Seismic Analysis of High-Rise Open Ground Storey Framed Building

Krushna B. Avhad

***Abstract**: The concept of open ground building (OGS) has taken its place in the Indian urban environment due to the fact that it provides the parking facility in the ground storey of the building. The cost of construction of this type of building is much less than that of a building with basement parking. Surveys of buildings failed in the past earthquakes show that this types of buildings are found to be one of the most vulnerable. The majority of buildings that failed during the Bhuj earthquake (2001) and Gujraat earthquake were of the open ground storey type. The collapse mechanism of such type of building is predominantly due to the formation of soft-storey behavior in the ground storey of this type of building. The sudden reduction in lateral stiffness and mass in the ground storey results in higher stresses in the columns of ground storey under seismic loading. In conventional design practice, the contribution of stiffness of infill walls present in upper storeys of OGS framed buildings are ignored in the structural modelling (commonly called bare frame analysis). Design based on such analysis, results in under-estimation of the bending moments and shear forces in the columns of ground storey, and hence it may be one of the reasons responsible for the failures observed. After the Bhuj earthquake took place, the IS 1893 code was revised in 2002, incorporating new design recommendations to address OGS framed buildings. According to this clause 7.10.3(a) of the same code states: "The columns and beams of the soft-storey are to be designed for the multiplication factor of 2.5 times the storey shears and moments calculated under seismic loads of bare frame". The prescribed multiplication factor (MF) of 2.5, applicable for all OGS framed buildings, is proved to be fairly higher and suggests that all existing OGS framed buildings (those designed to earlier codes) are highly vulnerable under seismic loading. This MF value however does not account for number of storeys, number of bays, type and number of infill walls present, etc and hence it is independent of all of the above factors. Present study deals with various aspects related to the performance of OGS buildings. The values of magnification factor recommended in literatures vary from 1.0 to 4.8 (Kaushik, 2009).The main objective of present study is the study of comparative performance of OGS buildings designed according to various MFs using nonlinear analysis. As the more realistic performance of the OGS building requires the modelling the stiffness and strength of the infill walls, the stiffness and strength of the infill walls also considered. The variations in the type of the infill walls using in Indian constructions are significant. Depending on the modulus of elasticity and the strength, it can be classified as strong or weak. The two extreme cases of infill walls, strong and weak are considered in the study. The behavior of buildings depends on the type of foundations and soils also. Depending on the foundations resting on soft or hard soils, the displacement boundary conditions at the bottom of foundations can be considered as hinged or fixed. As the modeling of soils is not in the scope of the study, two boundary conditions, fixed and hinged, that represent two extreme conditions are considered.*

***Keywords—**: infill walls, diagonal strut, open ground storey, pushover analysis, High rise building.*

I. INTRODUCTION

Open ground storey (also known as soft storey) buildings are commonly used in the urban environment nowadays since they provide parking area which is most required. This type of building shows comparatively a higher tendency to collapse during earthquake because of the soft storey effect. Large lateral displacements get induced at the first floor level of such buildings yielding large curvatures in the ground storey columns. The bending moments and shear forces in these columns are also magnified accordingly as compared to a bare frame building (without a soft storey). The energy developed during earthquake loading is dissipated by the vertical resisting elements of the ground storey which resulting the occurrence of plastic deformations which transforms the ground storey into a mechanism, in which the collapse is unavoidable. The construction of open ground storey is very dangerous if not designed suitably and with proper care. This paper is an attempt towards the study of the comparative performance evaluation of three OGS buildings case studies.

Fig. 1 Some Typical Example of Open Ground Storey Building

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* Correspondence Author
Krushna B. Avhad*, ME Second Year Late G. N. Sapkal College of Engineering, Nasik, India.

