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RESEARCH ARTICLE

BEHAVIOUR OF SOFT STOREY BUILDINGS AGAINST BASE SHEAR

*Natchimuthu, S.

Assistant Professor, Arba Minch Institute of Technology, Arba Minch University, Ethiopia

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ABSTRACT

One of the observed common reinforced concrete (RC) structural failures during recent earthquakes is column shear failure. When the stiffness and associated strength are abruptly reduced in a structure along the height, earthquake-induced deformations tends to concentrate at the flexible and/or weak storey. The concentration of damage in a storey leads to large deformation in vertical members. The excessive deformation in vertical members often leads to the failure of these members and the collapse of the storey. Soft/weak first stories are especially common in multi-story residential buildings in urban areas, where the first storey often is used for open space, commercial facilities or garages. Structural walls that separate residential units in levels above may be discontinued in the first storey to meet the change in use. The first-story columns during strong earthquake shaking must resist a large base shear, inevitably leading to large storey drift concentrated in that storey. Experimental and analytical experiment was planned and conducted to study the influence of brick masonry infill against the lateral loading. In this study, one third scaled frame, with centrally brick infill in the frame along loading direction has been taken for experimental investigation. Totally two frames with two columns, along loading direction and one beam with and without infill were constructed in the frame. Until the cracks developed in infill and beam column joints, the contribution of lateral loading is being carried out, the change in lateral stiffness, strength, ductility and of the framed structure due to the presence of in fills and bare frame against lateral loading is investigated using experimental and analytically.

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INTRODUCTION

From the engineering points of view, the effects on a building of wind loads and lateral loads arising from seismic excitation become more significant as the height of the building is increased. Under lateral loads, the requirements for lateral stiffness and stability usually dominate over the requirements for vertical load and conventional framed-structures satisfying these requirements would require members both impractical and uneconomical. New systems must therefore be developed in order include the shear wall/core wall system, the tube-in-tube system, and the infilled frame system which is applicable to tall buildings with frame skeleton. In framed-type structures, walls and partitions are usually considered non-structural and it is a common practice to neglect the effects of infilling walls during structural analysis and design. However, the contributions of the infilling walls to the lateral stiffness and stability of framed structures have long been recognized. Experiments had been performed to investigate the behavior of infilled frames under lateral loads and the contributions of the in fills to the lateral stiffness and load-carrying capacity of the structures confirmed. Theories were also proposed in the later stages.

***Corresponding author:* Natchimuthu, S.**
Assistant Professor, Arba Minch Institute of Technology, Arba Minch University, Ethiopia

The object of the early researches was the possibility of taking into consideration the effects of the existing infilling walls to resist lateral load, which implied that the experimental models had to be conformable with practice and the infills used were usually made of brickwork or precast concrete units not bonded to the frame. This category of infilled frames has the disadvantage of being unstable and highly indeterminate, mainly due to the existence of slip between the frame and the infills when the structure is loaded laterally; and in addition, to the great variation in the properties and behaviour of the brick infills. Experimental evidences also indicated that under lateral load. Separations existed between the frame and the infills, which opened to an appreciable extent long before the ultimate strength of the structure was reached. To the occupants, the structure is at its ultimate state when the widths of the separations become intolerable, hence although the ultimate strength and the lateral stiffness of the frame is greatly increased by the presence of the infills, this amount of increase can only be considered as a 'reserve' of the structure which cannot be fully relied upon to resist lateral loads.

Infilled Frames: The idea of utilizing the in filled frame as a structural element was arise recently. To take full advantage of the infills, separations must be limited to tolerable values before the ultimate strength of the structure is reached. In this paper, test results of one bay single storey with filled and infilled frame models are presented to examine the behavior of the two categories of multistory infilled frame under lateral static loads. The merits of the two categories of infilled frames as lateral load resisting elements are compared and conclusions are drawn on the lateral stiffness, strength and failure modes of infilled frames under static lateral loadings.

