seismic zone III. Results and discussion based on Equivalent Static Method & Response Spectrum Method have done by comparing the parameters top storey displacement, base shear, drift and time period. Performance of the shear wall at the centre and the corner are checked and the results are checked by comparing the parameters defined above. Time period and base shear are obtained by Equivalent static method. It is found out that the increase in slope angle increases the top storey displacement and reduces the time period. The step back setback configuration having less displacement compare to the other two configurations also performance of shear wall at corner performs better stability and strength as compared when placed in the centre.
- Kumar, Dr BG Naresh, and Avinash Gornale [3] (2012) studied on the topic "Seismic Performance Evaluation of Torsionally Asymmetric Buildings". Here the effect of eccentricity between centre of mass (CM) and centre of storey stiffness (CR) and the effect of storey stiffness of infill walls on the performance of the building is presented. In this study the gravity load analysis and lateral load analysis done as per the seismic code IS 1893:2002 (Part-1) for asymmetric buildings. **Non linear static pushover analysis is carried out to find out the difference between the capacity and the demand** of structure as per the guidelines of ATC-40. A five storied with and without consideration of stiffness of the walls, with open ground storey and unreinforced masonry infill walls in the upper stories are chosen. The bottom storey height is 4.5m and the height is 3.2m is kept for all the other storeys, bay dimensions in both directions are kept as 4m. Default hinge properties available in ETAB as per the ARC-40 are assigned to the frame elements. There are four building models namely –

| Model | Plan | Storey stiffness | Walls in 1$^{st}$ storey | Wall in upper stories | Stiffness of wall | Eccentricity |
|---|---|---|---|---|---|---|
| I | S | A | N | Y | C | N |
| II | S | A | N | Y | W & W | 19.12% |
| III | S | A | N | Y | W & W | 29.16% |
| IV | S | A | N | Y | W & W | 37.26% |

S = Symmetric, A = Asymmetric, N = No, Y = Yes, W & W = With and without,
C = Considered

Fundamental natural time period, computer analytically (ETAB) is higher than that given by codal provisions, for all models. Base shear and roof displacement at performance point have calculated analytically. Lateral displacement and ductility ratio calculation analytically done. It is concluded that the model considering stiffness of wall have more base shear value at performance point. Models which have taken wall stiffness, brittle failure occurs and models not including infill walls shows ductile behaviour. Also when calculated for the seismic design demand of reinforcement increases than what it have got by early design methods.

- Patel, Mohammed Umar Farooque, A. V. Kulkarni, and Nayeemulla Inamdar [4] worked on the topic "A performance study and seismic evolution of RC frame buildings on sloping ground". The plan layout of model is same to study the effect of step backs. The storey height is kept 3.5mfor all buildings. The building is considered to be located in the seismic zone-III and intended for office use. Number of bays are 5 in each x and y direction. Lateral load analysis have done as per the seismic code for the bare frame and concrete Shear wall structure is carried out to access the seismic vulnerability by performing pushover analysis (ETAB).

In this study six models are studied as –

| Building on sloping ground | Building on plain ground |
|---|---|
| MODEL –I (Bare Frame) | MODEL –IV (Bare Frame) |
| MODEL –II (Shear wall at centre) | MODEL –V (Shear wall at centre) |
| MODEL –II (Shear wall at corner) | MODEL –VI (Shear wall at corner) |

For the analysis purposes methods used are Equivalent static analysis, Response spectrum method and pushover analysis. By analysis the models for these methods finally some conclusions concluded that includes like buildings resting on sloppy ground have more displacement than on plain ground. Lateral displacement and storey drift considerably reduced when shear wall presence is there. Shear wall at corners have less displacement results than in the centre. It is found that the plastic hinges are more in case of building resting on sloping ground as compared to buildings resting on plain ground. Hence the structural elements which lies in the range of collapse point increases the seismic vulnerability of the structure and such elements requires retrofitting. The performance of the building on sloppy ground results in an increase of vulnerability of the structure along with formation of column hinges at the base level and beam hinges at each story level at performance point.

