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SEISMIC RESISTIVITY AND RETROFITTING OF RC FRAME BUILDINGS

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ABSTRACT

Generally, in open ground storey buildings, unreinforced brick masonry infill's are present in all floors except the ground storey. This leads to severe stiffness and strength irregularity and even sometimes leads to torsion irregularity. Buildings with these irregularities has consistently shown poor performance during past earthquakes like 1999 Turkey, 1999 Taiwan and 2001 Bhuj, 2003 Algeria earthquakes and many others.

In India, most of the existing as well as new infill RC frame buildings has been designed and are being designed without considering strength and stiffness of Infill's (bare frame modeling). Due to inclusion of infill's behavior and failure modes of buildings changes. This leads to serious concern about seismic safety of existing buildings. In the present study, various strengthening techniques for open ground storey will be discussed. This techniques can be broadly categorized in two groups: 1) Strengthening of existing members, 2) Addition of new members.

1) Reinforced Concrete jacketing and Steel jacketing.
2) There are two popular methods;

- Addition of shear wall
- Addition of friction dampers.

Addition of new shear wall can efficiently be used for buildings with only local interventions.Addition of friction

damper is attractive and easy to construct but needs sophisticated method for proper fixation with existing frames.

In this study SAP2000 is used to analyze the buildings models.

Keywords:-Geo-Polymer, Metakaolin, Ambient curing.

I. INTRODUCTION

1.1 General

In many countries, it is a common practice to construct RC frame building with open ground storey (i.e. unlike other stories, no or scanty infill walls are provided in the ground storey) in order to generate parking space, gardening space, and other utility spaces for various purposes.Providing parking spaces in multi-storey buildings is an essential requirement. Architect finds an easy solution by keeping ground storey open. Also, the local municipal/building bylaw at many places supports/directs the same for solving the parking problem. This is leading to a large number of open ground storey building construction.

Generally, in open ground storey buildings, unreinforced brick masonry infills are present in all floors except the ground story. This leads to severe stiffness and strength irregularity and even sometimes leads to torsion irregularity. Buildings with these irregularities has consistently shown poor performance during past earthquakes like 1999 Turkey, 1999 Taiwan and 2001 Bhuj, 2003 Algeria earthquakes and many others. Normally, infill walls are considered as non-structural member; however, practically it provides significant stiffness under lateral load. If special provisions have not been followed in design, absence of infill at ground storey will lead to formation of soft ground storey. Under lateral loading, lack of infill stiffness will lead to larger inter-storey drift concentrated to ground storey leading to an early formation of plastic hinges, further impending collapse of structure.

As per IS1893 (Part I): 2002 storey is considered as soft if its lateral stiffness is less than 70% of that in the storey immediately above or less than 80% of the combine stiffness of the three stories above. Also, an extreme

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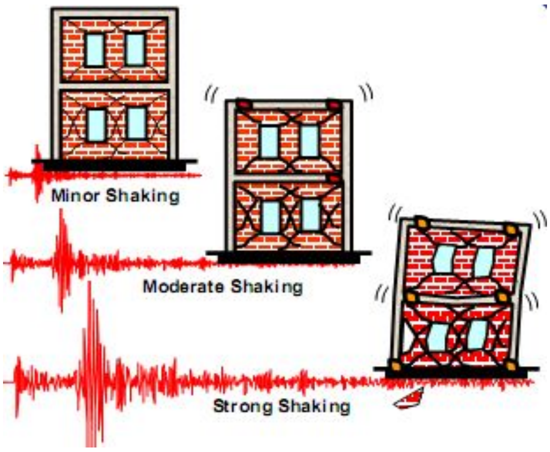
soft storey is one in which the lateral stiffness is less than 60% of that in the storey above or less than 70% of the average stiffness of the three stories above.

Recent earthquakes in the Indian state Gujarat earthquake on January 26, 2001 with a magnitude of 7.6 on Richter scale have led to an increase in the seismic zoning factor over many parts of the country. Also, ductility has become an issue for all those buildings that were designed and detailed using earlier versions of the codes. Under such circumstances, seismic qualification of existing buildings has become extremely important. Seismic qualification eventually leads to retrofitting of the deficient structures. Pushover analysis and evaluation of performance of building using Capacity Spectrum Approach or Displacement Coefficient Method are increasingly used for this purpose.