Early Researches: Yaw-jengchiou, et.al jyh-cherngtzeng and yuh-wehnliou, *et al* (1999) have done an experimental investigation on experimental and analytical study of masonry infilled frames and concluded that the partially infilled masonry wall induces a short column effect and leads to severe failure of the column; on the other hand, the completely filled masonry wall increases the stiffness of the structure. Shan-huaxu and et.al di-taoniu, et.al (2003) have done on seismic behavior of reinforced concrete braced frame and concluded that, in braced frame structures that combine frame structures and the braces, a high degree of rigidity is secured and an effective energy dissipation mechanism is formed in which braces with elastic-plastic restoring force characteristics can dissipate a greater degree of the energy exerted by earthquake. Armin b. Mehrabi have done experimental and analytical studies have been carried out to investigate the performance of masonry- infilledrc frames under in-plane lateral loadings and concluded that the finite element models are able to simulate the failure mechanisms exhibited by infilled frames including the crushing and cracking of the concrete frames and masonry panels, and the sliding and separation of the mortar joints.

Basic Principles of Earthquake Resistant Design: Earthquake forces are generated by the dynamic response of the building to earthquake induced ground motion. This makes earthquake actions fundamentally different from any other imposed loads. Thus the earthquake forces imposed are directly influenced by the dynamic inelastic characteristics of the structure itself. While this is a complication, it provides an opportunity for the designer to heavily influence the earthquake forces imposed on the building. Through the careful selection of appropriate, well distributed lateral load resisting systems, and by ensuring the building is reasonably regular in both plan and elevation, the influence of many second order effects, such as torsional effects, can be minimised and significant simplifications can be made to model the dynamic building response.

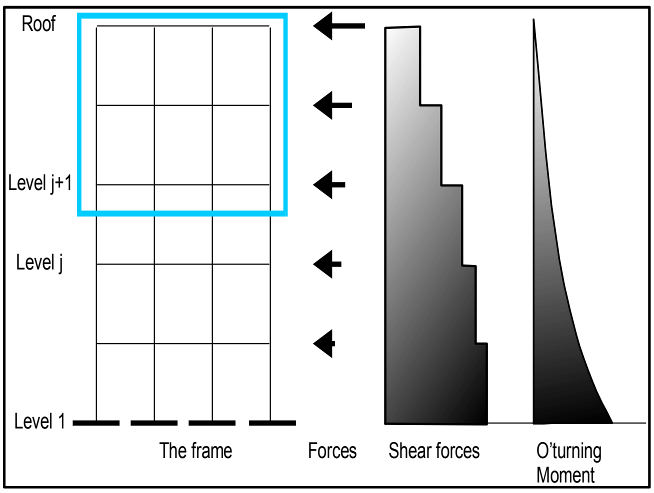

Figure 1. Loading Pattern and Resulting Internal Structural Actions

Most buildings can be reasonably considered as behaving as a laterally loaded vertical cantilever. The inertia generated earthquake forces are generally considered to act as lumped masses at each floor (or level). The magnitudes of these earthquake forces are usually assessed as being the product of seismic mass (dead load plus long-term live load) present at each level and the seismic acceleration generated at that level. The design process involves ensuring that the resistance provided at each level is sufficient to reliably sustain the sum of the lateral shear forces generated above that level to be avoided. Secondly earthquakes are highly variable dynamic events which designers tend to simplify into a set of quasi-static lateral loads. This approach enables relatively simple analysis and design, but noticeably departs from reality. It is therefore important to build into the structure a degree of toughness or robustness which will avoid the development of undesirable collapse mechanisms. Thirdly, although there is geological and seismological understanding of how earthquakes are initiated and how the energy release mechanisms translate into surface ground motion, earthquakes still inherently contain a higher level of uncertainty than do other forms of loading.

Soft Storey

The soft storey concept is very dangerous in earthquakes. A soft storey may be conveniently defined as one where the stiffness is less than 70% of the storey above it. This commonly occurs in multi-storey offices and hotels due to the desire for higher ceilings and more open spaces on the ground floor. Several design strategies are available for dealing with this situation.