Modern seismic codes just neglect the effects of non-structural infill walls during analysis. Conventional practice neglects the effect of infill stiffness by assuming that this would give some conservative results, Fardis and Panagiotakos (1997). However this is not true in the case of columns present in the open ground storey. Many codes (e.g., IS 1893- 2002, EC -8, IBC) recommended a factor to take care for the magnification of bending moments and shear forces. Scarlet (1997) studied the quantification of seismic forces in OGS buildings proposing a multiplication factor for base shear for soft-storey type of building. This procedure requires the analysis of OGS framed building by modelling the infill walls considering their stiffness. The proposed multiplication factor ranges from 1.86 to 3.28 as the number of storeys increases from six to twenty. Fardis et. al. (1999) observed that the bending of the columns in the more infilled storey (first storey of OGS building) under the lateral load is in an opposing direction to that of the less infilled storey (ground storey). Based on this observation, an alternate capacity design rule was proposed for the beams present at the top (first floor level) of the less infilled storey i.e. ground storey. According to this rule, the demand on the beams in the first floor should also be increased, depending on the capacity of the columns in the first storey. IS 1893-2002 recommends a factor 2.5 accounting for the magnification of the forces in the ground storey of an OGS building. According to the clause, the shear forces and bending moments in the ground storey columns, obtained from the bare frame analysis are to be multiplied by a factor 2.5. The factor is to take care for the increase in the forces in the ground floor columns due to the presence of soft-storey. There are many such open ground storey buildings existing in the India which have been designed with earlier codes. Such buildings are designed only for gravity load condition. But as per the present code, both seismic lateral loads and the magnification factor shall be considered while designing any building. But the surveys of some existing buildings in India comments that there are existing OGS buildings that are designed for seismic lateral loads as per design code but not by considereing the magnification factor of value 2.5.It was recognized subsequently that the MF of value 2.5 should not be applied to the beams as because this is likely to result in the formation of 'strong beam-weak column' situation (with the plastic hinge forming at the column end, rather than the beam end). The clause was amended in the year 2005 as follows: It is not advisable to design the beams of the soft-storey also to design for higher storey shears as recommended by the above clause. Strengthening of beams will further increase the demand on the columns, and deny the plastic hinge formation in the beams. These recommendations have met with some resistance in design and construction practice due to the congestion of heavy reinforcement in the columns. Hence the aims of this thesis are to review the design provisions for OGS buildings, to study their behavior and also to provide a rational approach to enable the design of ground storey columns in OGS buildings. The behavior of OGS framed building is totally differently as compared to a bare framed building (without any infill) or a fully infilled framed building under lateral loads. The bare frame is much less stiffer than a fully infilled frame; it resists the applied lateral load through frame action and shows well-distributed plastic hinges at failure condition. But when this frame is fully infilled, truss action is introduced. A fully infilled frame shows lesser inter-storey drift, though it attracts higher base shear (due to increased stiffness). A fully infilled frame yields lesser force in the frame elements and hence dissipates greater amount of energy through infill walls. The strength and stiffness of infill walls in infilled frame buildings are ignored during the structural modelling in conventional design practice. The design in such cases will generally be conservative in the case of fully infilled framed building than others. But things will be somewhat different for an OGS framed building. OGS building being slightly stiffer than the bare frame, has larger storey drift (especially in the ground storey), and fails due to soft storey-mechanism at the ground floor. Therefore, it may not be conservative to ignore strength and stiffness of infill wall while designing OGS buildings. The failure pattern observed in the buildings during the Jabalpur earthquake in 1997 showed higher vulnerability of OGS buildings. Some reinforced concrete framed building which collapsed partially, had open ground storey on one side, and brick infill walls on the other side.

II. TYPICAL MASONRY INFILLED BUILDINGS

Typical masonry infilled frames contain infill walls throughout the building in all storeys uniformly. Although infill walls are known to provide the stiffness and strength to the building globally, these are considered as 'non-structural' by design codes and are commonly ignored in the design practice for more convenience. The presence of infill walls in a framed building not only enhance the lateral stiffness in the building, but also alters the transmission of forces in beams and columns, as compared to the bare frame. In a bare frame, the resistance to lateral force occurs by the development of bending moments and shear forces in the beams and columns through the rigid jointed action of the beam-column joints. In the case of infilled frame, a substantial truss action can be observed, contributing to reduced bending moments but increased axial forces in beams and columns, (Riddington and Smith, 1977; Holmes, 1961).The infill in each panel behaves somewhat like a diagonal strut as shown in Fig. below.