- Maske, Sachin G., and Dr PS Pajgade Inamdar [5] (2013) studied on the topic "Torsional Behaviour of Asymmetrical Buildings". The structural analysis and design of four storey RC asymmetrical frame building has been done with the help of ETAB software. The building is assumed as shopping complex. Linear static analysis has been done. The structure is assumed to be located in seismic zone IV on a site with the medium soil. Two cases are there. In CASE-1, seismic analysis of the building is done without considering design eccentricity. In CASE-2, seismic analysis of the building is done by considering torsion in the structure. For the case-1, modelling is done in the ETAB and the linear static analysis performed. While in the case-2, modelling is done on same way as in case-1 but calculations for design eccentricity is carried out here and included in the analysis. It is concluded that a difference comes out when we consider design eccentricity, resulted in increase the value of moment by the addition of torsional moment due to asymmetric of the structure. It also concluded that most of the designer holds approximate analysis for the torsional analysis which is appropriate.
- Ramin, Keyvan, and Foroud Mehrabpour [6] (2014) studied on the topic "Study of short column behavior originated from the level difference on sloping lots during earthquake (special case: Reinforced concrete buildings)". The short column problem mainly rising from different column height of basement than above storey columns. Two four storey reinforced concrete moment resisting frame (MRF) building modelled, one of which is located on a flat lot and the other one is on a lot sloped by 20°. The plan of both buildings is completely symmetric and similar to each other. The modelling and linear static analysis and design were carried out using ETAB 2000 software, while SAP 2000 software was employed for non linear static analysis of the structures. Columns are of (400*400) mm for the first and second floors and (350*350) mm for the third and fourth floors. Building is situated in the seismic zone III with medium soil type. The two dimension structural frames with different base support conditions have been modelled for frames by existing short column. After modelling samples, deformed shape frame in accordance to first mode shape was considered. It is clear from the deformed shape that short column's support conditions, is affected on whole frame's deformation. Also in initial storey columns with hinge support of frame, the axial force of column elements was increased. Shear force is also becoming larger at bottom stories due to the deterioration of the slopes. Bending moment also increases in amount at bottom stories in hinged supports case. It is clear from the Equivalent Static method that storey displacement at the lower level is low than above storeys. Therefore the first floor is a floor of relatively high rigidity and stiffness which results in smaller displacement in the case of an earthquake. However, short column is stiffer as compared to the tall column so it attracts more earthquake forces because more the stiffness more is force required for its deformation. Results of the Non linear static analysis shows that the more ductility of the common structures and although more initial stiffness of the sloping lot structures. Finally comparing all the results it concluded that: In short columns because of their short height and early increase in stiffness it leads to absorption of shear force and bending moment rises. So to serve high resistance it needs more steel. Due to different columns height torsion exits and it needs concern during design stage. As there is increase in stiffness of sloppy lot structures, its natural frequency increases and hence because of stiffness accession, its period decreases so that is smaller than the period of common structure for first thee modes but differences is not so clear after fourth mode.

- Birajdar, B. G., and S. S. Nalawade [7] (2004) studied on the topic "Seismic analysis of building resting on sloping ground". Three configurations namely step back; step back setback and setback are taken for the modelling. The first two configurations are on sloppy ground and the third one on the plain ground. The slope taken is 27° which is neither steep or nor too flat. The height and length of building in a particular pattern are in multiple of blocks, the size of block is being maintained at (7*5*3.5) m. Seismic zone of building is III. The building has labelled as STEP4 to STEP11 for 4 to 11 storey. The building with equal number of storeys / bays has same floor area in all three configurations. They performed analysis for the three configurations one by one and results tabulated separately to catch every little change in designing parameters with respect to change in geometric configurations.

After performing analysis comparison is carried out which states that the step back building attracts more shear forces further resulted in torsional moments which was more than the results formed in step back setback building. And between step back setback building and setback building there is somehow same value of resulted torsional moment but due to considerations of issues like stability of slopes, vulnerability during earthquake ground motion and cost of exaction in levelling the surface reflects priority to setback configuration. For the sloppy terrain, the step back setback configuration is better and have good seismic assessment.

