To Review and Study the Existing Methods and Procedures Available For the Analysis and Design of Masonry Buildings With and Without Openings under Seismic Loading Conditions

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Abstract — Many existing buildings that do not meet current seismic requirements are at risk of sustaining significant damage or even collapsing when exposed to severe ground motions. The purpose of seismic evaluation is to assess the ability of earthquake-vulnerable or earthquake-damaged buildings to withstand future seismic events. This evaluation can also help determine the extent of intervention required for seismically deficient structures and retrofitting needs. Seismic evaluation aims to assess the potential seismic response of buildings that may be seismically deficient or have experienced earthquake damage, with the goal of determining their suitability for future use. By conducting a thorough evaluation, the seismic performance of these structures can be quantified, specifically in terms of yield and collapse capacities, using various ground motion indices derived from Incremental Dynamic Analysis (IDA) curves. IDA is a structural analysis method that involves performing a series of nonlinear dynamic analyses using multiple scaled ground motion records. In this study, the IDA procedure is adopted to analyze a sample masonry structure. A suite of seven selected ground motion time histories is used to conduct the IDA of the masonry structure. The yield capacity of the structure is defined as the intensity level at which the IDA curve deviates from the linear path, while the collapse capacity is defined as the intensity level at which the IDA curve becomes horizontal. Fragility curves, which represent the probability of exceeding a certain damage level (yielding or collapse) at various intensity levels, are then developed based on the results of the time-history analyses. These curves provide valuable insights into the structural vulnerabilities and probabilities of yielding and collapse at different ground motion intensities. By applying a log-log linear ground motion hazard model, hazard-survival curves can be generated by converting the intensity axis of the fragility curves to annual probability of exceedance. These results provide a concise representation of the probabilities of yielding and collapse for different levels of ground motion intensities. The Masonry structure is analyzed using SAP2000 software (version-14), which allows for pushover analysis, incremental dynamic analysis, and fragility analysis. The findings of this study can serve as a guideline for understanding the seismic behavior of masonry structures and inform future seismic design and assessment practices.

Keywords: Masonry Building, Seismic Analysis, Incremental Dynamic Analysis (IDA).

I. INTRODUCTION

Masonry holds a paramount position as a construction material throughout human history. Over thousands of years, it has been extensively employed in various forms to build both public and residential structures. The existence of numerous well-preserved ancient masonry buildings stands as a testament to its ability to withstand loads and environmental factors, providing long-lasting shelter for people and their belongings when properly conceived and constructed. Among the different types of masonry, brick and stone structures excel in durability, fire resistance, heat resistance, and aesthetic appeal. Due to the easy availability of materials, economic viability, and aforementioned advantages, masonry construction is widely utilized in rural, urban, and hilly regions, adapting flexibly to prevailing environmental conditions.

However, findings from past earthquake surveys have revealed the vulnerability of masonry buildings, which have experienced significant damage and collapse during strong seismic events. The impact of earthquakes on masonry structures has been particularly severe, with instances of wall separation and even out-of-plane collapse. Even when the structural layout of these buildings appeared favorable and the walls were well connected, the quality of the masonry materials often proved insufficient to withstand diagonal cracking, disintegration, and ultimate collapse. Therefore, the structural layout of contemporary masonry buildings has become an exceedingly important consideration. Buildings with structural walls in only one direction, typically transverse, have been unable to withstand earthquakes with predominant ground motion in the weaker direction of the structure.

II. OBJECTIVE OF THE WORK

1) To review and study the existing methods and procedures available for the analysis and design of Masonry Buildings with and without openings under seismic loading conditions.
2) To conduct nonlinear seismic analysis on Masonry Buildings, considering the nonlinear behavior of the structure under earthquake forces.
3) To explore Incremental Dynamic Analysis (IDA) using SAP2000 software for the Masonry Building under consideration. IDA allows for the assessment of the structural response under various levels of ground motion intensity.
4) To determine the drift ratio of the Masonry Building under consideration. The drift ratio provides an indication of the relative lateral displacement and deformation experienced by the structure during seismic events.
5) To perform fragility analysis on the Masonry Building. This involves assessing the probability of the structure exceeding predefined damage states based on different ground motion parameters. The fragility curves will be

utilized to evaluate the performance of representative sample frames.