The earthquake design philosophy may be summarized as follows:

1. Under minor but frequent shaking, the main members of the building that carry vertical and horizontal forces should not get damaged. However, building parts that do not carry load may sustain some repairable damage.
2. Under moderate but occasional shaking, the main members may sustain some repairable damage, while the other parts of the building may be damaged such that they even have to be replaced after the earthquake, and
3. Under strong but rare shaking, the main members may sustain severe damage, but the building should not collapse.



Importance of Seismic Design Codes:

Ground vibrations during earthquakes cause forces and deformations in structures. Structures need to be designed to withstand such forces and deformations. Seismic codes help to improve the behavior of structures so that they may withstand the earthquake effects without significant loss of property and life. Countries around the world have procedures outlined in seismic code to help design engineers in the planning, designing, detailing and constructing structures. Seismic codes are unique to a particular region or country. They take into account the local seismology. Accepted level of seismic risk, building types and materials and methods are used in construction. Further, they are indicative of the level of progress a country has made in the field of earthquake. The first Indian earthquake design code was published in the year 1962 as IS 1893:1962. Today the Bureau of Indian Standards (BIS) has the following seismic codes.
IS 1893(Part 1):2002 (Fig. 2) - Indian Standard criteria for earthquake resistant design of structures (5^{th} revision).
IS 4326:1993 - Indian Standard code of practice for earthquake resistant design and construction of buildings (2^{nd} revision).
IS 13827:1993 - Indian Standard guidelines for improving earthquake resistance of earthen buildings.
IS 13828:1993 - Indian Standard guidelines for improving earthquake resistance of low strength masonry buildings.

List of Major Earthquakes:

The table below represents the list of major earthquake that took place from 18th to 19th century.

Table 1 Major earthquake in India

Date	Event	Deaths	Magnitude on Richter Scale	Time of occurrence
16 June 1819	Cutch	1500	8.3	11:00
12 June 1897	Assam	1500	8.7	17:11
15 August 1950	Assam	1530	8.5	19:31

Need for the Dissertation work:

The objective of this study is to identify an efficient retrofitting method for existing open ground story reinforced concrete frame buildings. Failure of several soft-stored buildings in the past earthquakes underscores the need to retrofit existing soft-story buildings. A common cause for the collapse of multi-storied buildings is the occurrence of soft story in the ground floor due to the presence of infill walls in the upper story. During the Bhuj (Gujarat) earthquake of 6thJanuary 2001 several soft storied building failed there by confirming the vulnerability of such buildings to earthquake loading. This underscores the need to retrofit existing soft story buildings to prevent their total collapse. The existing building structures, which were designed and constructed according to early codal provisions, do not satisfy requirements of current seismic code and design practices. Generic plan of RC frame building selected. Building will be model for different height i.e.,G+3, G+7, G+15 suitable modeling techniques in SAP Modeling, design and comparison of base shear and period of vibration of these building.

Objectives of the Study

The present work aims at the study of following objectives:

1. To determine theseismic resistivityof the R.C. framed Buildings subjected to Non-Linear Time History Analysis
2. To compare period & base shear of different frame like bare frame, infill frame, and shear wall frame by IS code & SAP model.
3. Comparison of performance enhancement of these building with different retrofitting techniques.
4. Identification of most suitable retrofitting techniques.

Seismic behavior of URM in filled frame

Unreinforced masonry (URM) infill walls are generally considered as non-structural element. However, it has been observed that the behavior of infilled frame significantly vary in comparison to bare frame under lateral loading. Modelling of "Frame-Wall interaction" has remained a difficult task due to various reasons, such as opening in wall, gap between wall and frame, and variation of material strength along with significant increase in computational effort.

