Seismic Behaviour of Open Ground Storied Building

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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 Gujarat earthquake were of the open ground storey type. Many low-rise and medium rise framed buildings have been constructed in the recent past, without proper attention paid in their design for wind or earthquake loads. 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. Therefore it is need of time to take immediate measures to prevent the indiscriminate use of soft first storey in buildings. With the availability of fast computers, so that software usage in civil engineering has greatly reduced the complexities of different aspects in the analysis and design of projects. In the dissertation work a parametric study is performed on multistoried building with soft first storey, located in seismic zone III. The study is carried out on a building with the help of different mathematical models considering various methods for improving the seismic performance of the building with soft first storey. Analytical models represent all existing components that influence the mass, strength, stiffness and deformability of structure. It is intended to describe the performance characteristics such as storey drift, inter-storey drift, shear force, bending moment, base shear, time period and frequency. The response spectrum and time history analysis is carried out on the entire mathematical 3D model using the software SAP2000. The objective of this study is to identify an efficient retrofitting method for open ground story reinforced concrete frame buildings. The effect of window opening is also considering. The results are compared and conclusions are made in view of IS-1893 (2002) code.**

Keywords—Clay brick infill wall, Autoclaved Aerated Concrete, Soft Storey, Equivalent Diagonal Strip Method.

I. Introduction

Due to increasing population since the past few years car parking space for residential apartments in populated cities is a matter of major concern. Hence the trend has been to utilize the ground storey of the building itself for parking. These types of buildings having no infill masonry walls in ground storey, but infilled in all upper stories, are called Open Ground Storey (OGS) buildings (soft strey). They are also known as 'open first storey building' (when the storey numbering starts with one from the ground storey itself), 'pilotis', or 'stilted buildings'.

A soft storey is also known as weak storey. It is a storey in a building that has substantially less resistance or stiffness than the stories above or below. A soft storey has inadequate shear resistance or inadequate ductility to resist the earthquake induced stresses. Such features are highly undesirable in buildings built in seismically active areas. The soft storey consists of discontinuity of strength stiffness which occurs the second storey connection. Soft storey concept has technical and functional advantages over the conventional construction. Because firstly, the reduction in spectral acceleration and base shear. Due to increase of natural period of the vibration of structure as in base isolated structure. Secondly, soft storey adopted for parking of vehicles and retail shopping, a large space for meeting room or a banking hall. The Indian seismic code IS 1893:2002 (Clause no.4.20 on Page no.10) defines the soft storey as the "one in which the lateral stiffness is less than 70% of that in the storey immediately above, or less than 80% of combined stiffness of three stories above."

A. Addition of Infill walls

It is one of the global retrofitting technique. The lateral stiffness of a storey increases with infill walls. Addition of infill walls in the ground storey is a viable option to retrofit buildings with open ground stories. Due to the 'strut action' of the infill walls, are substantially reduces. Infill walls do not increase the ductility of the overall response of the building. The new wall should be placed on a foundation or tie beam in absence of plinth beams.

B. Column Jacketing

It is one of the local retrofitting technique. Retrofit of deficient columns is essential to avoid collapse of a storey. Hence it is more important than the retrofitting of beams. The columns are retrofitted to increase their flexural and strength, to increase the deformation capacity near the beam-column joint and to strengthen the regions of faulty splicing of longitudinal bars. Column jacketing consists of concrete jacketing, steel jacketing, fiber reinforced polymer wrapping. The concrete jacketing involves addition of a layer of concrete, longitudinal bars and closely spaced ties. The jacket increases both the flexural and shear strength of the column. Steel jacketing refers to encasing the column with steel plates and filling the gap with non-shrink grout. The jacket is effective to remedy inadequate shear strength and provide passive confinement to the column. Fiber reinforced jacketing has desirable physical properties like high tensile strength to weight ratio and corrosion resistance.

The objectives of my present study are,

- To create the models with various infill materials and retrofitting schemes.
- To select a better model and material from these models on the basis of the parameters like storey drift, inter-storey drift, shear force, bending moment, base shear, time period and frequency.
- To provide various dimensions of openings to the selected model.
- To compare the seismic performance of the building with various dimensions of window opening.

II. SYSTEM DEVELOPMENT

A. Modelling of infilled wall

Most of the previous research model infill walls as an equivalent strut and the modeling of infill wall as an equivalent diagonal strut has introduced by Holmes (1961). The thickness of the equivalent diagonal strut was recommended as the thickness of the infill wall itself, and the width recommended as one-third of the diagonal length of infill panel. In my thesis the infill walls are modeled as “equivalent diagonal strut method” was used for modeling the infill wall. In this method the infill wall is idealized as diagonal strut and the frame is modeled. For this the infill walls are assigned as line springs and it resists only compression. The stiffness value of spring element is obtained from the behavior of reinforced concrete frames infilled with light weight materials under seismic loads introduced by Imran I and Aryanto A (2009). An experimental study was conducted and the infill materials used are clay brick materials and autoclaved aerated concrete material is used as light weight material. From their study the stiffness value of clay brick material is obtained as 37760 kN/m and stiffness value of autoclaved aerated concrete is obtained as 22650 kN/m.

Various dimensions of opening (mm X mm) on infilled walls are selected from the previous researchers are 500 X 1000, 500 X 1500, 500 X 2000, 1500 X 2000, 1000 X 500, 1500 X 500, 2000 X 500, 1500 X 1000, 2000 X 1000, 2000 X 1500.

B. Modelling of building

The buildings were modeled on the basis of IS 456:2000, IS 800:2007, IS 1893:2002 and IS 875: 1967. The study is carried out on reinforced concrete moment resisting frame building with open first storey and unreinforced brick infill walls in the upper stories. The building considered G+14 stories, of which the ground storey is intended for parking. The building is kept symmetric in both orthogonal directions in plan to avoid the torsional response under pure lateral forces. Further the columns are taken to be square to keep the discussion focused only on the soft first storey effect, without being distracted by the issue like orientation of columns. Response spectrum method and time history method are used for analysis. The plan dimension of the building is 12 m X 12 m. Height of each storey is kept same as 3.0 m. Other relevant data are as follows:

Height of each storey	3.00m
Depth of foundation	1.50m
Thickness of walls	230mm
Live load at roof level	1.5 kN/m^2
Live load at all floors	2.0 kN/m^2
Floor finish	0.306 kN/m^2
Ceiling	0.013 kN/m^2
Dead load of clay brick infill	8.49 kN/m^2
Dead load of autoclaved aerated concrete infill	3.427 kN/m^2
Density of Concrete	25 kN/m^3
Density of clay brick	14.77 kN/m^3
Density of autoclaved aerated concrete	5.96 kN/m^3

The various models in my study are:

1. Without window opening

Model I Uniform infill walls in all stories with clay brick as infill material (without column jacketing)
Model II Uniform infill walls in all stories with autoclaved aerated concrete as infill material (without column jacketing)
Model III Building with open first storey and clay as infill material (without column jacketing)
Model IV Building with open first storey and clay as infill material (with column jacketing)
Model V Open first storey with clay brick walls at specific locations (Ist & IVth bay) in the first storey (without column jacketing)
Model VI Open first storey with clay brick walls at specific locations (Ist & IVth bay) in the first storey (with column jacketing)
Model VII Open first storey with clay brick walls at specific locations (IInd & IIIrd bay) in the first storey (without column jacketing)
Model VIII Open first storey with clay brick walls at specific locations (IInd & IIIrd bay) in the first storey (with column jacketing)
Model IX Open first storey with clay brick walls at specific locations (Ist & III^{thrd} bay) in the first storey (without column jacketing)
Model X Open first storey with clay brick walls at specific locations (Ist & IIIrd bay) in the first storey (with column jacketing)

Model XI Building has no wall in the first storey and clay brick infill wall in upper stories and below plinth (without column jacketing)
Model XII Building has no wall in the first storey and clay brick infill wall in upper stories and below plinth (with column jacketing)