6) To develop hazard survival curves and determine the probabilities of surviving specified damage states. These curves will provide insights into the likelihood of the Masonry Building sustaining different levels of damage under various seismic events.

By accomplishing these objectives, this study aims to enhance the understanding of the seismic behavior of shell structures and contribute to the development of improved analysis and design approaches for Masonry Buildings under seismic loading conditions.

III. METHODOLOGY

The current project focuses on the seismic performance analysis of masonry structures. The proposed methodology for this analysis is outlined as follows:

1) Conduct an extensive literature survey on the response of masonry structures to seismic loading.
2) Based on numerical and parametric studies, develop a step-by-step procedure for simplified seismic analysis of masonry structures.
3) Perform linear static and linear dynamic analysis (Response Spectrum Analysis) using SAP2000 to evaluate the base shear of the masonry frame. Compare the obtained base shear with the manually calculated base shear according to IS: 1893.
4) Select a masonry building problem and analyze it using pushover analysis.
5) Based on numerical and parametric studies, propose a step-by-step procedure for simplified seismic analysis of the masonry frame.

A. *Analysis Procedure*

Various analysis procedures are considered for the seismic evaluation of the masonry building frame. These procedures include:

1) Linear-Static Procedure (NSP) - Pushover Analysis:

This procedure involves applying incremental lateral loads to the structure and analyzing its response in a step-by-step manner. It provides information on the strength and deformation of the structure, offering insights into its performance. NSP is relatively simpler to apply for everyday design use but may not provide highly accurate results.

2) Nonlinear-Dynamic Procedure (NDP) - Time-History Analysis:

NDP is considered the most accurate procedure for analyzing structures subjected to ground motion excitations. It involves modeling the structure in three dimensions and considering the detailed hysteretic behavior of its elements. However, applying this procedure can be challenging due to the complexity of 3D modeling, uncertainty in structural properties, and the need for reliable ground motion data.

3) Incremental Dynamic Analysis (IDA):

IDA involves conducting a series of time-history analyses with increasing ground motion intensities. The analysis results are used to develop Intensity-Damage (IDA) curves, which provide information about the structural response at different levels of ground motion intensity. IDA can help assess the vulnerability and damage potential of the masonry building frame.

4) Fragility Analysis:

Fragility analysis utilizes the IDA curves to derive fragility functions, which estimate the probability of exceeding certain damage states for given ground motion levels. Fragility analysis helps in quantifying the vulnerability of the masonry structure and determining its reliability under seismic events.

After studying these analysis procedures, it is observed that Linear-Static Procedures (LSP) and Linear-Dynamic Procedures (LDP) may not yield highly accurate results for the masonry building frame. NSP provides useful information about the structure's strength and deformation but has limitations. NDP, although more accurate, presents challenges related to modeling complexity, uncertain properties, and ground motion data. However, considering the detailed hysteretic behavior of the structural elements is crucial for the analysis.

By selecting an appropriate analysis procedure and addressing the associated difficulties, a comprehensive understanding of the seismic behavior and performance of the masonry building frame can be obtained.

Plot Intensity-Duration-Area (IDA) curves between Peak Ground Acceleration (PGA) and drift ratio for the seven selected ground motions. Utilize these IDA curves to obtain fragility and hazard survival curves.

The methodology outlined above provides a systematic approach for analyzing the seismic performance of masonry structures, incorporating both simplified analysis techniques and more detailed nonlinear time history analysis.