The Advantages (Tabeshpour, et al., 2011) in the conversion of flexural action to axial action are:

1) Reduce contribution of frame in lateral resisting
2) Reducing the lateral deformations

The Disadvantages (Tabeshpour, et al.2011) of converting the flexural action to axial action:

1) Increase of the axial load in the column and foundation,
2) Creation of the concentrated shears at top and bottom of the column,
3) Creation concentrated shears at beginning and end of the beam
4) Creation of huge shears on the foundation

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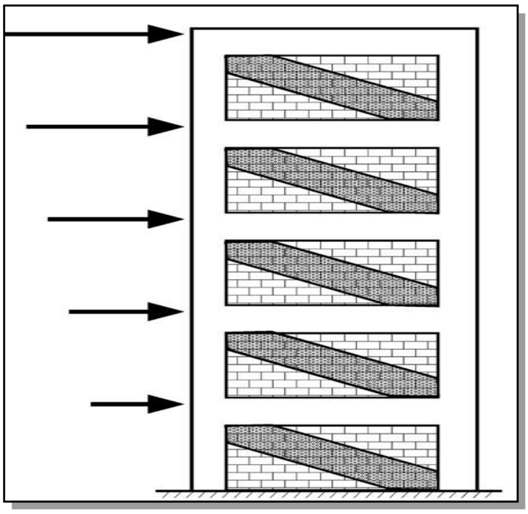
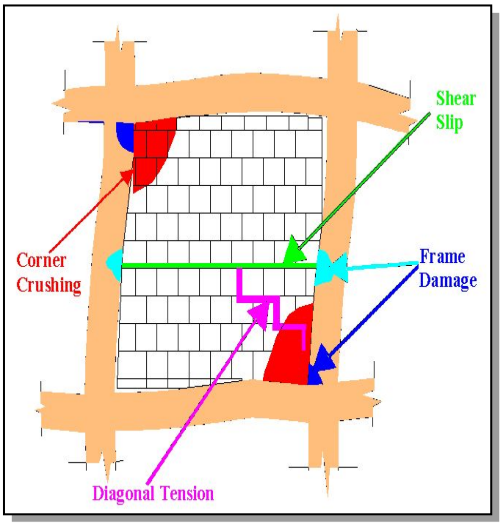


Figure 2.9 Typical failure modes of URM infill wall and frame.(Photo from Klingner 1976)



Objective of seismic retrofitting is only to improve seismic performance of building.

Retrofitting strategies

Retrofitting strategy is the basic overall approach to enhance the probable seismic performance of the building or to otherwise reduce the existing risk to an acceptable level [ATC-40].

1) Retrofitting strategies can be categorized as
2) Completion of load path and removal of structural irregularity Strengthening of structure
3) Enhancing deformation capacity of structure and
4) Reducing earthquake demand.

- Stiffness increase,
- Strength increase
- Ductility increase,
- Mass reduction

But we are mainly focusing on **stiffness and strength** increase of structure due to retrofitting.

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II. METHODOLOGY

The purpose of the NLTHA is to evaluate the expected performance of a structural system by estimating its strength and deformation demands in design earthquakes by means of a dynamic inelastic analysis, and comparing these demands to available structures with base isolators and tuned mass dampers so as to observe the decrease in the response of structures of interest. The evaluation is based on an assessment of performance parameters, like global drift, inter-storey drift, inelastic element deformations (either absolute or normalized with respect to a yield value), deformations between elements and element and connection forces.

III. ANALYSIS OF R.C.C & COMPOSITE STRUCTURE

This chapter copes with the analysis of R.C.C & composite structures with BRB frames under temperature loads. The buildings have been analyzed by NLTHA method in SAP-2000.

IV. DATA COLLECTION

Table 4.1 Assumed Preliminary data required for the Analysis of the frame

S.No	Variable	Data
1	Type of structure	Moment Resisting Frame
2	Number of Stories	Model- I : G + 5 Model-II : G + 10 Model-III : G + 12
3	Floor height	Commercial (Ground & 1st Floor) = 4.25m Residential (2nd& Above) = 3.40m
4	Live Load	Commercial (Ground & 1st Floor) = 4 KN/m² Residential (2nd& Above) = 3 KN/m²
5	Dead load	Commercial (Ground & 1st Floor) = 2 KN/m² Residential (2nd& Above) = 1.25 KN/m² wall load of 10 KN/m²
6	Materials	Concrete : M40 for Footings & Columns M35 for Beams & Slab Reinforced with HYSD bars (Fe500)
7	Size of Columns	RCC structure 450x450 mm, 600x600mm, 900x600mm
8	Size of Beams	RCC structure 300x600 mm , 300x450mm
9	Depth of slab	150 mm thick
10	Specific weight of RCC	25 kN/m³
11	Zone	II
12	Importance Factor	1
13	Response Reduction Factor	3
14	Type of soil	Medium