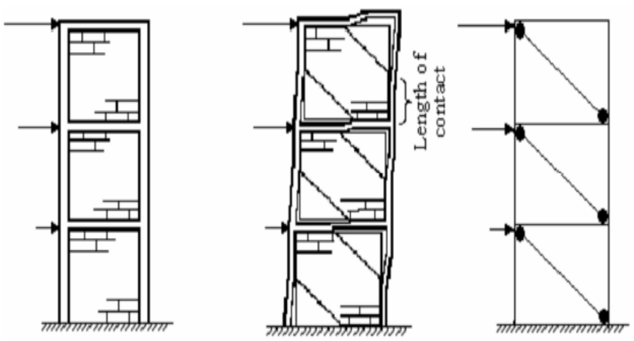

Fig. 2 a) Infilled Frame b) Deformed Frame c) Equivalent Strut Model

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Fig. Showing behavior of infilled frame building. Hence these infill walls are beneficial to the building, only when they are evenly placed in plan and elevation. These infill walls come to rescue the structure at worst lateral loads such as seismic loading and wind loading owing to its high stiffness and strength.

III. OPEN GROUND STOREY (OGS) BUILDINGS

The presence of infill walls in the upper storeys of the OGS building increases the stiffness of the building, as seen in a typical infilled framed building. Due to increase in the stiffness, the base shear demand on the building increases while in the case of typical infilled frame building, the increased base shear is shared by both the frames and infill walls in all the storeys. In OGS buildings, where the infill walls are not present in the ground storey, the increased base shear is resisted entirely by the columns of the ground storey, without the possibility of any load sharing by the adjoining infill walls. The increased shear forces in the ground storey columns will induce increase in the bending moments and curvatures, causing relatively larger drifts at the first floor level. The large lateral deflections further results in the bending moments due to the P-Δ effect. Plastic hinges gets developed at the top and bottom ends of the ground storey columns. The upper storeys remain undamaged and move almost like a rigid body. The damage mostly occurs in the ground storey columns which is termed as typical 'soft-storey collapse'. This is also called a 'storey-mechanism' or 'column mechanism' in the ground storey as shown in the figures below. These buildings are vulnerable due to the sudden lowering of stiffness or strength (vertical irregularity) in the ground storey as compared to a typical infilled frame building.

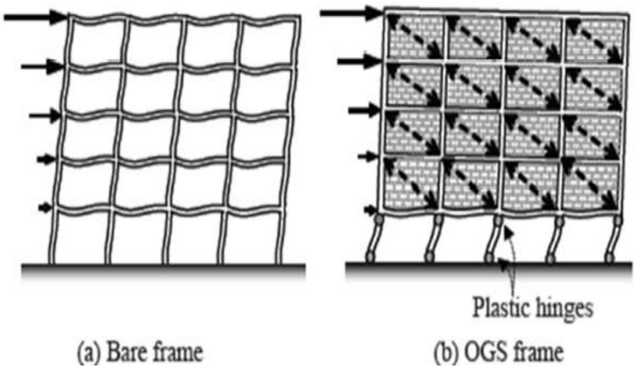

Fig. 3 Showing difference in Behavior between Bare, Infill and OGS Building Frame

IV. STUDY AREA

The accurate analysis of the OGS buildings requires the modeling of such building frames with infill walls for its stiffness and strength. There are many implications of considering infill walls in the OGS buildings but our aims for the case study or the area of our concern are stated below:

a) The project illustrates a simple computer-based analysis technique called pushover analysis for performance-based design of building frameworks subjected to earthquake loading.

b) The technique is commonly based on the conventional displacement method of elastic analysis under constant gravity loads and incrementally increasing lateral loads. Such inelastic analysis procedures help to demonstrate how building really performs by identifying the failure modes and the potential for progressive collapse. For this there should be a clear need to assess the design guidelines recommended by various codes. Existing recommendations for the design of OGS buildings do not depend on the factors such as number of storeys, number of bays, type and the number of infill walls present, etc.