The SAP2000 software is utilized to conduct Nonlinear Dynamic Analysis of Masonry Structures using a displacement control strategy. Prior to the pushover analysis, gravity loads are applied to the structure. By examining the Incremental Dynamic Analysis (IDA) curves for a specific building subjected to a particular ground motion, the yielding and collapse behavior can be determined with reasonable accuracy.

The yield capacity of the structure is defined as the point on the IDA curve where it deviates from the linear path. This point indicates the intensity measure (IM) at which the structure starts to exhibit nonlinear behavior. On the other hand, the collapse capacity of the structure is reached when further increases in the IM result in an infinite increase in Engineering Demand Parameters (EDP).

It is worth noting that the relationship between EDP and IM varies for different ground motions. This implies that the response of the structure in terms of displacement or other EDPs is influenced by the characteristics of the specific ground motion applied. Therefore, the IDA curves provide valuable insights into the EDP-IM relationship and highlight the variations in structural response for different ground motions.

Through the Nonlinear Dynamic Analysis and the interpretation of IDA curves, engineers can gain insights into the behavior of masonry structures under dynamic loads and assess their capacity to withstand seismic events. This information is crucial for evaluating the structural performance, identifying potential vulnerabilities, and making informed decisions regarding design modifications or retrofitting measures.

B. Parameter of Masonry Building Used

Span in the X direction: 3.6 meters
Wall thickness: 0.2 meters
Live load: 3 kN/m²
Grade of Concrete: M-20
Type of Steel: HYSD bars
Column Height: 6.0 meters
Column Size: 0.2 meters x 0.2 meters
Column Longitudinal Reinforcement: 1% reinforcement
Column Transverse Reinforcement: 10d @ 150 center to center
Column Support Condition: Fixed
Beam Size: 0.20 meters x 0.10 meters
Opening Size: 1 meter x 2 meters
Selection of 7 Ground Motions for IDA

1) *Record ID: P1540*

Earthquake Event: Duzce, Turkey 1999/11/12
Station: Duzce
Component: DUZCE/DZC 270
Magnitude: 7.1
Range (Km): 8.2
PGA (g): 0.53

2) *Record ID: P0178*

Earthquake Event: Imperial Valley 1979/10/15 23:16
Station: 942 El Centro Array #6
Component: IMPVALL/H-E06-UP
Magnitude: 6.5
Range (Km): 1
PGA (g): 1.65

3) *Record ID: P0454*

Earthquake Event: Morgan Hill 1984/04/24 21:15
Station: 57191 Halls Valley
Component: MORGAN/H VR240
Magnitude: 6.2
Range (Km): 3.4
PGA (g): 0.31

4) *Record ID: P0052*

Earthquake Event: San Fernando 1971/02/09 14:00
Station: 135 LA - Hollywood Stor Lot
Component: SFERN/PEL1 80
Magnitude: 6.6
Range (Km): 24.6
PGA (g): 0.17

5) *Record ID: P0266*

Earthquake Event: Victoria, Mexico 1980/06/09 03:28
Station: 6604 Cerro Prieto
Component: VICT/CPE045
Magnitude: 6.4
Range (Km): 34.8
PGA (g): 0.62

6) *Record ID: P1040*

Earthquake Event: Kobe 1995/01/16 20:46
Station: 0 HIK
Component: 90
Magnitude: 6.9
Range (Km): 94.2
PGA (g): 0.14

7) *Record ID: P0141*

Earthquake Event: Tabas, Iran 1978/09/16
Station: 71 Ferdows
Component: FER-T1
Magnitude: 7.7
Range (Km): 94.4
PGA (g): 0.10