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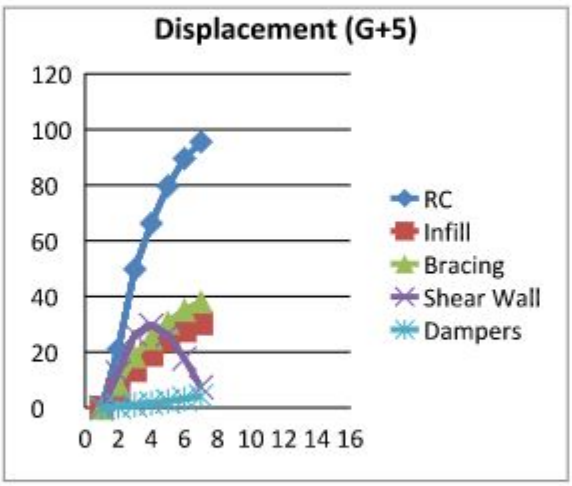
Table 4.2 General data collection and condition assessment of building

S.No.	Description	Information	Remarks
1	Building height- 12 storey 10 storey 5 storey	44.50m 38.05m 21.80m	Including the foundation level
2	Number of basements below ground	0	----
3	Open ground storey	Yes	----
4	Special hazards	None	----
5	Type of building	Regular Space frames	IS 1893:2002 Clause 7.1
6	Horizontal floor system	Beams and slabs	----
7	Software used	SAP 2000 V15	----

V. RESULTS & DISCUSSIONS

Non linear analysis of g+5 storey building



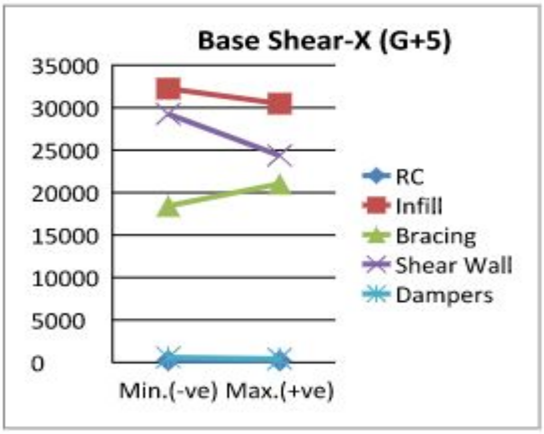


Figure 5.1(b): Base shear force comparison for G+5 storey for load case th-x.

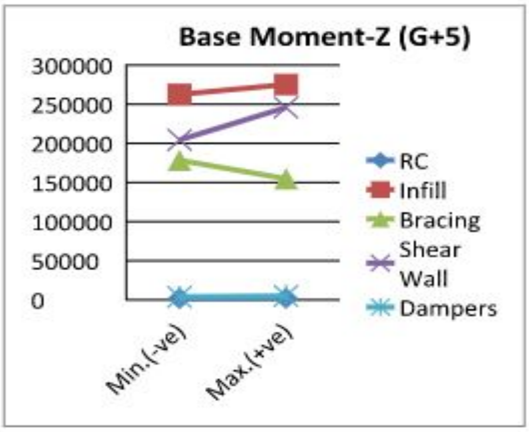


Figure 5.(c): Base Moment comparison for G+5 storey for load case th-x.

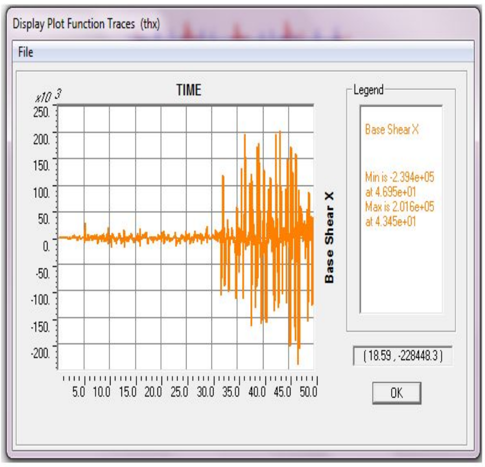


Figure 5.1(d): Base shear time history for G+5 storey structure for load case th-x