Effective Earthquake Resistance Materials:

Desirable features of structural materials for earthquake resistance are:

- High ductility
- High strength-to-weight ratio
- Homogeneity

Soft-Storey Buildings

An open-ground-storey building, having only columns in the ground storey and both partition walls and columns in the upper storey, has two distinct characteristics:

- It is relatively flexible in the ground storey, i.e., the relative horizontal displacement it undergoes in the ground storey is much larger than what each of the storey above it does. This flexible ground storey is also called soft storey.
- It is relatively weak in ground storey, i.e., the total horizontal earthquake force it can carry in the ground storey is significantly smaller than what each of the storey above it can carry. Thus, the open ground storey may also be a weak storey.

Often, open-ground-storey buildings are called soft-storey buildings, even though their ground storey may be soft and weak. Generally, the soft or weak storey usually exists at the ground storey level, but it could be at any other storey level too.

Experimental Investigation

Model testing technique was employed in the Experimental investigation to examine the actual behaviour of infilled frames under lateral static load. Frame models were fabricated, and tested to rupture. The models consisted of two categories of frames with and without infills .The models were grouped into two categories. The first category which consists of scaled model without any infills, and another model with infills which are capable of resisting the lateral forces. The models comprised of the scaled sizes with respect to prototype with the scale of 1: 3.The storey heights were one meter for all the models.

The Frame: The models were tested as vertical cantilevers. To provide full end fixity at the foundation, base slab is made to bolted to the loading frame slab, the frame is modeled for the ratio of 1: 3, uniform dimensions are maintained throughout the frame.

The Infills: The infills were 100 mm in thickness, In order to study the behavior of the in filled frame up to rupture, it was necessary to use brick as the infilling material. Mortar of 1: 5 is prepared to act as a bonding agent in between the bricks. Care is taken to have good bonding between the frames and brick along the corners.

Reinforcements: It is not the object of the present research to look into the detailing of the reinforcements in the frames and infills. However, secondary reinforcements including temperature and shrinkage reinforcements are always necessary for concrete members. Care has been taken to ensure that the placement of reinforcement is uniform in both the frames.

Material Properties: The concrete strength was equivalent to average 28-day cube strength of 20Mpa. in laboratory tests where accurate control of materials and test conditions was possible. Since the aggregates were scaled down, trial mixes were tested to obtain mixes that attained the required strength with good compaction and workability. At the age of 28 days, the model was ready for test.

Reinforcement Details of R.C.Frame: For two columns of both frames, 4 nos. of 6mm diameter HYSD bars were provided. The reinforcements were curtailed in storeys due to reduction in axial force and bending moments.. The two legged stirrups of 6 mm diameter bars were used with the spacing of 80 mm c/c near supports and 100 mm c/c in the middle portion. For the same storey level beams, 4 nos. of 6 mm diameter bars were provided. The stirrups of 6 mm diameter bars were provided with 80 mm c/c near ends and 100 mm c/c in the middle portion.

Loading Arrangements: A horizontal loading system was adopted to eliminate the effects of the self-weight of the models. The model was hence tested as a vertical cantilever. In order that the model could be in a vertical plane, adjustments were made using a plumb line in the setting up of the model. Load was applied laterally through 10-ton hydraulic jacks under a central oil pressure and distributed into equal point loads.

Finite element modeling- using ansys software: There are several methods are available for analysis the RC infills frames, the methods are fail to model the stiffening action between the frame and infills and therefore fail to model the interactive forces in the members. Majority of the finite element studies have been carried out to study the elastic behavior. The studies on RC frame with infills have been lacking and there is need to study the monotonic and hysteretic behaviour under lateral loads. The analytical investigation adopted in the paper consists of finite element analysis, treating the infilled frame subjected to in plane loads as a plane stress problem. The frame and the infills are idealized using solid in 3D-non-linear finite element analysis based on the following assumptions**.**

- The concrete material is assumed to be initially isotropic
- The infill material is isotropic
- The reinforcement is assumed to be "smeared" throughout the element
- The tensile strength of brick masonry and concrete are taken to be 0.1 times their corresponding compressive strengths.