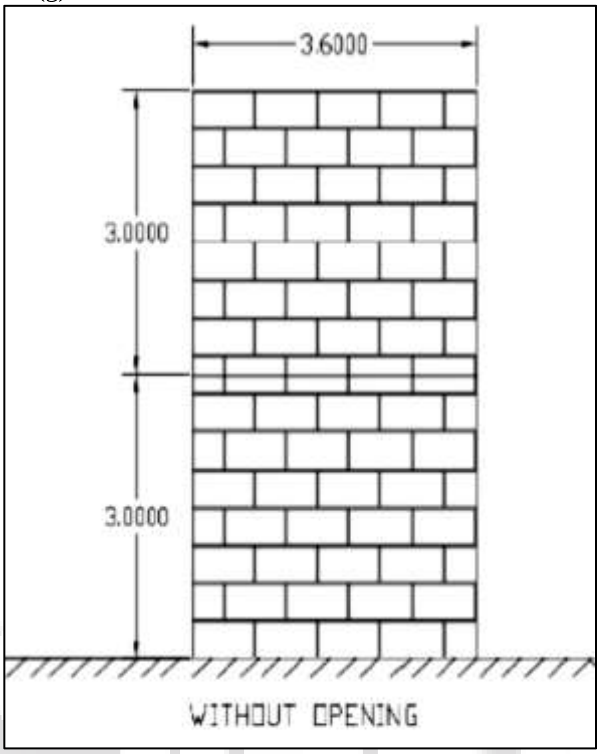

Fig. 1: Masonry wall without opening

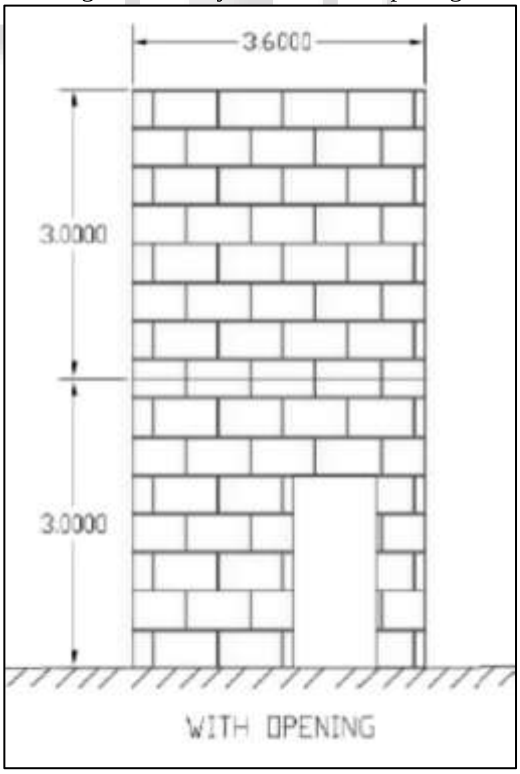

Fig. 2: Masonry wall with opening

IV. RESULTS AND DISCUSSION

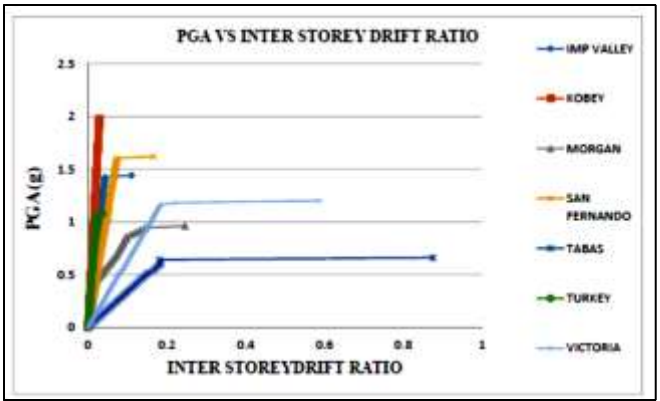

Fig. 3: IDA Curve for 7 Time Histories Without opening