V. OBJECTIVES OF THE THESIS

From the above discussion the objectives of the present study can be figure out as follows:

a. To study the behavior of Open Ground Storey buildings designed considering the magnification factor (M.F.) suggested by IS codes.
b. To study the performance and behavior of the typical OGS buildings using pushover Analysis.

VI. SCOPE OF THE STUDY

Open ground storey (OGS) buildings have been most common nowadays and are constructed heavily in high populated countries like India since they provide much needed parking space in an urban environment. Failures observed in past earthquakes proved that the collapse in such buildings is predominantly due to the formation of soft-storey mechanism in the columns of the ground storey building. The scopes of this project are summarized as:

- RC framed Buildings, which is regular in plan
- 10 storey buildings without basement and shear wall.
- Infill walls non-integrated with RC frames.
- Concept of out of plane action of masonry not taken into account.

Modeling of the selected buildings with and without considering their infill strength and stiffness. Models need to consider the above mentioned two types of end support conditions.

1. Performing nonlinear analysis of the selected building models and a comparative study on the results obtained from the analyses.
2. Finally the observations of results and discussions

VII. LITERATURE REVIEW

IS code 1893-2002 recommendations-

The OGS buildings is considered to be as extreme soft-storey type of buildings in most of the practical situations, and shall be designed considering special provisions so as to increase the stiffness in lateral direction or strength of the soft/open ground storey.

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A dynamic analysis is suggested which includes the strength and stiffness effects of infill walls and also the inelastic deformations of members, particularly suggested in those soft-storey of such buildings. The members in the soft/open storey shall be designed as per suggested by the codes considered in this project. However, IS 1893-2002, does not give any explicit recommendations on the torey g of the infills for the open ground torey building frame.

A. Conventional Design Practice-

Conventional design practice follows the equivalent static analysis i.e. linear static analysis, ignoring the stiffness of the infill walls. This bare frame analysis as suggested by the design code, is preferable because the modeling of infill walls is much required for the design office environment. Moreover, inelastic dynamic analysis, which includes the degradation of stiffness and strength of infill walls can be quite complicated. A check on the stiffness ratio (*k0/k1*, where *k0* and *k1* are the stiffness in the lateral direction of ground storey and first storey respectively), will almost invariably, yield at a value less than 0.7 in OGS buildings. Hence the shear forces and bending moments of the ground storey columns, calculated from an equivalent static analysis of the bare frame ignoring the stiffness of infill walls, should be multiplied by a factor of 2.5 for design purposes as suggested by the code. In some of the cases, especially in the presence of infill walls with large openings, the OGS frame may resemble to be vertically regular as per the code, and strictly, as per the code, no multiplication of column forces in the ground storey is required. An approach similar to IS 1893 -2002 is followed by the European codes, except that the expression used for the multiplication factor being different. Concepts given by (Scarlet, 1997; Kaushik, 2006; Fardis *et. al.*,1999; Arlekar *et. al.*, 1997; Hashmi and Madan, 2008) and others Fardis *et. al.* (1999) noted out that the MF proposed by the EC 8 (2004) expression not only results to higher seismic forces and reinforcements to the building frame but also lacks a rational basis. Due to these reasons, despite of its general effectiveness in protecting the columns of the soft ground storey buildings, MF proposed by Euro code needs to be revised. A revision was also proposed in this study at the end based on capacity based design for the beams of the open ground storey. Kaushik (2006**)** commented that the ambiguity in the use of expression given by EC 8 (2004) for infilled building frames. It is seen that the natural time period of vibration of the infilled building frames suggested by EC 8 (2004) for the estimation of base shear is an inverse function of the total area of the infill walls in the ground storey frame. For GS type of buildings, the natural time period of vibration becomes unrealistically much higher due to zero value of area of infill wall in the ground storey.