The frame is modeled in 3D using eight node solid elements. The reinforced cement concrete member of the frame namely, beams and columns have been modeled using SOLID 65 element which has 3DOF'S at each node available in the element library of ANSYS software. The above elements have been used for modeling bare. RC frame shown in fig.3 and the infilled RC frame as shown in fig.5 masonry have been modeled using SOLID 45 element which has 3DOF'S at each available in the element library of ANSYS software. Link element with 2 DOF at each node was used to model the behavior at the infilled frame interface. Non-linear material properties have been assigned to the elements. Additional concrete material data, such as transfer coefficient, tensile stresses, and compressive stresses are input in the data table typical shear transfer coefficient range from 0.0 to 1.0, with 0.0 representing a smooth crack and 1.0 representing a rough crack (no loss of shear transfer). This specification may be made for both the closed and open crack. In the present analysis the shear transfer coefficient for an open crack is assumed as 0.3 and that for closed crack is assumed as 0.7 if cracking occurs at an integration point, the cracking is modeled through an adjustment of material properties, which effectively treats the cracking as a "smeared band" of cracks, rather than discrete cracks.

Properties of Element: SOLID65 is used for the 3D modeling of solids with or without reinforcing bars (rebars). The solid is capable of cracking in tension and crushing in compression with the following assumption and restrictions:

- The element must have eight nodes
- The element is nonlinear and requires an iterative solution
- The beam must not have a zero length, area, or moment of inertia
- The following two options are not recommended if cracking or crushing nonlinearities are present
- Stress-stiffening effects
- Large strain and large deflection. Results may not converge or may be incorrect, especially if significantly large rotation is involved.

SOLID45 is used for the 3-D modeling of solid structures. The element is defined by eight nodes having three degrees of freedom at each node: translations in the nodal x, y, and z directions. The element has plasticity, creep, swelling, stress stiffening, large deflection, and large strain capabilities.

Faliure Modes

The possible failure modes as shown in figures 3 to 5 are considered in the analysis.

1) Frame members
   - Cracking in tension
   - Compressive failure
   - Yielding of reinforcement
2) Infills
   - Crushing of strut
   - Diagonal cracking
   - Shear bond failure
   - Tensile failure of tie member

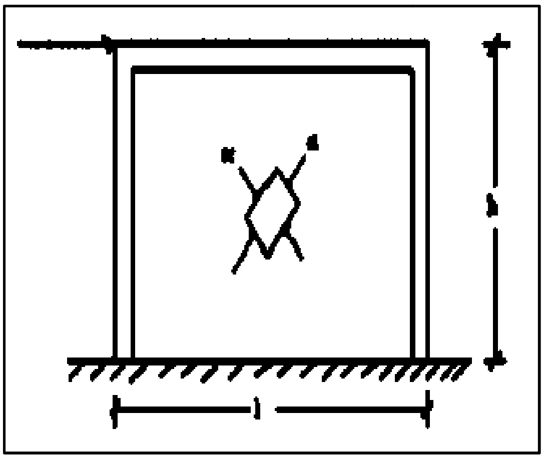

Fig. 3. Lateral loads on the frame

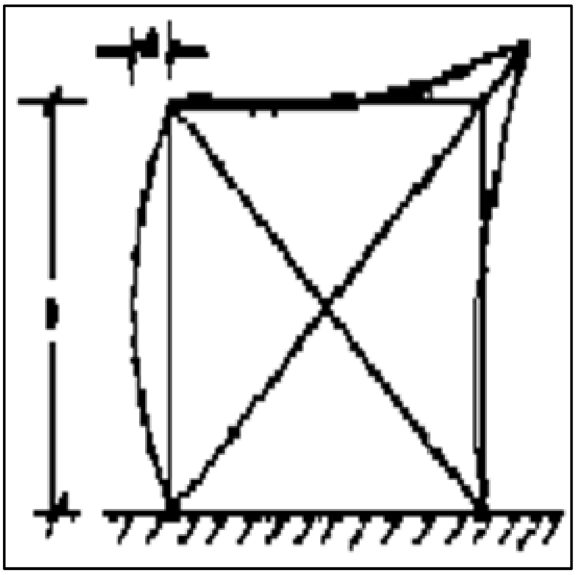

Fig. 4. Inter face cracking

RESULTS AND DISCUSSION

The lateral stiffness, strength and failure mode of the models recorded in the experimental investigations. For convenience in comparison, the stiffness of a model is measured by the magnitude of the total lateral load in KN required to produce a lateral displacement at the beam column joint and the ultimate load of the model is given by the Magnitude of the largest total lateral load the model could sustain immediately before failure. In order to examine the merits of the infills, the test results of a bare frame are also included. The general behavior of infilled frames under lateral static load will be discussed in the following Articles with respect to load-deflection characteristics, Length of contact, crack propagation and failure model, strain Distribution, stiffness and strength.