- Irfan, Mohd, Abhay Sharma, and Vivek Garg [8] (2014) studied on the topic "Strengthening demand of columns in a RCC structure due to construction of an additional storey". Analysis of the new proposed structure (additional storey constructed over existing two storey structures) is done using Staad Pro V8i. Building is having 24m and 17m respectively in length and breath. Building is located in the zone –II with medium type soil. Comparative study to evaluate the increase in column forces and identifying the weak zone. Moments ( Mz, My) and

Axial force (Fx) effects are studied to find out the differences. And finally it was concluded that due to construction of an additional storey causes extra axial forces increase in every columns in lower floors. There is an increase in the critical value of axial force of 50% in columns below plinth level and first storey and 152% for second storey columns. Also there is increase in Bending moment critical value with 30% in columns below plinth level and first storey and 50% for second storey columns increases.

- K.P.Jaya, Jessy Mathai [9] (2012) studied on the topic "Strengthening of RC column using GFRP and CFRP". A six storey RC building was analysed to simulate the vertical load and lateral load that would act on the interior column of the ground storey. The height of the column used in the analysis was 3000mm with a cross section of (300*300) mm and the length of the beam was 4500mm with (300*600) mm cross section. Four specimens are of GFRP i.e. one specimen was tested without GFRP jacketing and other three specimens were tested with 2 layers, 4 layers and 6 layers. Three specimens are of CFRP i.e. one specimen was tested without CFRP jacketing and other two specimens were tested under a constant axial load and reversed cyclic lateral loading. Experiment was conducted on six samples, one third scaled columns. The test set up consists of a reaction frame, a hydraulic actuator (used to apply reversed cycle load) of capacity 200 KN with a stroke length of +-100mm and a loading frame with hydraulic jack (used to apply constant axial compressive load) with 50 KN to apply loads to the test specimens. In all the cases, the columns failure was the result of the rupture of the FRP jacket, associated with concrete crushing at the beam column junction and marked by wraps rupturing in the circumferential direction. It was concluded that the strength and ductility have increased 32% and 70% respectively of the specimen with 6 layers of GFRP compared to the specimen without GFRP. For the CFRP it was concluded that the strength and ductility have increased 98.3% and 2.7% respectively of the CFRP specimen compared to the specimen without CFRP. At the low displacement levels the energy absorbed by both the specimens was less than specimen without fibre specimen. But for the later displacement levels the energy absorption was much higher. Due to increase in the cost construction of CFRP and its less increase in ductility compared to GFRP it was concluded that GFRP wrapping is much better for the RC columns retrofitting. An analytical result is performed to cross check the results of experiment and it was found out that the variations are within 10%.
- Waghmare, Shri Pravin B [10] (2011) studied on the topic "Materials and jacketing technique for retrofitting of structures". The main objective of jacketing is to increase the seismic capacity of the moment resisting framed structures. It should be noted that retrofitting of a few members with jacketing or some other enclosing techniques might not be effective enough to improve the overall behaviour of the structure, if the remaining members are not ductile. Jacketing of column consists of addition of concrete with reinforcement and stirrups around the existing columns. It is also observed that the jacketing of columns is not successful for improving the ductility. The jacketing of columns is generally carried out by two methods: RC jacketing and steel jacketing. Also CFRP (Carbon fibre reinforcement polymer) is flexible and can improve the strength and ductility to a good extent. Jacketing of the beam carried out by different ways, the most

common are 1 side jacket, 3 sides' jacket and 4 sides jacket. The change in behaviour in jacketed elements, whose shear span/depth ratios are significantly reduced, due to their jacketing, needs to be clarified.