VIII. PROJECT WORK

To perform any sort of analysis i.e. linear/non-linear, static/dynamic it's necessary to develop a computational model.

A. EXAMPLE FRAMES

The type of building frames considered for the case study is vertically irregular. The building was of 10 storeyed with the number of bays remaining constant i.e. 6.

B. MAGNIFICATION FACTOR (MF)

It is a factor which is considered when any building frame is designed ignoring its infill wall but considering its weight i.e. for OGS type of building. Since we know that the function of infill wall in a building is to provide stiffness to the building so that it can stand on the surface but since we neglect infill wall in such building, the purpose of providing that stiffness and help any building to stand is provided by other element which is column. Whatever load the building was withstanding is now multiplied by this MF value so that it can stand still by providing sufficient stiffness. Talking about MF value there are several codes which suggests different values of MF. But in our case we have considered the Indian Code which suggests the MF value to be 2.5.

- Frame type-Bare, Full Infilled & OGS
- Storeys-10
- Bays-6
- MF-1.0 & 2.5
- Type of Infill walls-No infill walls, Strong & Weak
- Support conditions-Hinged & Fixed

Apart from variations in height we have considered other variations in the type of building frames for this project. The same frames were redesigned for other different cases like variation in their base support (fixed and hinged), types of infill wall provided (strong and weak)and also in terms of Open Ground Storey (OGS) introducing a term called Magnification factor (MF).

C. SEISMIC DESIGN DATA

1 Seismic Zone- V
2 Zone factor (Z)- 0.36
3 Response reduction factor (R)- 5
4 Importance factor (I)- 1
5 Soil type- Medium soil
6 Damping ratio- 5%
7 Frame Type- Special Moment Resisting Frame

D. MATERIAL PROPERTIES

1 Unit weight of concrete 25 kN/m3
2 Unit weight of Infill walls 18kN/m3
3 Characteristic Strength of concrete 25 MPa
4 Characteristic Strength of concrete 415 MPa
5 Compressive strength of strong masonry (*Em*) 5000MPa
6 Compressive strength of weak masonry (*Em*) 350MPa
7 Modulus of elasticity of Masonry Infill walls (*Em*) 750*f'm*
8 Damping ratio 5%
9 Modulus of elasticity of steel 2E5 MPa
9 Frame Type Special Moment Resisting Frame
10 Slab thickness 150 mm
11 Wall thickness 230 mm

E. STRUCTURAL ELEMENTS

The dimensions of the elements of the structure were:

1. Beam : 230 mm x 350 mm

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2. Column : 300 mm x 300 mm
3. Slab thickness : 150 mm
4. Wall thickness : 230 mm
5. Parapet height : 230 mm

F. LOADS CONSIDERED

The types of load considered during the design were:
1. Self-weight of beams and columns
2. Weight of slab
3. Infill weight
4. Parapet weight
5. Floor finish of 1.5 KN/m2
6. Live load of 3 KN/m2(as per IS 1893-2002)

G. DESIGN OF BUILDING FRAMES

All the above building frames were first designed in the software called Staad Pro. After designing in the software, necessary data such as shear forces, bending moment, axial load, reinforcement detailing of each beam and column were imported to another software called SAP for modelling purpose.

H. STRUCTURAL MODELLING

All the above structures were now ready for modelling and were about to be modelled in the software SAP. As per our objective we were focused on the behavior analysis of the building frame here in this step we introduced the type of non-linear analysis to study the behavior said to be as pushover analysis.