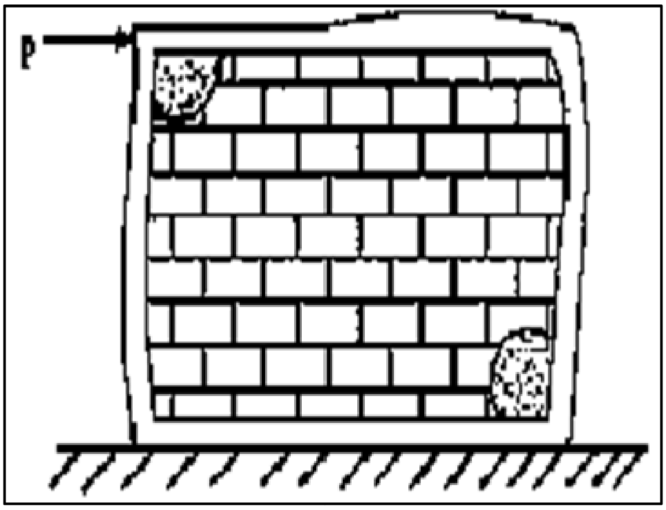

Fig. 5. Corner crushing mode

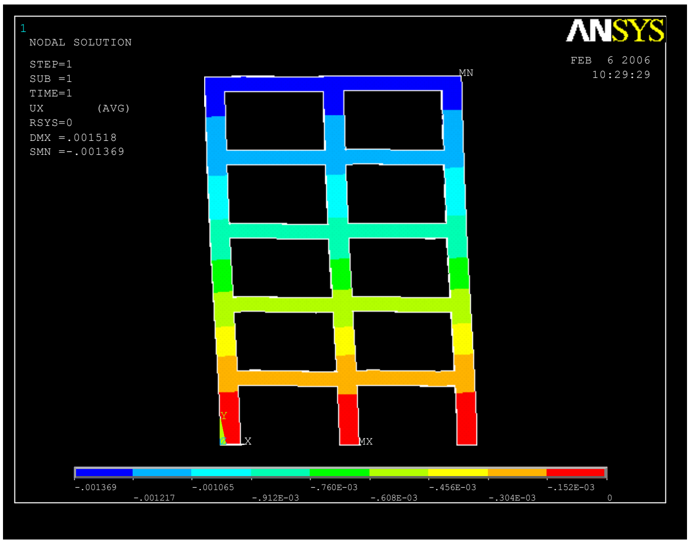

Fig. 6. Stress flow diagrams concrete frame

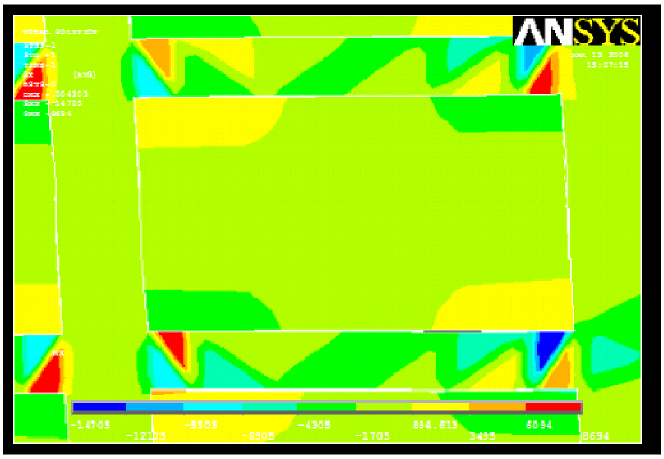

Fig. 7. Stress flow diagram for the infilled frame

Load-Deflection Curves

The load-deflection curves for the single bay frame models up to approximately 90% of the ultimate load. At the ultimate stage, due to excessive creeping, the deflections were increasing continuously until the models failed. Hence the ultimate deflections are obtained using LVDT, which records the deflection at the each level. The load deflection curves of the two categories of models are discussed in the following articles.