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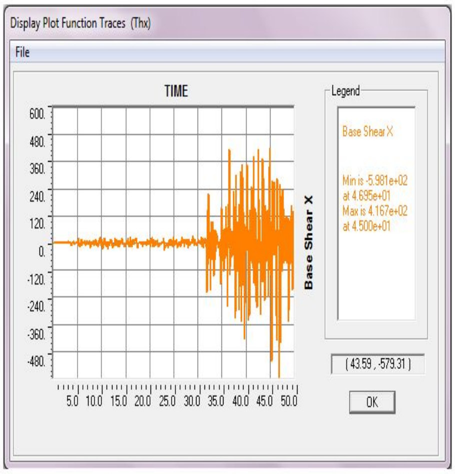

Figure 5.1(e): Base shear time history for G+5 storey structure for load case th-x

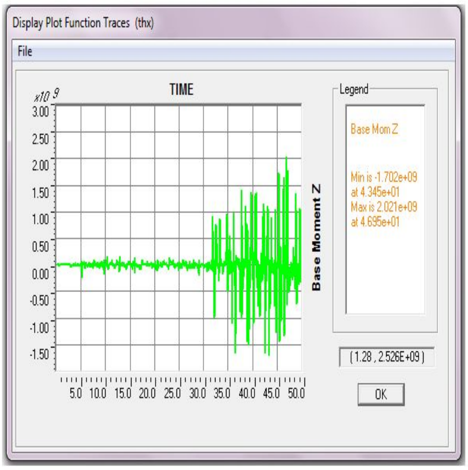

Figure 5.(f): Base moment time history for G+5 storey structure for load case th-

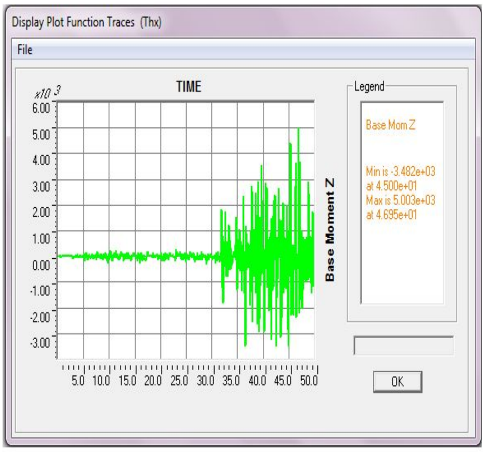

Figure 5.1(g): Base moment time history for G+5 storey structure for load case th-x

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5.4 response of rc frame structure with retrofitting technichies.