IX. PUSHOVER ANALYSIS

Pushover analysis is a static, nonlinear procedure to analysis any building where the building is loaded incrementally with a certain definite predefined pattern (i.e., inverted triangular or uniform). Local nonlinear effects are modelled and the structure is pushed until a collapse mechanism is developed in the same building. With increase in the magnitude of loads, weak links and failure modes of the building areobserved. At each step, the structure is pushed until enough hinges form to develop a curve between base shear and the corresponding roof displacement of the building and this curve commonly known as pushover curve.At each step, the total base shear and the top displacement are plotted to get this pushover curve at various phases.this gives an idea of the maximum base shear that the structure is capable of resisting and the corresponding inelastic drift that it can overcome. For regular buildings, it also gives the estimate of global stiffness of the building.

A. STRUCTURAL ELEMENTS MODELLING

Beams and columns-
They are modelled as frame elements with central lines joining at nodes.
Beam-column joints-
The rigid beam-column joints are modelled by giving end offsets at the joints. A rigid zone factor of 1.0 was taken.
Slabs-
The floor slabs are assumed to act as diaphragms, ensuring the integral action of all the vertical lateral loadresisting elements. The weight of the slab was distributed in triangular and trapezoidal form to the surrounding beams as per IS 456:2000.

B. MODELLING OF INFILL WALL

Infill walls are two dimensional elements that can be modelled with orthotropic plate element for linear analysis of buildings with infill wall. But the nonlinear modelling of a two dimensional plate element is not understood well. Therefore infill wall has to be modelled with a one-dimensional line element for nonlinear analysis of the buildings. All of these buildings model with infill walls modelled as onedimensional line element is used in the present study for nonlinear analysis. Infill walls are modelled here as equivalent diagonal strut elements. In a linear structural analysis, the required properties of an equivalent strut are the effective width, thickness, length and elastic modulus. The thickness (*t*) is assumed to be same as that of the infill wall. The length (*d*) is the diagonal length of the frame. The remaining properties to be determined are the effective width (*w*) and elastic modulus (*Es*) of the equivalent strut. The strength of the equivalent strut is required to check its capacity with the axial load demand in the strut. The simplest form *w* and *Es* are taken equal to *d*/4 and *Em* (modulus of masonry), respectively.

X. ELASTIC MODULUS OF EQUIVALENT STRUT

The elastic modulus of the equivalent strut Es can be equated to Em, the elastic modulus of the masonry. Krishnakedar (2004) conducted a series of experiments on masonry prisms on various types of bricks in India. Following range of values for Em were obtained. Em= 350 to 800 MPa for table moulded bricks Em= 2500 to 5000 MPa for wire cut bricks

A. COMPARISON OF BEHAVIOR OF BARE FRAMES DESIGNED WITH VARIOUS MF

1) Result of the pushover curves of 10 storeyed 6 bay Frame with MF=1.0 Fixed support, 10 stored 6 bay Frame with MF=2.5 Fixed support And 10 stored 6 bay Frame with MF=3 Fixed support

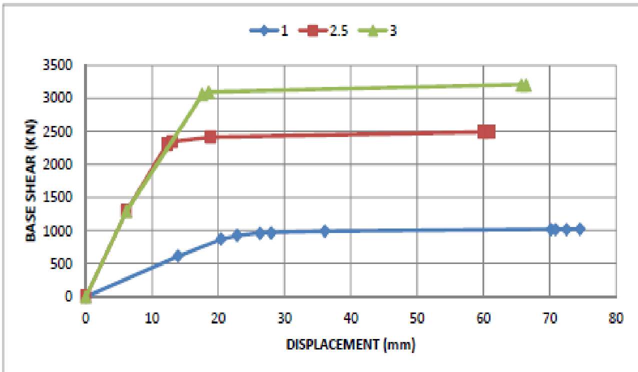

Fig. 4 Pushover Curves of Bare Frames MF1.0, 2.5& 3.0-Hinged

From the graph above base shear capacity of a 10 storeyed building designed with MF of 3.0 & 2.5 is about 28 % more than that designed with MF 1.0 whereas the deflection vary by note more than 15 mm between them.