Loads-deflection characteristics of infilled frames: The models in this category consisted of the modeled frame with infill provided in between the two frames of the column and the beams. The curves are characterized by the phenomenon of slips and slopes are smaller compared with models with infill, but the ultimate deflections are much lower than the bared frames. Slip may be due to the loss of bond between the frame and the infills, and re-adjustment of the infills within the frame, Causes additional deflections to occur under constant load. Since solid infills have larger area of contact and better fit within the frames. It is interesting to note that no slip had been recorded in models. The existence of slip in infilled frames renders the initial higher stiffness of the structure unsafe to be utilized in practice. Hence the stiffness of the structure is to be considered as the stiffness available after slip has occurred. This criterion is recommended in all stiffness calculations. The length of contact is defined as the remaining contact length between the frame and the infills after separation has occurred, and is hence a parameter specific to infilled frames.

Length of Contact: In the testing of series, almost immediately after the model was loaded, boundary cracks indicating relative movement between the frame and the infills could be observed to develop around the infills in frames, which propagated around the boundary ,as the load was increased until slip occurred, when the cracks were found to surround the entire boundary of the infills be observed after slip had occurred; the first visible separation could usually be observed immediately after slip and the gap widened with further increase in load. The variations with load of the observed length of contact for the interfaces of the infills with the windward columns and the beam are observed. In this model, separations were detected between the windward columns and the infills.

Crack Propagation and Failure Mode: The propagation of cracks observed in the experiments, in which the loads are acting from right to left and the values indicate the magnitude of the total lateral load in KN. It can be observed that, in general, the crack pattern in models were characterised by considerably large number of cracks in the beam column joints , propagation of cracks in much high in the windward column, where else the formation of hinges failure are also much higher in the windward column, this resulted in the earlier failure of the column. Leeward column are affected by means of the failure in the beam column joints, and with few crack pattern in the column joints.

Load-deflection characteristics of bare frames: The models in this category consisted of the modeled frame without infill provided in between the two frames of the column and the beams. The curves are characterized by the phenomenon of slips and slopes are smaller compared with models without infill, but the ultimate deflections are much larger than the infilled frames. Failure of the beam column joints, due to the lateral application of load, causes additional deflections to occur under constant load. Since there is no lateral resistance of the structure against the lateral loading, it is interesting to note that slip had been recorded in models.

Fig: 8. loading arrangement set up (infilled frames)

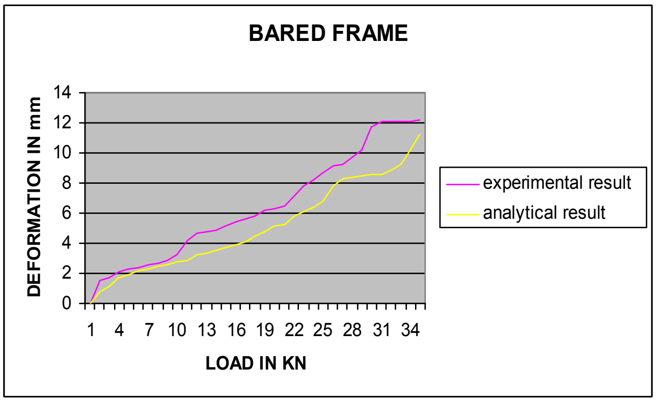

Fig. 9. Load Vs deflection graph

As a result of larger unbalance lateral loading, failure of the hinges of the column have occurred, this causes the failure of the total bared frames.

Strain Distribution: The distribution of strains in the infill of the models due to the total load approximately equal to 80% of the ultimate load. Strains are calibrated using the DEMECH. In general, the strains were very small in the initial stage and increased slowly with load increments. At the intermediate stage the compressive strains increased at a quicker rate while the tensile strains increased abruptly, resulting in continuous cracking throughout the infills. This phenomenon persisted to the ultimate stage when the phenomenon of creep was very prominent and the strains were growing continuously until the models failed.