2. *With window opening*

Model XIII Building with open first storey and clay as infill material (with column jacketing and window opening size 500 x 1000)
Model XIII Building with open first storey and clay as infill material (with column jacketing and window opening size 500 x 1000)
Model XIV Building with open first storey and clay as infill material (with column jacketing and window opening size 500 x 1500)
Model XV Building with open first storey and clay as infill material (with column jacketing and window opening size 500 x 2000)
Model XVI Building with open first storey and clay as infill material (with column jacketing and window opening size 1000 x 1500)
Model XVII Building with open first storey and clay as infill material (with column jacketing and window opening size 1000 x 2000)
Model XVIII Building with open first storey and clay as infill material (with column jacketing and window opening size 1500 x 1000)
Model XIX Building with open first storey and clay as infill material (with column jacketing and window opening size 1000 x 500)
Model XX Building with open first storey and clay as infill material (with column jacketing and window opening size 1500 x 500)
Model XXI Building with open first storey and clay as infill material (with column jacketing and window opening size 2000 x 500)
Model XXII Building with open first storey and clay as infill material (with column jacketing and window opening size 1500 x 1000)
Model XXIII Building with open first storey and clay as infill material (with column jacketing and window opening size 2000 x 1000)
Model XXIV Building with open first storey and clay as infill material (with column jacketing and window opening size 2000 x 1500)

C. Defining Process

Here the material properties, section properties, load patterns, load cases, load combinations and functions (response spectrum and time history) etc are defined. The spacing between columns is provided as 3 m in both X and Y directions and height of each floor is 3 m. Then material properties (M_{25} concrete, Fe 415 steel and rebar) are defined. Section properties of beams are rectangular cross section and assumed 300 mm X 400 mm and 500 X 500 mm size. The column section is square cross section and assumed 500 mm X 500 mm and 600 mm X 600 mm size. Area section (slab) is designed as thin type shell and assumed depth is 100 mm. In load patterns live load in roof and other floors, dead load, floor finish, ceiling, infill walls load, earthquake load x and y direction, wind load in x and y direction is defined as per IS 1893:2002 and IS 875: 1967. The zone III is selected since Kerala comes under this zone and zone factor is 0.16. The important factor is 1 and response reduction factor is 5. The soil type is medium soil (type II) and load combinations and load cases are defined as per code. For time history analysis Bhuj earthquake was selected. For this time period Vs ground acceleration graph is plotted.

D. Analysis and Design of the building

Response spectrum analysis and time history analysis has been performed as per IS 1893:2002. For time history analysis Bhuj earthquake and L Center earthquake are selected. Lateral load calculation and its distributed along the height is done. Then design the building by using IS 456:2000.

III. RESULTS AND DISCUSSION

For buildings with various retrofitting techniques and various dimensions of infill wall openings, various parameters like storey drift, inter-storey drift, shear force, bending moment, base shear, time period and frequency has been compared. Obtained results for each parameter comparisons are expressed as graph.

A. Response Specctrum Analysis

1. *Without window opening*

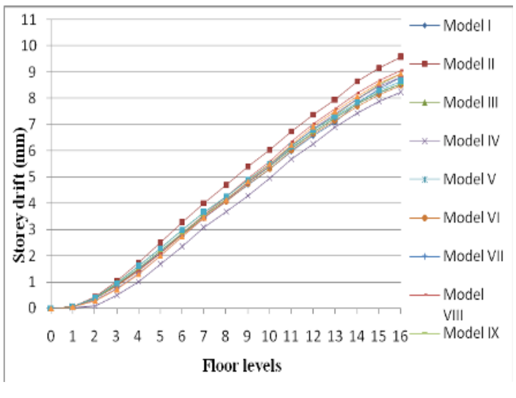

Fig. 1 Comparison of Storey Drift for different models without window opening

A graph is plotted taking floor level s the abscissa and storey drift as the ordinate for different models as shown in Fig. 1. From the storey drift graph in it is observed that large displacement occurs in the case of soft storey building (Model II). On the other hand if there is open first storey with column jacketing (Model IV) has the displacement is very small in first storey. The displacement for the building with column jacketing is small as compared to the building with column jacketing. Open first storey with clay brick walls at specific locations (I^{st} & IV^{th} bay) in the first storey (with column jacketing) (Model VI) reduces the displacement up to 48% as compared to Model II. Building has no wall in the first storey and clay brick infill wall in upper stories and below plinth (with column jacketing) (Model XII) reduces displacement up to 52% as compared to Model II.

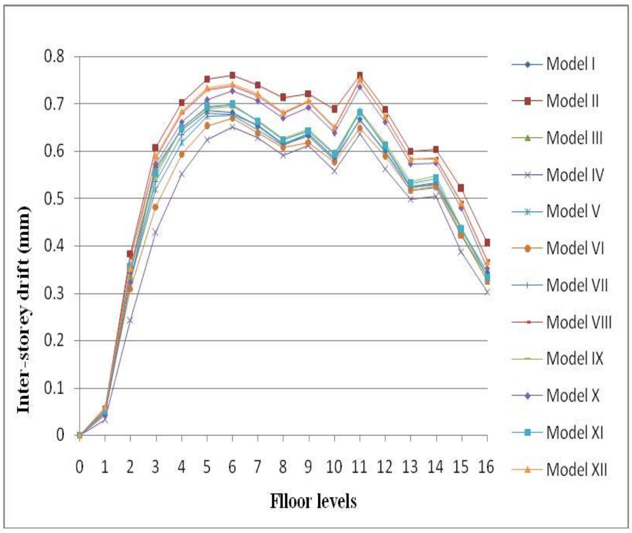

Fig. 2 Comparison of Inter-storey Drift for different models without window opening

From the inter-storey drift graph in it is observed that large inter-storey drift occurs in the case of soft storey building (Model II). On the other hand if there is open first storey with column jacketing (Model IV) has the inter-storey drift is very small (42% as compared to Model II) in first storey.

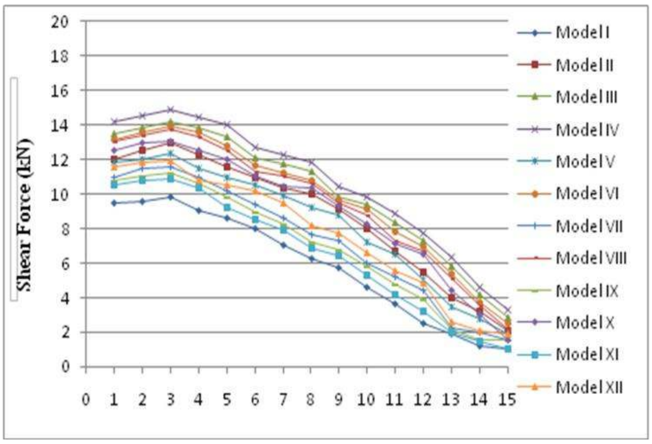

Fig. 3 Comparison of Shear Force for different models without window opening

From the shear force graph in it is observed that large shear force occurs in the case of soft storey building with column jacketing (Model IV). On the other hand if there is building with uniform clay brick infill walls in all stories (Model 1) has the shear force is very small (68% as compared to Model IV) in first storey.

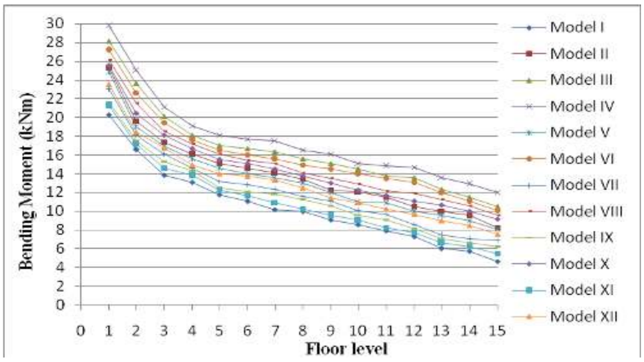

Fig. 4 Comparison of Bending Moment for different models without window opening

From the bending moment graph in it is observed that large bending moment occurs in the case of soft storey building with column jacketing (Model IV). On the other hand if there is building with uniform clay brick infill walls in all stories (Model 1) has the bending moment is very small (62% as compared to Model IV) in first storey

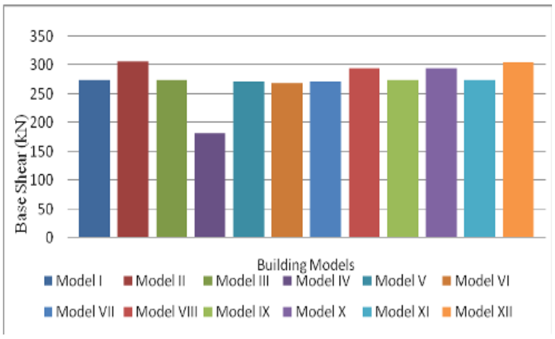

Fig. 5 Comparison of Base Shear for different models without window opening

From the base shear graph in it is observed that large base shear occurs in the case of soft storey building (Model II). On the other hand if there is open first storey with column jacketing (Model IV) has the base shear is very small(15% as compared to Model II).