- Sarafraz, M., and F. Danesh [11] (2008) studied on the topic "Flexural enhancement of RC columns with FRP". For columns maximum strains and moments occurs in the plastic hinge zone. To increase flexural capacity of the columns, the technique (NSM) FRP rod is proposed. The strengthening technology called Near Surface Mounted rods. Use of the NSM FRP rods increases the flexural and the shear strength of deficient column. Further to increase the resistance of the column capacity in this plastic hinge zone flexural capacity is also enhanced by covering FRP laminates. Load vs. Moment interaction (P-M) diagram of a rectangular column are drawn to shown the effect of NSM FRP rods and covering of FRP laminates around the column. In FRP NSM Rods – Tensile strength capacity increases in the tension side of the P-M diagram resultant of which moment carrying capacity increases. In FRP Jacket – Load carrying capacity increases in the compression side of the P-M diagram resulted of which compressive load carrying capacity increases. Combination of FRP Jacket + FRP NSM Rods = Increase in both compressive and tensile capacity of the section. In addition, the presence of the jacket contributes to the stability of the rods and controls epoxy paste cracking. So use of both in combination leads to the better results in improving the performance of the damage/deficient member.
- Kose, Mehmet Metin [12] (2009) studied on the topic "Parameters affecting the fundamental period of RC buildings with infill walls". The main objective of the study is to obtain a new equation, which was a function of the selected parameters (i.e. building height, number of bays, ratio of shear walls to area of floor, ratio of infill panels to total number of panels and type of the frame) based on the results of study using multiple linear regression analysis. And to quantify the difference in the fundamental time period of building calculated based on the equations provided by the different codes with the new equation developed. In modelling of the infill walls, only the walls which were enclosed by two columns/shear walls and two beams were taken into consideration and rigidity of the infill walls were modelled as equivalent diagonal compression struts. The equivalent compressive struts were assumed to show the same linear behaviour under compression and tension. Analysis is performed and checked an equivalent compressive strut action whether it was under tension, it was removed and then the model was reanalysed. This procedure was repeated until all the equivalent compressive struts were under compression. Finally after a multiple linear multiple regressions an equation, for use in predicting the fundamental period of reinforced concrete moment resisting frames;

  **T=.0935 + .0301H + .0156B + .0039F - .1656S - .0232I**

  It was found out that number of floors was the primary parameter affecting the fundamental period of the models, percentage of the shear wall was the second most important parameter, based on the sensitivity. The percentage of the infill walls and the number of the bays had almost the same effect on the fundamental period of the building models and then the effect of infill walls on the fundamental period became smaller as ratio the infill walls was increased. The study also showed that current code predictions agree well with computer modelling when the building have shear walls and the number of bays equal to ,or larger than 4. However when there are no shear walls in models and the number of bays is equal to 3, the fundamental period determined by code equation was less than fundamental period calculated by computer modelling.
- Essa, Ahmed Sayed Ahmed Tawfik, Mohamed Ragai Kotp Badr, and Ashraf Hasan El-Zanaty [13] (2014) studied on the topic "Effect of infill wall on the ductility and behaviour of high strength reinforced concrete frame". An experimental study is carried out. The experiment contains four specimens.

  F1 Bare Frame
  F2 Frame with infill wall thickness 12cm of hole red bricks
  F3 Frame with infill wall thickness 6cm with red bricks
  F4 Frame with infill wall thickness 12cm of cement bricks

  The mix used for the base of the frame is of M-30 and frame is of M-65. Three infill wall prisms were taken from the same bricks for each wall. The infill wall prisms were tested to determine the compression strength for each wall. Four Linear Voltage Displacement Transducers (LDTVs) were used to measure the various types of deformation on frame. After checking out the results shown by load displacement curves for the specimen, failure load and displacement worked out. Ductility factor and energy dissipation also find out. Finally it is concluded that the ductility factor for F2, F3 and F4 with infill was less than the bare frame F1. The ultimate lateral load resistance for F2, F3 and F4 with infill wall was greater than the bare frame F1. As the thickness of infill wall decreases, the lateral load resistance of frame decreases by a significant value because infill wall with small thickness takes over more buckling and the failure takes over at small lateral load. The energy dissipation for the infill frames is higher than the bare frames.
- Pranay Ranjan and Poonam Dhiman [14] studied on the topic "Retrofitting of Columns of an Existing Building by RC, FRP and SFRC Jacketing Techniques". A building is modelled in the Staad Pro software.