Strain distribution in infilled frames: In this type of model, the combined action of all the infills as a lateral load resisting element can be observed from the strain distribution. Along the compression diagonal which extended from the leeward column/beam, junction at 45° to the horizontal to intersect the windward column, a 'compression band' could be figured out from the strain distribution which was characterised by enormous magnitude in both tensile and compressive strains compared with other locations. Although the strains along the compression diagonal are not prominent at low load the abrupt increase at high load is obvious. In model with infills the maximum tensile strain recorded at the bottom infill after cracking had occurred.

Strain distribution in bared frames: In case of this type of model, the effect of bare frame against lateral loading can be examined using the strain distribution. As a result of the lateral loading, leeward column experience the hinges failure at the beam column joint, these results in the formation of the tensile strains in the leeward column, and compressive strains at windward column, these results in the failure of the frame.

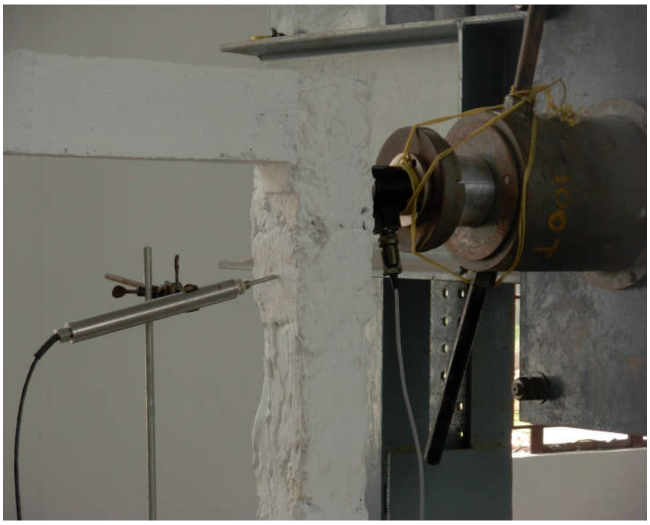

Fig. 10. Experimental setup (bared frame)

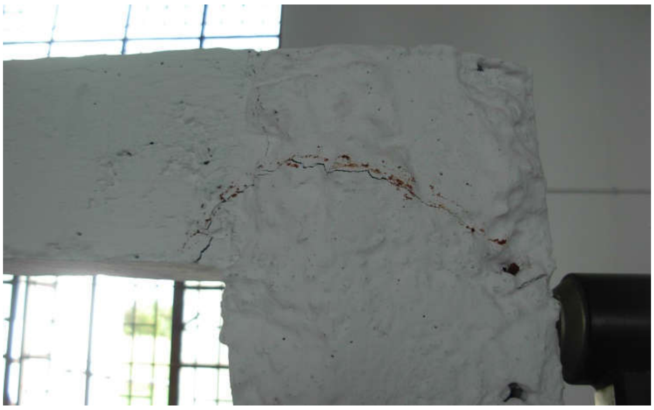

Fig. 11. Crack pattern (bared frame)

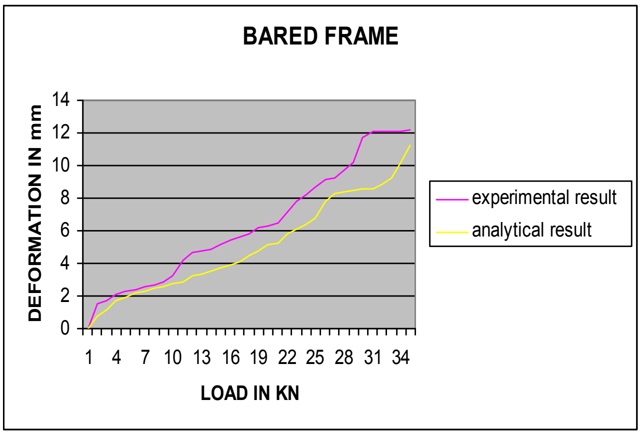

Fig. 12. Load VS deformation graph

Comparison of Results

The experimental results were compared with analytical results and graphs were plotted load vs. deflection. In the initial stage the analytical result are more or less equal to the experimental value compare to analytical value. In the later stage the deflection from analytical work is lesser than the deflection obtained from experimental work. The ANSYS results are more accurate as compared to the experimental results because in ANSYS the whole frame is divided into elements for analysis. So the deflection in analytical is lesser than experimental.