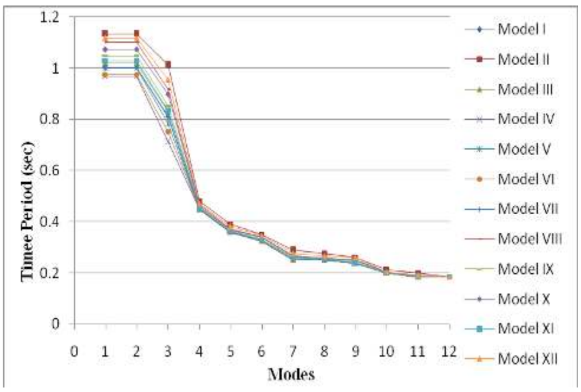

Fig. 6 Comparison of Time Period for different models without window opening

From the time period graph in it is observed that large time period occurs in the case of soft storey building (Model II). On the other hand if there is open first storey with column jacketing (Model IV) has the time period is very small.

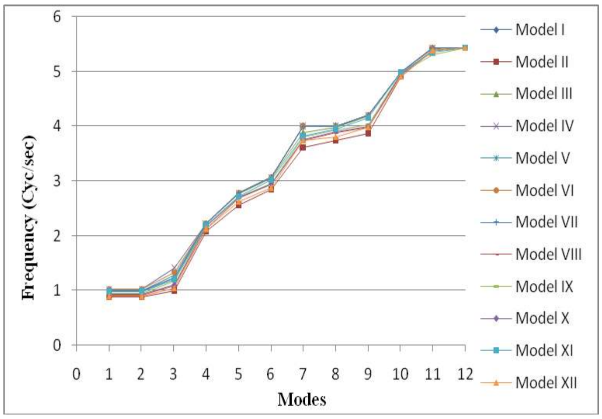

Fig. 7 Comparison of Frequency for different models without window opening

From the time period graph in it is observed that large time period occurs in the case of soft storey building (Model IV). On the other hand if there is open first storey with column jacketing (Model II) has the time period is very small.

2. With window opening

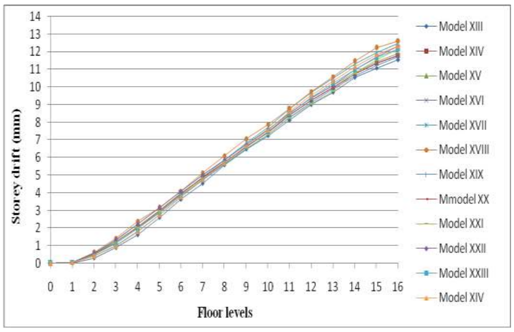

Fig. 8 Comparison of Storey Drift for different models with window opening

A graph is plotted taking floor level s the abscissa and storey drift as the ordinate for different models as shown in Fig. 8. From the storey drift graph in it is observed that large displacement occurs in the case of soft storey building with open first storey and clay as infill material (with column jacketing and window opening size 1500 x 1000) (Model XVIII). On the other hand if there is building with open first storey and clay as infill material (with column jacketing and window opening size 500 x 1000) has the displacement is very small (60% as compared to Model XVIII) in first storey.

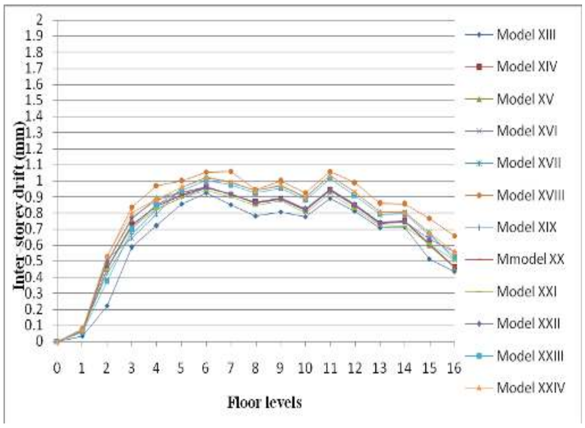

Fig. 9 Comparison of Inter-storey Drift for different models with window opening

From the Inter-storey drift graph in it is observed that large inter-storey drift occurs in the case of soft storey building with open first storey and clay as infill material (with column jacketing and window opening size 1500 x 1000) (Model XVIII). On the other hand if there is building with open first storey and clay as infill material (with column jacketing and window opening size 500 x 1000) has the inter-storey drift is very small (43% as compared to Model XVIII) in first storey.

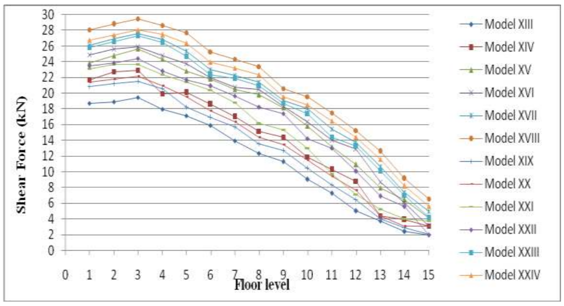

Fig. 10 Comparison of Shear Force for different models with window opening

From the storey drift graph in it is observed that large shear force occurs in the case of soft storey building with open first storey and clay as infill material (with column jacketing and window opening size 1500 x 1000) (Model XVIII). On the other hand if there is building with open first storey and clay as infill material (with column jacketing and window opening size 500 x 1000) has the shear force is very small (64% as compared to Model XVIII) in first storey.

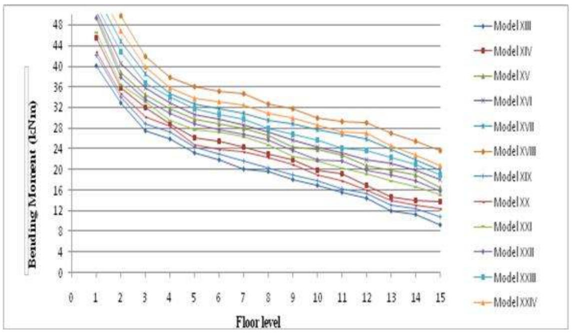

Fig. 11 Comparison of Bending Moment for different models with window opening

From the storey drift graph in it is observed that large bending moment occurs in the case of soft storey building with open first storey and clay as infill material (with column jacketing and window opening size 1500 x 1000) (Model XVIII). On the other hand if there is building with open first storey and clay as infill material (with column jacketing and window opening size 500 x 1000) has the bending moment is very small (61% as compared to Model XVIII) in first storey.

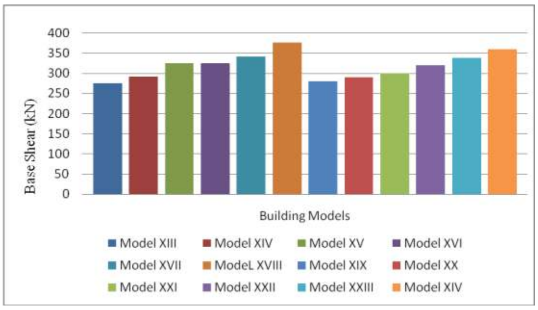

Fig. 12 Comparison of Base Shear for different models with window opening

From the storey drift graph in it is observed that large base shear occurs in the case of soft storey building with open first storey and clay as infill material (with column jacketing and window opening size 1500 x 1000) (Model XVIII). On the other hand if there is building with open first storey and clay as infill material (with column jacketing and window opening size 500 x 1000) has the base shear is very small (59% as compared to Model XVIII) .