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B. COMPARISON OF PUSHOVER CURVES OF INFILL WALL CONDITION

In this topic we will be comparing the pushover curves obtained between strong infill versus weak infill for both fixed and hinged support as shown in graph below. For strong infill condition the value of modulus of elasticity of brick is taken as 5000 MPa whereas for weak infill it is taken as 350 MPa. The pushover curves obtained due to the design of this type of building frame are shown below:

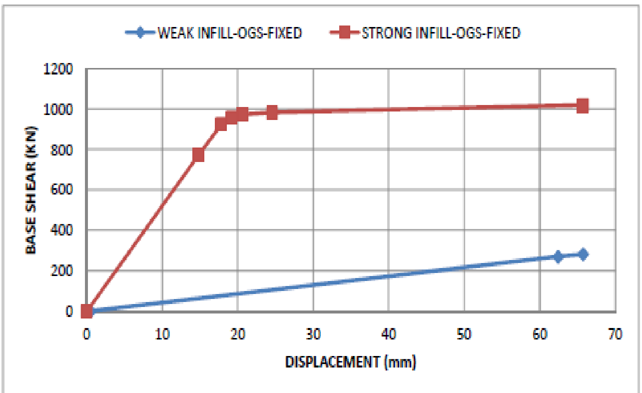

Fig. 5 Pushover Curves of OGS-MF2.5-Weak-Fixed, OGS-MF2.5-Strong-Fixed

From this pushover curve above the same thing we can predict that the frame designed with strong infill has the higher capacity than that of the weak infill. The magnitude of load that the strong infill can take is about 1000 KN whereas that of weak infill has about 300 KN. Strong infill 10s frame with fixed support can take 3 times more load than that with weak infill whereas the deflection being almost same about 66 mm for both the cases. Also for weak infill in this case it seems that this frame doesn't provide any warning before failure since it is varying linearly but the strong one it has a definite curve and possesses the ability of giving some warning before failure.

C. COMPARISON BETWEEN FIXED AND HINGED TYPE OF SUPPORT

Here we will be discussing between pushover curves that obtained between fixed and hinged type of support only for strong infill for both 4 and 10 storeyed building frame.

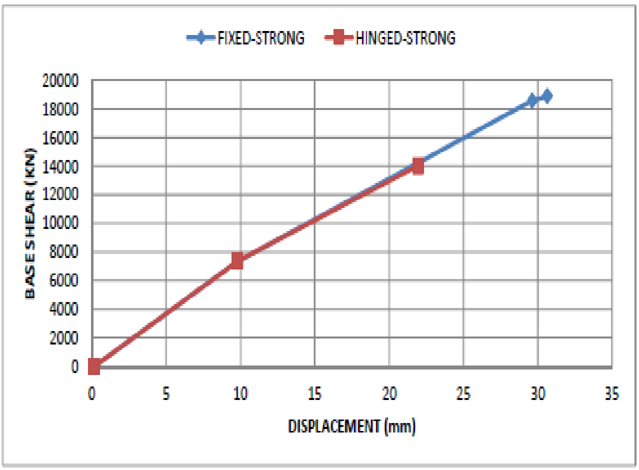

Fig. 6 Pushover Curves of MF=1.0, Hinged And MF=1.0 Fixed

For 10S frame also the behavior of fixed & hinged supported frame with full infill is almost same only the difference being in the base shear. For fixed support the strength is more than hinged one almost by 29% and the deflection that the fixed supported frame can go up to 31 mm whereas hinged up to 22 mm.