Comparison of deformations

- The ultimate base shear is reached in the sixteenth cycle of loading. After reaching the ultimate load, post ultimate cycles are performed to study the behavior of the RC frame until final collapse. The base shear versus storey deflection in each cycle till failure is obtained.
- It is observed that at a maximum base shear, cracks are initiated at the junction of the loaded and middle end of the beam and column storey where the moment and shear forces are maximum. The crack pattern indicated a combined effect of flexure and shear failure.
- Separation of infill occurred at the tension corners and the high stress concentration at the loaded diagonal ends lead to early crushing of the loaded corners.
- Cracks developed in the leeward column (opposite to the loaded end) of the bottom.
- Secondary reinforcements contribute to the stiffness and strength of the structure by increasing the modulus of elasticity of the infilling material. They also serve to limit the widening of cracks and spalling of the infills after cracks have developed.
- The contributions of the infills to the lateral stiffness and strength of the structure is usually great when the action in the infills is compressive.
- Tension cracks in the infills will not result in total collapse of the structure, cracks in infilled frames are generally not extensive and few in number. They usually develop along the compression diagonals and in the lintel. Beams in form of tension cracks. Infilled frames with solid infills usually fail by compression at the two compression corners.

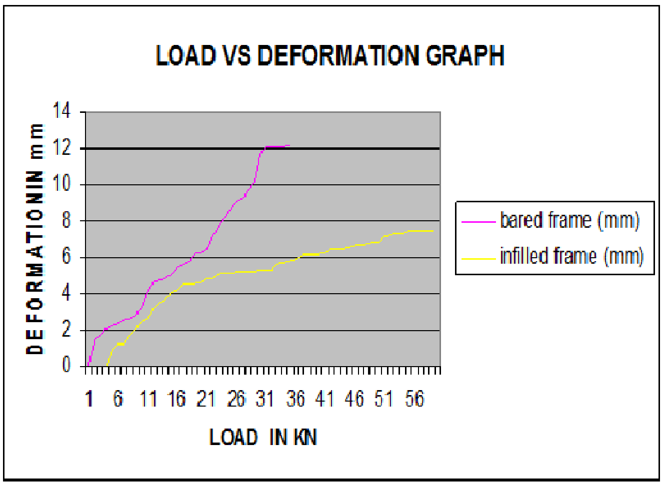

Fig: 13. Comparison of bared frame and infilled

Behaviour of Infilled frames under lateral static load: With reference to the behavior of the infilled frame and bared frame models under lateral static, the following conclusions can be drawn for the preformation of the soft storey frames:

- When the breadth/height ratio of the infill is increased, the lateral stiffness and strength of the structure is also increased.
- The strains are comparatively high along the compression diagonals, but still significant at other locations.
- Cracks in infilled frames are generally extensive and numerous and in form of diagonal shear cracks. Usually, tension cracks will not result in total collapse of the structure.

Scope for further studies: To go on with the further development in this study, experimental program can be carried out with the presence of the connectors in between the frames and infill can be provided.

REFERENCES

Diptesh Das and C.V.R. Murty,"Brick masonry infills in seismic design of RC framed buildings",(Part-l &ll) Indian concrete journal, July 2004.

Murthy C.V.R, *IITK – BMTPC Earthquake tips*, Indian Institute of Technology, Kanpur, India, 2002

Paulay.T and Priestley.M.J.N. *Seismic Design of Reinforced concrete and Masonry Buildings*, John Wiley & Sons, 1992

Structural behavior of reinforced concrete frames with confined infill Dr.C. Umarani, AICTE-ISTE STTP course on "Earthquake Resistant Design of High-rise Structures"

Teresa Guevara L. and Luis E. Garcia, "The Captive- and Short-column effects", *Earthquake Spectra*, 21(1), 2005, pp. 141-160

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