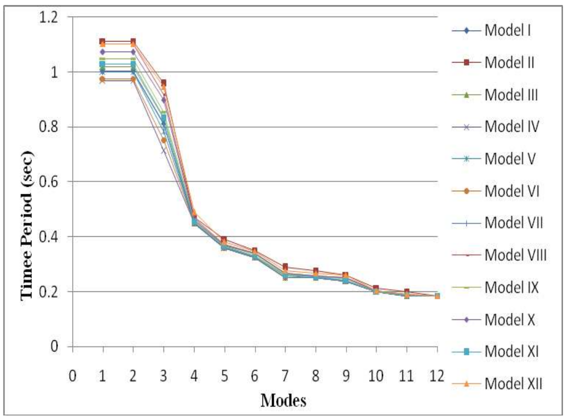

Fig. 13 Comparison of Time Period for different models with window opening

From the time period graph in it is observed that large time period occurs in the case of soft storey building with open first storey and clay as infill material (with column jacketing and window opening size 1500 x 1000) (Model XVIII). On the other hand if there is Building with open first storey and clay as infill material (with column jacketing and window opening size 500 x 1000) has the time period is very small (30% as compared to Model XVIII).

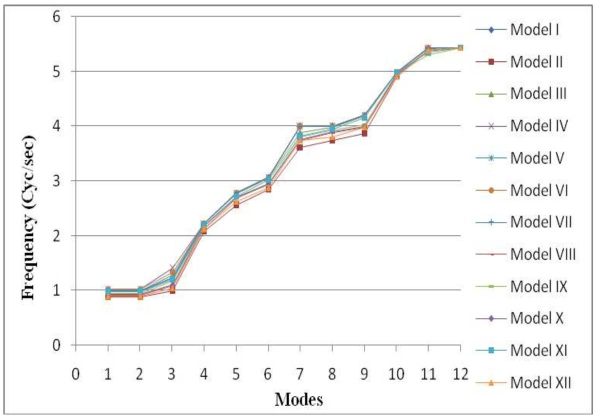

Fig. 14 Comparison of Frequency for different models with window opening

From the frequency in it is observed that small frequency occurs in the case of soft storey building with open first storey and clay as infill material (with column jacketing and window opening size 1500 x 1000) (Model XVIII). On the other hand if there is Building with open first storey and clay as infill material (with column jacketing and window opening size 500 x 1000) has the displacement is very large.

B. Time Hystory Analysis (Bhuj Earthquake)

1. Without window opening

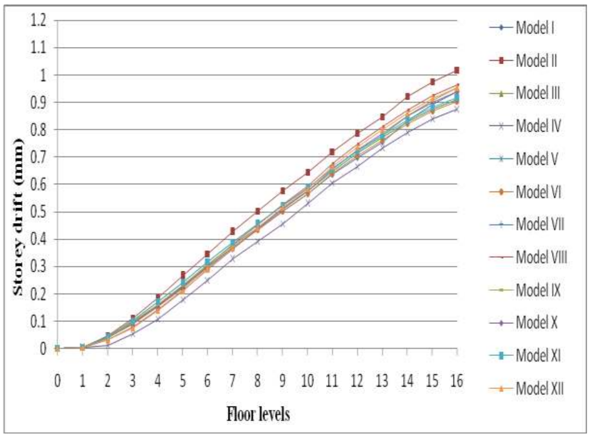

Fig. 15 Comparison of Storey Drift for different models without window opening

A graph is plotted taking floor level s the abscissa and storey drift as the ordinate for different models as shown in Fig. 1. From the storey drift graph in it is observed that large displacement occurs in the case of soft storey building (Model II). On the other hand if there is open first storey with column jacketing (Model IV) has the displacement is very small in first storey. The displacement for the building with column jacketing is small as compared to the building with column jacketing. Open first storey with clay brick walls at specific locations (Ist & IVth bay) in the first storey (with column jacketing) (Model VI) reduces the displacement up to 48% as compared to Model II. Building has no wall in the first storey and clay brick infill wall in upper stories and below plinth (with column jacketing) (Model XII) reduces displacement up to 52% as compared to Model II.

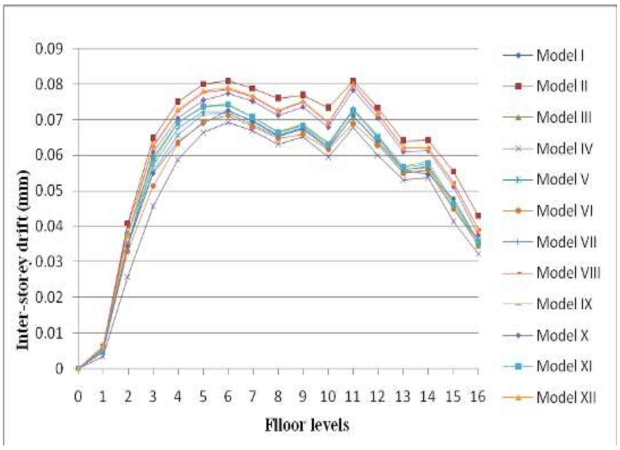

Fig. 16 Comparison of Inter-storey Drift for different models without window opening

From the inter-storey drift graph in it is observed that large inter-storey drift occurs in the case of soft storey building (Model II). On the other hand if there is open first storey with column jacketing (Model IV) has the inter-storey drift is very small (42% as compared to Model II) in first storey.

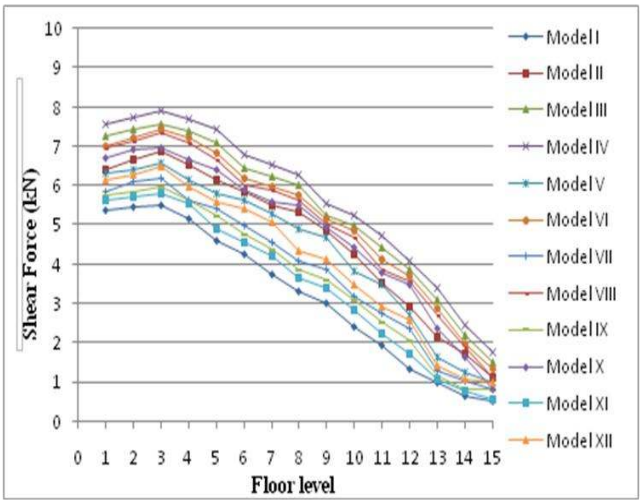

Fig. 17 Comparison of Shear Force for different models without window opening

From the shear force graph in it is observed that large shear force occurs in the case of soft storey building with column jacketing (Model IV). On the other hand if there is building with uniform clay brick infill wall in all stories (Model I) has the shear force is very small (58% as compared to Model I) in first storey

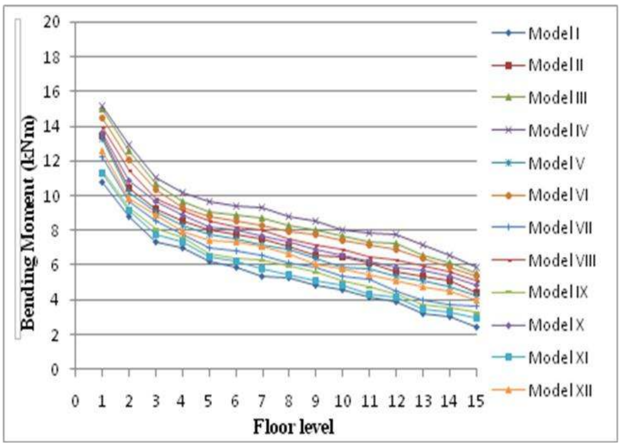

Fig. 18 Comparison of Bending Moment for different models without window opening

From the bending moment graph in it is observed that large bending moment occurs in the case of soft storey building with column jacketing (Model IV). On the other hand if there is building with uniform clay brick infill wall in all stories (Model I) has the bending moment is very small (57% as compared to Model II) in first storey

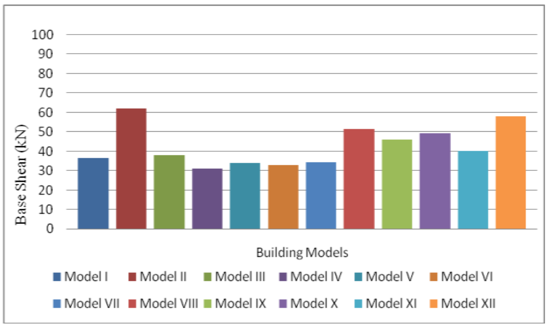

Fig. 19 Comparison of Base Shear for different models without window opening

From the base shear graph in it is observed that large base shear occurs in the case of soft storey building (Model II). On the other hand if there is open first storey with column jacketing (Model IV) has the base shear is very small(15% as compared to Model II).