D. COMPARISON OF PUSHOVER CURVES OF 10S BUILDING FRAME

1. Base shear capacity of OGS frame designed for MF = 3 is about 1.5 times more than that of MF =2.5,
2. Base shear capacity of OGS frame designed for MF = 2.5 is about 2.5 times more than that of MF =1.0,
3. Base shear capacity of full infilled frame designed for MF = 1.0 is about 1.1 times more than that of Bare frame,
4. Base shear capacity of full infilled frame designed for MF = 1.0 is about 9.5 times more than that of OGS frame designed with MF = 2.5,

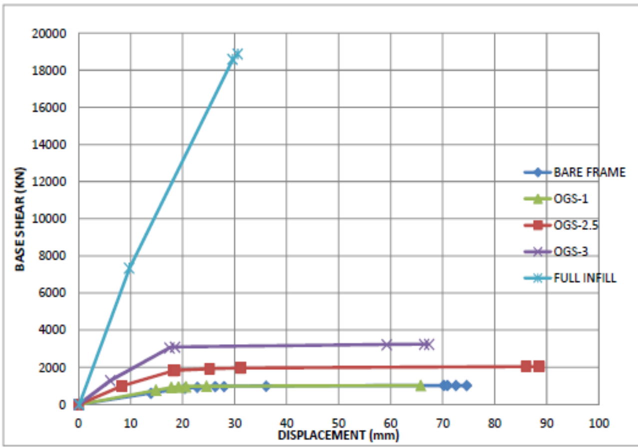

Fig. 7 Pushover Curves of 10S Building Frame

5. The base shear capacity of bare frame is the lowest
6. The highest deformation can be seen in the case of frame designed with MF 2.5 which is about 90 mm whereas for others it's maximum up to 75 mm only.
7. Here also the highest load taking frame is that designed with infill wall condition and has the value of approximately 19000 KN but its deflection value is that with the least one which is about 30 mm.
8. Among the OGS frames though that designed with MF 3.0 has the highest value of undertaking load but has the ability of deforming earlier than that designed with MF 2.5. earlier one can take load upto more than 3000 KN whereas that with MF 2.5 can take below 2000 KN.
9. From deformation point of view the frame designed with MF value 2.5 has the higher value of deformation to undergo than that of MF 3.0.
10. That designed with bare frame shows the least performance.
11. The load withstanding ability of bare frame and that with MF 1 are nearly same. The only difference in their nature is in the term of deformation. The one with MF 1 has the higher ability of undergoing higher deformation.

XI. RESULTS AND CONCLUSIONS

-Base shear Capacity of a 10 S6B bare frame designed with MF of 3.0 & 2.5 is about 28 % more than that designed with MF 1.0 whereas the deflection vary by note more than 15 mm between them

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-Base shear Capacity of a 10S6B bare frame designed with MF of 3.0 & 2.5 is about 28% more than that designed with MF equal to 1.0 whereas the deflection vary by note more than 10 mm between them.
-Strong infill 10s frame with fixed support can take 3 times more load than that with weak infill whereas the deflection being almost same about 66 mm for both the cases.
- For 10S frame also the behavior of fixed & hinged supported frame with full infill is almost same only the difference being in the base shear. For fixed support the strength is more than hinged one almost by 29% and the deflection that the fixed supported frame can go up to 31 mm whereas hinged up to 22 mm.
- 10S OGS-2.5 frame with fixed support possesses 3 times higher strength than that with hinged support whereas in deflection point of view hinged has higher ability of deforming than fixed by 10 mm.
Conclusions from pushovers curves of 10S6B with all variations
• Base shear capacity of OGS frame designed for MF = 3 is about 1.5 times more than that of MF =2.5,
• Base shear capacity of OGS frame designed for MF = 2.5 is about 2.5 times more than that of MF =1.0,
• Base shear capacity of full infilled frame designed for MF = 1.0 is about 1.1 times more than that of Bare frame,
• Base shear capacity of full infilled frame designed for MF = 1.0 is about 9.5 times more than that of OGS frame designed with MF = 2.5,
• The base shear capacity of bare frame is the lowest • The highest deformation can be seen in the case of frame designed with MF 2.5 which is about 90 mm whereas for others it's maximum up to 75 mm only.

XII. ACKNOWLEDGMENT

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