The building is situated in Patna, Bihar. Building have G+3 storey building with storey height 3m for all, with plan (18m*9m) is taken. Building have irregular bays in X and Y direction. As existing building was modelled as per cross section of columns provided and load applied and analyse in Stadd Pro V8i and found that till 4th storey there is no any failed columns because initially building was designed as per 4 storey. As we model 5th storey, some of columns (six columns) of building failed. Columns that failed are highlighted in the model diagram. As we model 6th storey, many columns failed. Design of RC Jacketing of failed columns for 5 storey building with the guidelines given in the IS 15988:2013. Design of Fibre Reinforced Polymer Jacketing as per FIB Model Code for concrete structure 2010. Design of Steel Fibre Reinforced Concrete Jackets. At last comparison between these three techniques have carried out. In the RC jacketing: Sizes of the sections are increased and the free available usable space becomes less and also huge and dead mass is added. FRP jacketing is better than RC and SFRC but is more costly than these two.

- Taghdi, Mustafa, Michel Bruneau, and Murat Saatcioglu [15] (2000) studied on the topic "Seismic Retrofitting of Low Rise Masonry and Concrete Walls using Steel Strips". In this study six sample of walls with rectangular cross sections were tested. Specimens were named as 9, 9R, 10, 10R, 11, 11RP, 11R. The notation R stands for retrofitted. Head and bed joints with an approximate thickness of 10 mm were used to provide effective masonry unit dimensions of (200*400) mm. Each wall consisted of a total 9 courses, providing a nominal height of 1800mm. Also steel is embedded to increase the ductility of the wall. Retrofit was finally accomplished by adding two 220 mm wide diagonal steel strips of gauge 9 thicknesses (3.81 mm) on each wall face. Steel strips were added on both sides of the wall to prevent an eccentric stiffness and strength distribution that may cause twisting of the retrofitted walls, enhancing the redundancy of the retrofitted walls. The steel strip width was chosen to ensue yielding of the gross section in tension prior to net fracture at the bolt locations. Two vertical steels trips were added as boundary elements on each side of the wall. Steel bolts were used to fasten the vertical and diagonal steel strips, respectively, to the walls. The test specimen includes two vertical actuators applied axial compression (100 KN) to the specimens, and a third one was positioned horizontally and supported by a frame to apply horizontal deformation reversals. Strain gauges were used to measure strains in the reinforcing bars and steel strips. The hysteretic loops are generated by tests and compared the results of every sample i.e. 9, 9R, 10, 10R, 11, 11RP, 11R. Cracking behaviour also studied. Finally it was concluded that steel strip enhances its out of plane properties. Anchor bolts along the vertical strips provided, giving lateral strength/support to the end bars of the existing RC/masonry walls also elimination bucking chances. Vertical steel strips are not as effective, as their ultimate strength can still be limited by their less ductile shear failure. This also leads to partially reinforced masonry walls tend to behave in a manner similar to infill frames. Reducing buckling rates by reducing drift% near ends, provides evidence to support building code requirements.
- Dizhur, Dmytro, Michael Griffith, and Jason Ingham [16] (2014) studied on the topic "Out–of-plane strengthening of unreinforced masonry walls using near surface mounted fibre reinforced polymer strips". Experimental results are stated here. ***Beam test***: First stage of experimental study consisted of testing nine single leaf masonry beams ranging in length from 498 mm (6 bricks) to 840 mm (10 bricks). Curing is done for 28 days. All beams were retrofitted using a single (15*1.2) mm CRPF strip inserted into (20*8) mm groove geometry. Allow for 7 days curing, allowing the epoxy filled around CRFP strip to reach its full strength and white coating is done on face to trace the cracking pattern. Initially four points loading was setup but due to B1 sample showed shear failure so load changed to three points loading. 2 LDTV's (Linear variable displacement transducers) were put up at the middle of the beam to catch mid span displacement.

***Wall test:*** Second stage of experimental study consisted of testing five walls built with either two leaf or three leaf wall thicknesses. Curing of 28 was done. The wall sample was first tested in the as built condition first and then retrofitted using the NSM CFRP retrofit techniques. All walls were tested using psedu-static loading, with walls W1, W2 and W3 were tested using reversed loading cycle. Each wall for test contains some changes. In the test setup, airbags are provided to apply uniform reversed cyclic face pressure. Lateral load was measured using eight 10 KN load cells (four on each side) and the lateral displacement was measured using LVDT located at mid height.