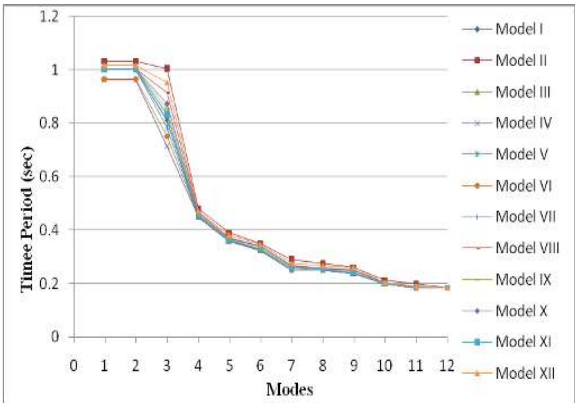

Fig. 20 Comparison of Time Period for different models without window opening

From the time period graph in it is observed that large time period occurs in the case of soft storey building (Model II). On the other hand if there is open first storey with column jacketing (Model IV) has the time period is very small.

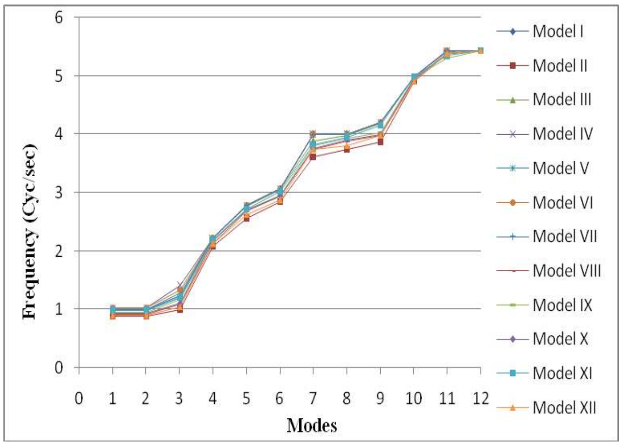

Fig. 21 Comparison of Frequency for different models without window opening

From the time period graph in it is observed that large time period occurs in the case of soft storey building (Model IV). On the other hand if there is open first storey with column jacketing (Model II) has the time period is very small.

2. *With window opening*

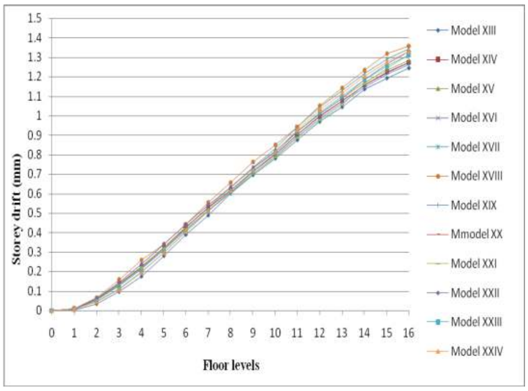

Fig. 22 Comparison of Storey Drift for different models with window opening

A graph is plotted taking floor level s the abscissa and storey drift as the ordinate for different models as shown in Fig. 8. From the storey drift graph in it is observed that large displacement occurs in the case of soft storey building with open first storey and clay as infill material (with column jacketing and window opening size 1500 x 1000) (Model XVIII). On the other hand if there is building with open first storey and clay as infill material (with column jacketing and window opening size 500 x 1000) has the displacement is very small (60% as compared to Model XVIII) in first storey.

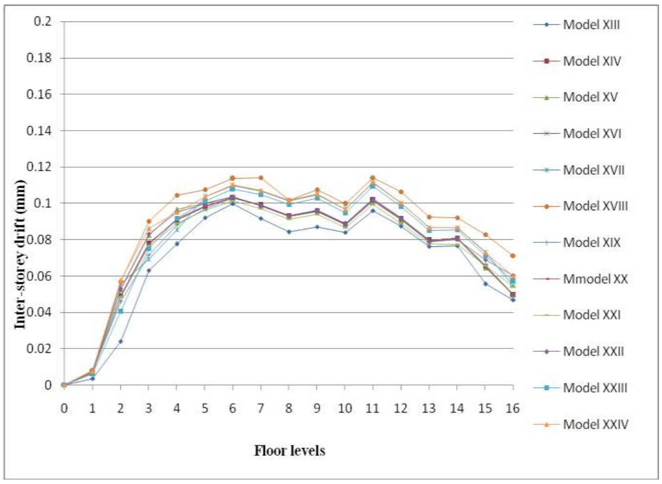

Fig. 23 Comparison of Inter-storey Drift for different models with window opening

From the Inter-storey drift graph in it is observed that large inter-storey drift occurs in the case of soft storey building with open first storey and clay as infill material (with column jacketing and window opening size 1500 x 1000) (Model XVIII). On the other hand if there is building with open first storey and clay as infill material (with column jacketing and window opening size 500 x 1000) has the inter-storey drift is very small (43% as compared to Model XVIII) in first storey.

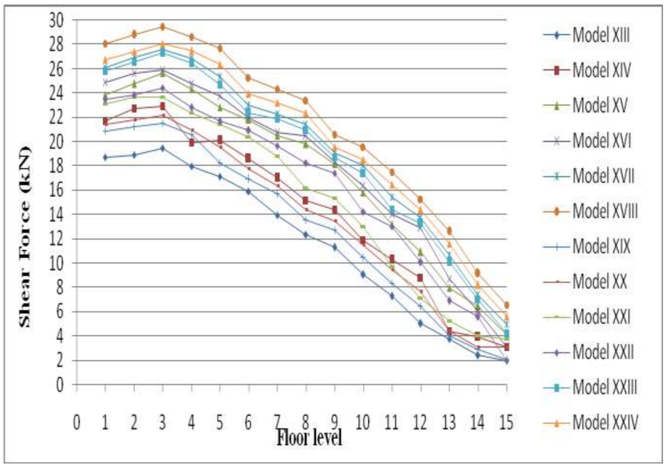

Fig. 24 Comparison of Shear Force for different models with window opening

From the storey drift graph in it is observed that large shear force occurs in the case of soft storey building with open first storey and clay as infill material (with column jacketing and window opening size 1500 x 1000) (Model XVIII). On the other hand if there is building with open first storey and clay as infill material (with column jacketing and window opening size 500 x 1000) has the shear force is very small (41% as compared to Model XVIII) in first storey.

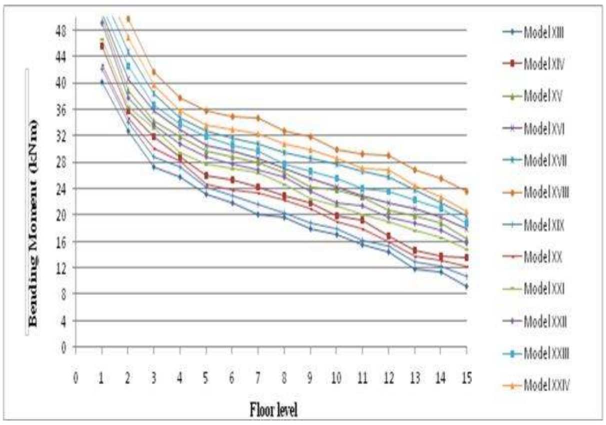

Fig. 25 Comparison of Bending Moment for different models with window opening

From the storey drift graph in it is observed that large bending moment occurs in the case of soft storey building with open first storey and clay as infill material (with column jacketing and window opening size 1500 x 1000) (Model XVIII). On the other hand if there is building with open first storey and clay as infill material (with column jacketing and window opening size 500 x 1000) has the bending moment is very small (42% as compared to Model XVIII) in first storey.