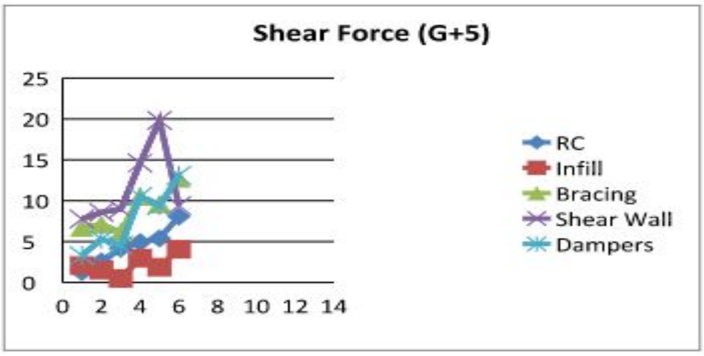


Figure 5.4(a): Shear Force comparison for G+5 storey for load case th-x

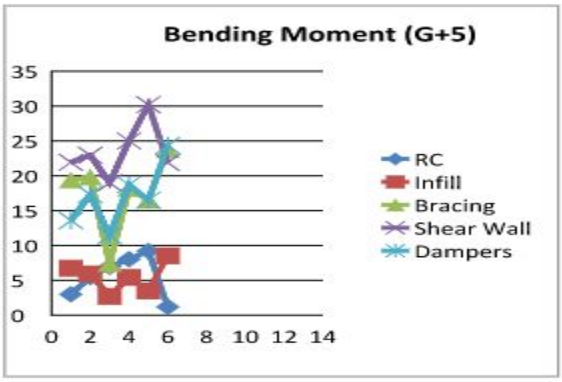
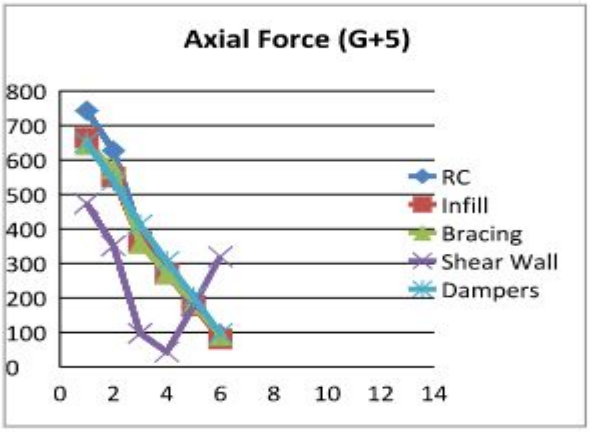


Figure 5.4(b): Bending Moment comparison for G+5 storey for load case th-x



VI. CONCLUSION

In India, most of the existing as well as new in filled RC frame buildings has been designed and are being designed without considering strength and stiffness of In fills (bare frame modeling). Due to inclusion of in fills, behaviour and failure modes of buildings changes. This leads to serious concern about seismic safety of existing buildings. In the present study, various strengthening techniques have been discussed. These techniques can be broadly categorized in two groups; 1. Strengthening of existing members, 2. Addition of new members.

A. In the first group, there are two methods; reinforced concrete jacketing and steel jacketing. In the present work, jacketing is done by

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1. In present work, due to retrofitting using infill wall with struds it gives good ductility and increase in strength carrying capacity and initial stiffness of Rc frame .the reduction of story drift by 46% compared to normal Rcc framed structure.
2. In present work, due to retrofitting using steel bracing it gives good ductility and increase in strength carrying capacity and initial stiffness of Rc frame .the reduction of story displacement by 40% compared to normal Rcc framed structure.
3. The overall results suggested that Strengthening of existing membersusing infill and steel bracing were excellent seismic control devices for symmetric building as the roof displacement is reduced by 46% and 40%. Compared to normal Rcc structure .

B. In the second group, there are two popular methods; addition of shear wall and addition of friction dampers.

1. Addition of friction damper is attractive and easy to construct but needs sophisticated method for proper fixation with existing frames. In present work, due to retrofitting with friction damper, there are change in ductility it increase up and also increase in strength carrying capacity and initial stiffness.the Base shear and Base moment is reduced by For Indian RC framed buildings, it is observed that beam column joints are most vulnerable to seismic failure, sometimes; addition of dampers without proper strengthening of joints may lead to catastrophic failure of building.
2. Addition of new shear wall can efficiently be used for buildings with only local interventions. In present work, due to addition of shear wall ductility which is increase compare to Rcc framed and also increase in strength carrying capacity and initial stiffness of Rcc framed structure. On the other hand, addition of shear wall needs laying of new foundation, which in itself a difficult task.

- since this retrofitting method showed a great improvement in the capacity of the building, it should be adopted as a suitable strategy for this case to reduce the seismic vulnerability of exiting RC buildings .
- The overall results suggested that Dampers are good technique for retrofitting for high rise building as it reduce the displacemrnt by 77% & 89%.

Future work

1. Single strut model for infills can accurately predict the lateral stiffness and strength of masonary infilled RC frame. However, use of single strut can only take into account its compressive failure; it can't predict local failure in frame member. Single strut models underestimate the force resultants in frame member.
2. In the present study, openings were not considered in infills. Presence of opening in infills significantly reduces the stiffness and strength of the infilled frames. Suitability of the proposed strengthening schemes must be verified for masonary-infilled frames with openings with walls.
3. Also for future work, non linear static analysis is a best method for analyzing the strengthening methods like friction dampers.

The experimental work should be carried out on a reduced scale three story with first story without infilled wall under gradually increased cyclic lateral displacements to further verify the effectiveness of proposed strengthening schemes

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