In the end it was found out that the use of vertically orientated CFRP strips significantly increases both the flexural strength (3.05-6.21 times)and the ductility capacity of the UR walls. NSM CFRP strengthening results in increase in flexural strength of walls with overburden loads. Due to sliding shear failure of the Wall 5, it is concluded that the termination near the wall support is not safe. For all cyclically loaded walls, high stiffness degradation noticed at low drift ratio and progressive degradation (low rate) at high drift ratio. Displacement induced de-boding was seen in several tested retrofitted beams. This type of out of plane de-bonding was attributed to the large change in the curvature of the strip.

## II. Conclusions

After going through all papers discussed above many conclusion have come up-

**For building on sloppy terrain-**

1. The base shear and storey drift value is more in the regular configuration than irregular because of the structure have more symmetrical dimensions than irregular configuration. (Mahesh, Mr S., and Mr Dr B. Panduranga Rao,2014) [1]
2. As an increase in slope angle causes increases the top storey displacement and reduces the time period. (Nagarjuna and Shivakumar B. Patil, 2015) [2]
3. Consideration of infill walls in design results in the high base shear and provides stiffness against earthquake ground motions. Models neglecting infill wall shows ductile behaviour but models with infill wall shows brittle failure. Demand of amount of steel reinforcement increase as we design for gravity + earthquake loads rather than gravity loads alone. (Kumar, Dr BG Naresh, and Avinash Gornale, 2012) [3]
4. As the thickness of infill wall decreases the lateral load resistance also drops down by a particular value. (Essa, Ahmed Sayed Ahmed Tawfik, Mohamed Ragai Kotp Badr, and Ashraf Hasan El-Zanaty, 2014) [13]
5. Buildings resting on sloping terrain have lager lateral displacement as compare to the building on the plain terrain. Hence presence of shear wall reduces the displacement.
   Shear walls presence have resulted in better when subjected to earthquake ground motions. (Patel, Mohammed Umar Farooque, A. V. Kulkarni, and Nayeemulla Inamdar) [4]
6. Including design eccentricity in design for torsional moment due to asymmetry (due to plan irregularity, short column effect) of building has proven well. (Maske, Sachin G., and Dr PS Pajgade, 2013) [5]
7. Results in more initial stiffness of a building in sloppy terrain while structures on plain terrain have more ductility. (Ramin, Keyvan, and Foroud Mehrabpour, 2014) [6]
8. For the sloppy terrain step back setback configuration is well safe as it results in less base shear than step back configuration. (Birajdar, B. G., and S. S. Nalawade, 2004) [7]

**Retrofitting (Needs and Techniques)-**

1. To fulfil current need people construct new storey over old which demands for retrofitting due to increase in axial forces and moments values. (Irfan, Mohd, Abhay Sharma, and Vivek Garg, 2014) [8]
2. For retrofitting: GFRP and CFRP techniques well developed. (Jaya, K. P., and Jessy Mathai, 2012) [9]
   GFRP: Have resulted increases in the high ductility.
   CFRP: Have resulted increase in the high strength.
   The cost construction of CFRP is greater than GFRP.
3. NSM with FRP rods: (Sarafraz, M., and F. Danesh., 2008) [11]
   NSM with FRP rods- Increases the tensile zone in the P-M zone.
   FRP Jacketing- Increases the compression zone in the P-M zone.
   So combination of these two results in enhancement of both flexural and axial loads carrying capacity.
4. FRP Jacketing is better than RC and SFRC. In RCC adds more dead load to the structure and free available space become less.(Pranay Ranjan and Poonam Dhiman) [14]
5. Steel stirrups have resulted an increase in the lateral load resistance of low rise masonry and concrete walls with improving out of plane displacements. (Taghdi, Mustafa, Michel Bruneau, and Murat Saatcioglu, 2000) [15]
6. Vertically placed CFRP strips have increased both the flexural strength and post cracking. (Dizhur, Dmytro, Michael Griffith, and Jason Ingham, 2014 ) [16]

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