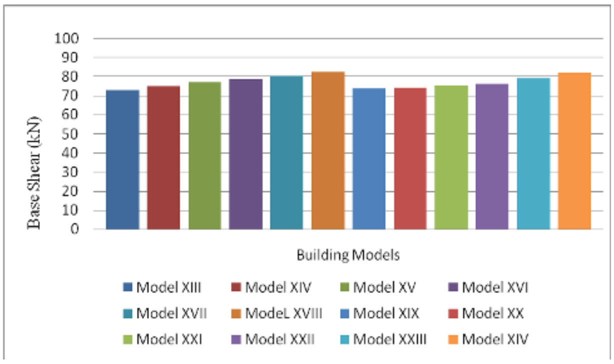

Fig. 26 Comparison of Base Shear for different models with window opening

From the storey drift graph in it is observed that large base shear occurs in the case of soft storey building with open first storey and clay as infill material (with column jacketing and window opening size 1500 x 1000) (Model XVIII). On the other hand if there is building with open first storey and clay as infill material (with column jacketing and window opening size 500 x 1000) has the base shear is very small (59% as compared to Model XVIII).

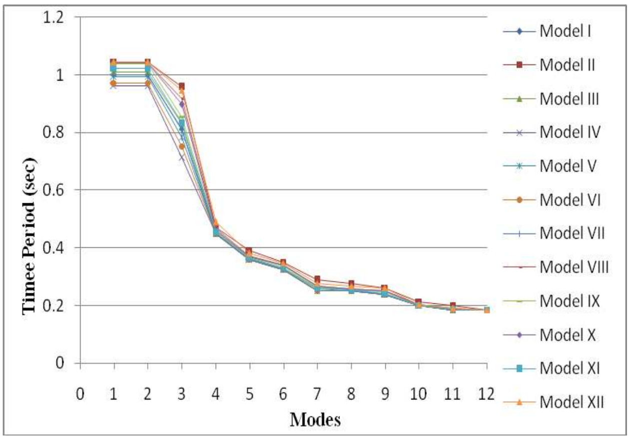

Fig. 27 Comparison of Time Period for different models with window opening

From the time period graph in it is observed that large time period occurs in the case of soft storey building with open first storey and clay as infill material (with column jacketing and window opening size 1500 x 1000) (Model XVIII). On the other hand if there is Building with open first storey and clay as infill material (with column jacketing and window opening size 500 x 1000) has the time period is very small (30% as compared to Model XVIII).

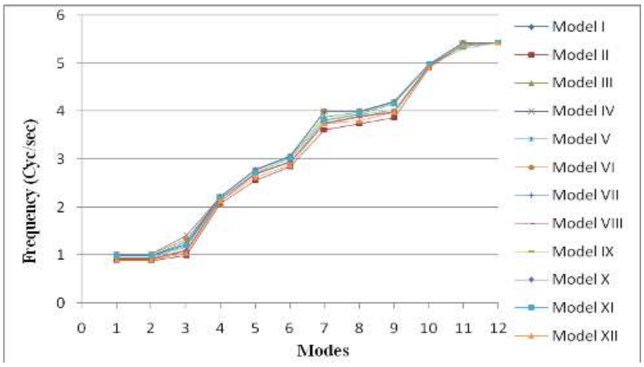

Fig. 28 Comparison of Frequency for different models with window opening

From the frequency in it is observed that small frequency occurs in the case of soft storey building with open first storey and clay as infill material (with column jacketing and window opening size 1500 x 1000) (Model XVIII). On the other hand if there is Building with open first storey and clay as infill material (with column jacketing and window opening size 500 x 1000) has the displacement is very large.

C. Time Hystory Analysis (L Center Earthquake)

1. Without window opening

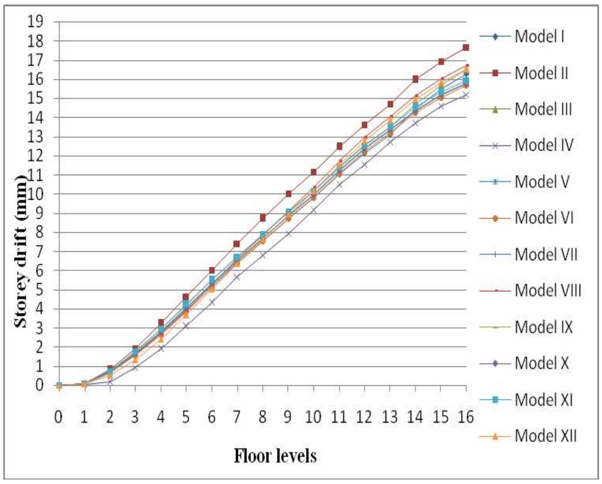

Fig. 29 Comparison of Storey Drift for different models without window opening

A graph is plotted taking floor level s the abscissa and storey drift as the ordinate for different models as shown in Fig. 29. From the storey drift graph in it is observed that large displacement occurs in the case of soft storey building (Model II). On the other hand if there is open first storey with column jacketing (Model IV) has the displacement is very small in first storey. The displacement for the building with column jacketing is small as compared to the building with column jacketing. Open first storey with clay brick walls at specific locations (I^{st} & IV^{th} bay) in the first storey (with column jacketing) (Model VI) reduces the displacement up to 48% as compared to Model II. Building has no wall in the first storey and clay brick infill wall in upper stories and below plinth (with column jacketing) (Model XII) reduces displacement up to 52% as compared to Model II.

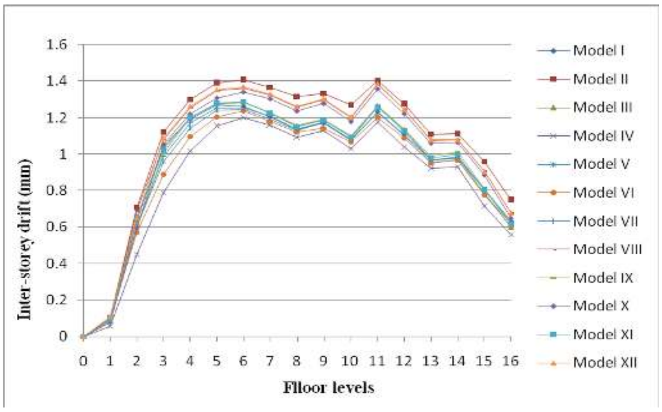

Fig. 30 Comparison of Inter-storey Drift for different models without window opening

From the inter-storey drift graph in it is observed that large inter-storey drift occurs in the case of soft storey building (Model II). On the other hand if there is open first storey with column jacketing (Model IV) has the inter-storey drift is very small (42% as compared to Model II) in first storey.

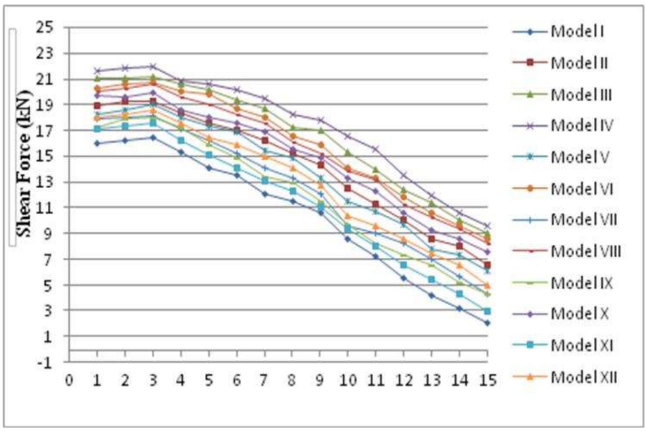

Fig. 31 Comparison of Shear Force for different models without window opening

From the shear force graph in it is observed that large shear force occurs in the case of soft storey building with column jacketing (Model IV). On the other hand if there is building with uniform clay brick infill walls in all stories (Model I) has the shear force is very small (54% as compared to Model IV) in first storey

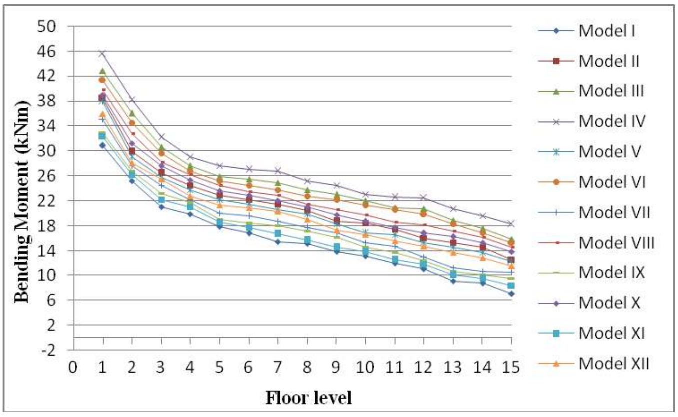

Fig. 32 Comparison of Bending Moment for different models without window opening

From the bending moment graph in it is observed that large bending moment occurs in the case of soft storey building with column jacketing (Model IV). On the other hand if there is building with uniform clay brick infill walls inall stories (Model I) has the bending moment is very small (53% as compared to Model IV) in first storey

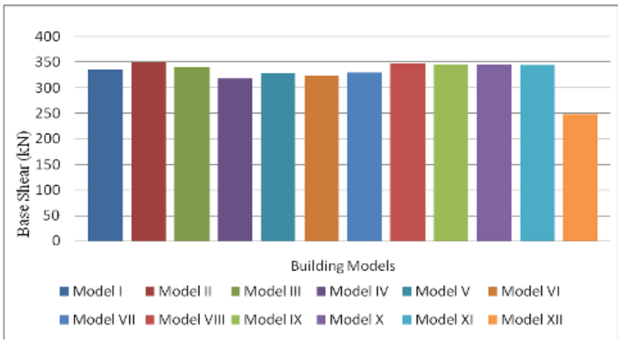

Fig. 33 Comparison of Base Shear for different models without window opening

From the base shear graph in it is observed that large base shear occurs in the case of soft storey building (Model II). On the other hand if there is open first storey with column jacketing (Model IV) has the base shear is very small(15% as compared to Model II).

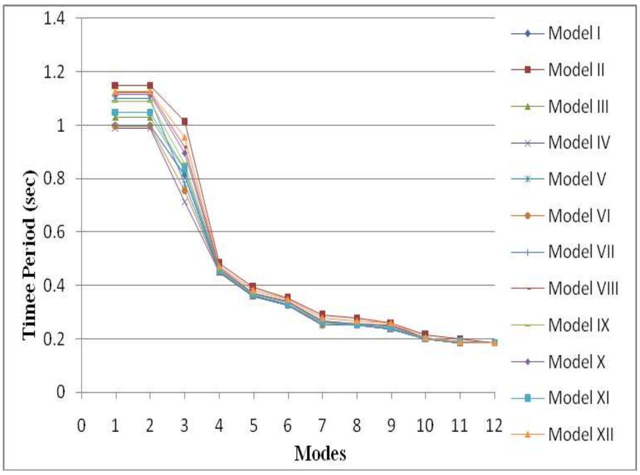

Fig. 34 Comparison of Time Period for different models without window opening

From the time period graph in it is observed that large time period occurs in the case of soft storey building (Model II). On the other hand if there is open first storey with column jacketing (Model IV) has the time period is very small.

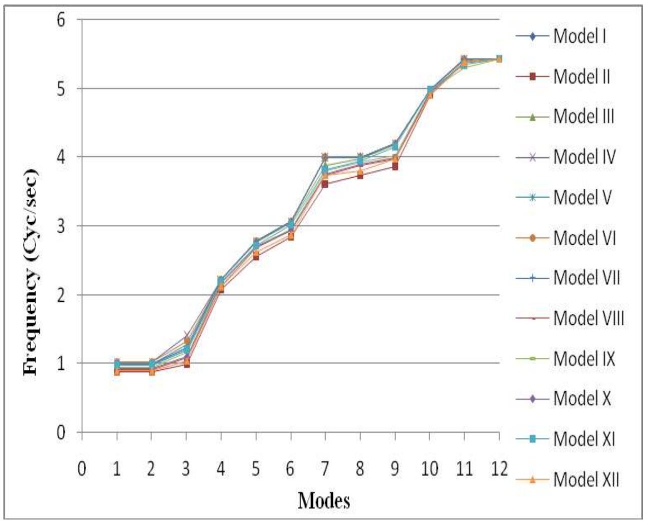

Fig. 35 Comparison of Frequency for different models without window opening

From the time period graph in it is observed that large time period occurs in the case of soft storey building (Model IV). On the other hand if there is open first storey with column jacketing (Model II) has the time period is very small.

2. *With window opening*

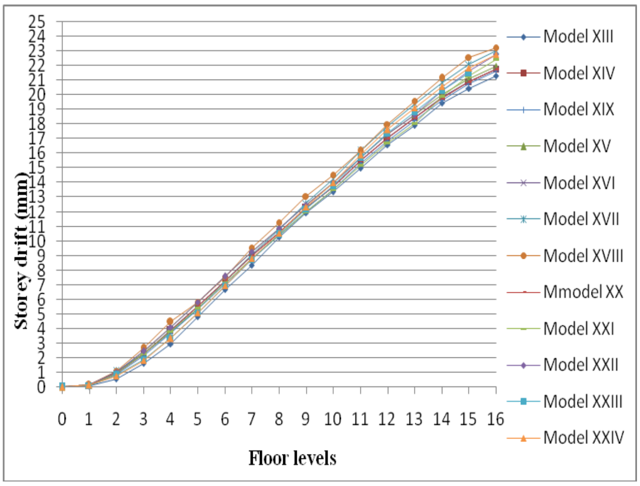

Fig. 36 Comparison of Storey Drift for different models with window opening

A graph is plotted taking floor level s the abscissa and storey drift as the ordinate for different models as shown in Fig. 8. From the storey drift graph in it is observed that large displacement occurs in the case of soft storey building with open first storey and clay as infill material (with column jacketing and window opening size 1500 x 1000) (Model XVIII). On the other hand if there is building with open first storey and clay as infill material (with column jacketing and window opening size 500 x 1000) has the displacement is very small (60% as compared to Model XVIII) in first storey.

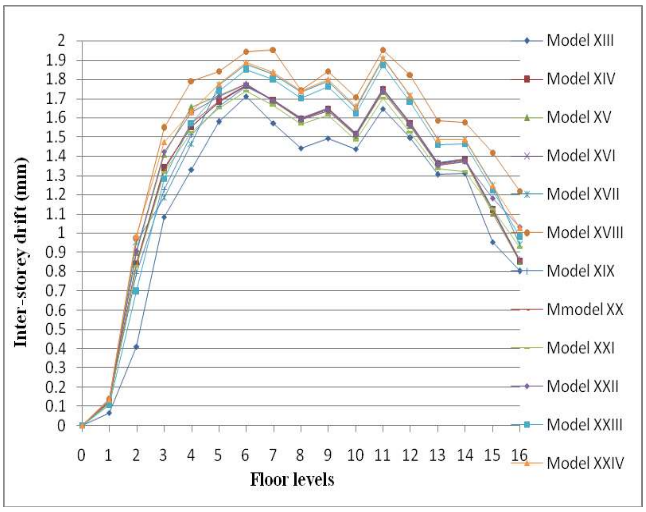

Fig. 37 Comparison of Inter-storey Drift for different models with window opening

From the Inter-storey drift graph in it is observed that large inter-storey drift occurs in the case of soft storey building with open first storey and clay as infill material (with column jacketing and window opening size 1500 x 1000) (Model XVIII). On the other hand if there is building with open first storey and clay as infill material (with column jacketing and window opening size 500 x 1000) has the inter-storey drift is very small (43% as compared to Model XVIII) in first storey.

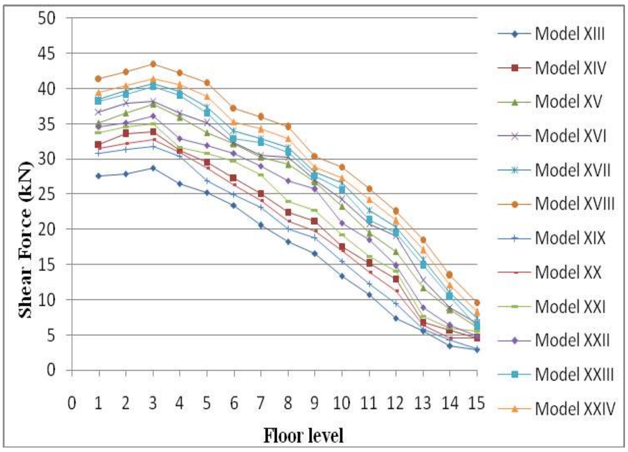

Fig. 38 Comparison of Shear Force for different models with window opening

From the storey drift graph in it is observed that large shear force occurs in the case of soft storey building with open first storey and clay as infill material (with column jacketing and window opening size 1500 x 1000) (Model XVIII). On the other hand if there is building with open first storey and clay as infill material (with column jacketing and window opening size 500 x 1000) has the shear force is very small (41% as compared to Model XVIII) in first storey.

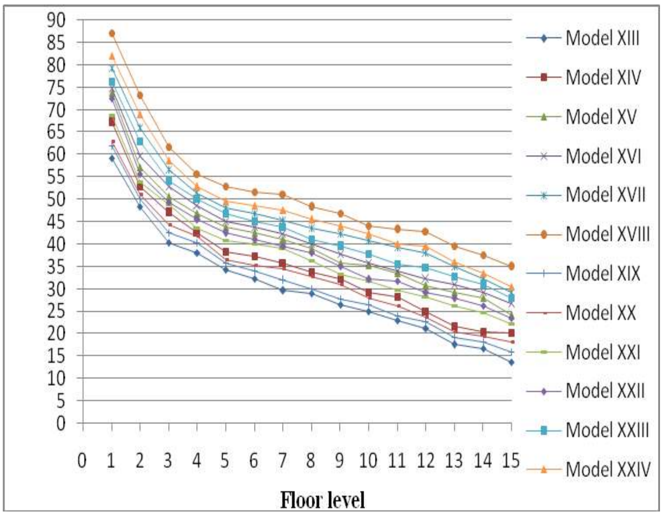

Fig. 39 Comparison of Bending Moment for different models with window opening

From the storey drift graph in it is observed that large bending moment occurs in the case of soft storey building with open first storey and clay as infill material (with column jacketing and window opening size 1500 x 1000) (Model XVIII). On the other hand if there is building with open first storey and clay as infill material (with column jacketing and window opening size 500 x 1000) has the bending moment is very small (42% as compared to Model XVIII) in first storey.

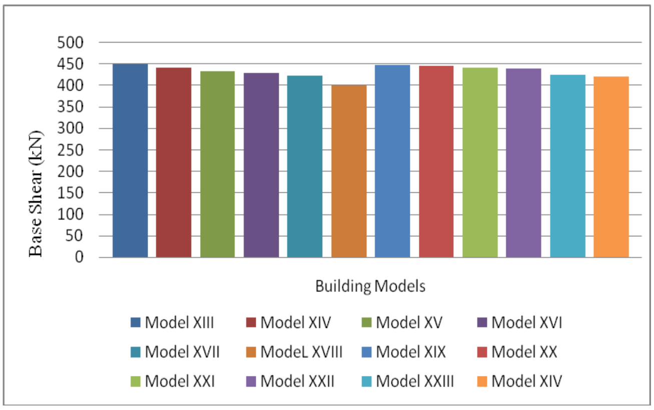

Fig. 40 Comparison of Base Shear for different models with window opening

From the storey drift graph in it is observed that large base shear occurs in the case of soft storey building with open first storey and clay as infill material (with column jacketing and window opening size 1500 x 1000) (Model XVIII). On the other hand if there is building with open first storey and clay as infill material (with column jacketing and window opening size 500 x 1000) has the base shear is very small (59% as compared to Model XVIII) .

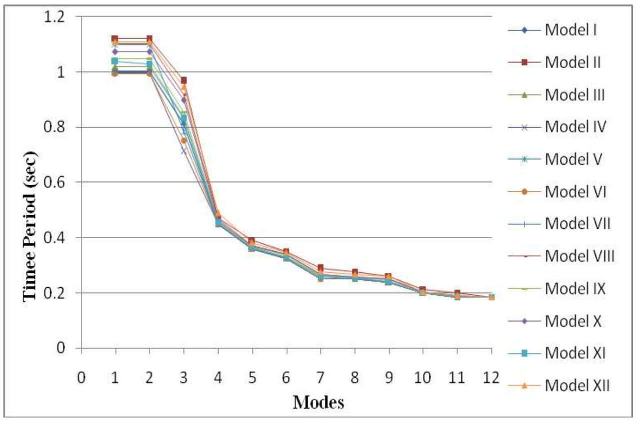

Fig. 41 Comparison of Time Period for different models with window opening

From the time period graph in it is observed that large time period occurs in the case of soft storey building with open first storey and clay as infill material (with column jacketing and window opening size 1500 x 1000) (Model XVIII). On the other hand if there is Building with open first storey and clay as infill material (with column jacketing and window opening size 500 x 1000) has the time period is very small (30% as compared to Model XVIII).

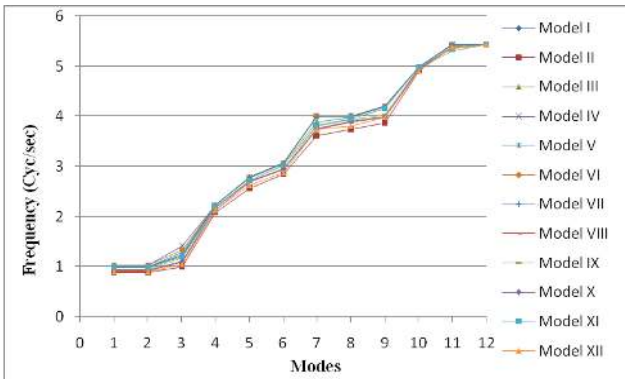

Fig. 42 Comparison of Frequency for different models with window opening

From the frequency in it is observed that small frequency occurs in the case of soft storey building with open first storey and clay as infill material (with column jacketing and window opening size 1500 x 1000) (Model XVIII). On the other hand if there is Building with open first storey and clay as infill material (with column jacketing and window opening size 500 x 1000) has the displacement is very large.

IV. CONCLUSION

In the present paper seismic behaviour study on open ground storied building has been done. From the parameters storey drift, inter-storey drift, shear force, bending moment, base shear, time period and frequency of different models are compared. From the study the following conclusions were drawn out.

- The building with clay brick infill reduces storey drift, inter storey drift, bending moment as compared to autoclaved aerated concrete infill.
- Higher size of columns (column jacketing) is effective in reducing the drift, but increases the shear force and bending moment in the first storey.
- If the window opening size increases then the drift, shear force, bending moment increases. So window opening dimension is important.
- The building with uniform clay brick infill walls in all stories has reduces the shear force, bending moment as compared to other models.
- In the case of response spectrum and time hystory analysis, soft storey with column jacketing have better results as compared to the building without column jacketing.
- Open first storey with infill walls on the specific locations (I^{st} and IV^{th} bay) with column jacketing in the first storey also have better result.
- The building with autoclaved aerated concrete infill walls has poor performance. Here shear force, bending moment, base shear is large as compared to other models.

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