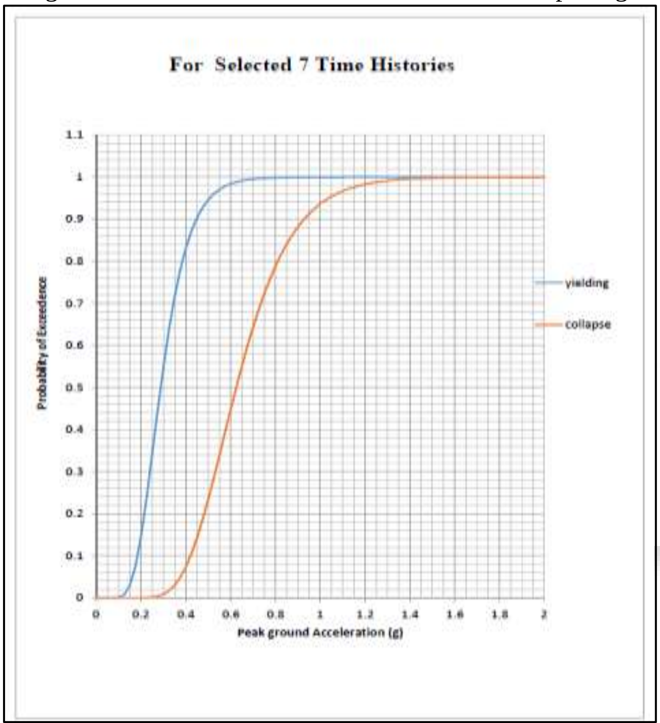

Fig. 4: Fragility Curve for Selected Ground Motion for without opening model

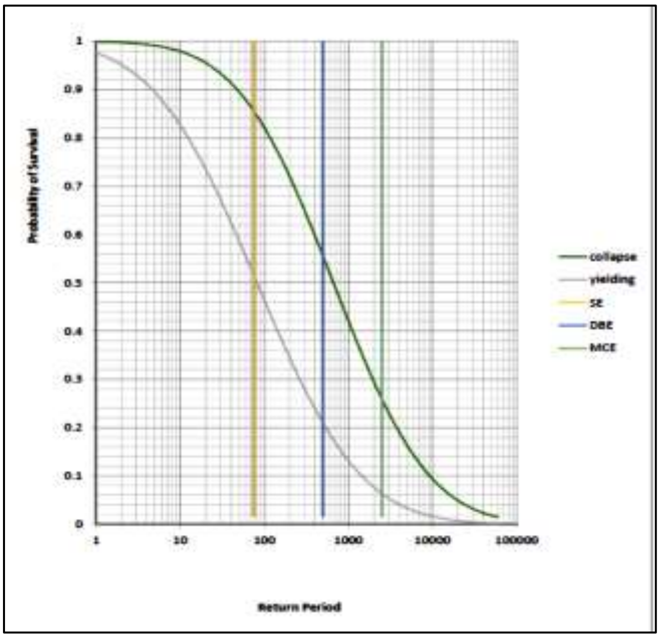

Fig. 5: Hazard Survival Curve

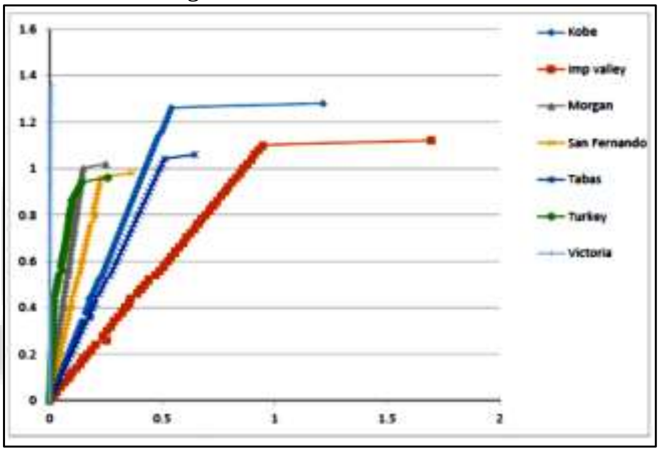

Fig. 6: IDA curve for 7 Time history with opening

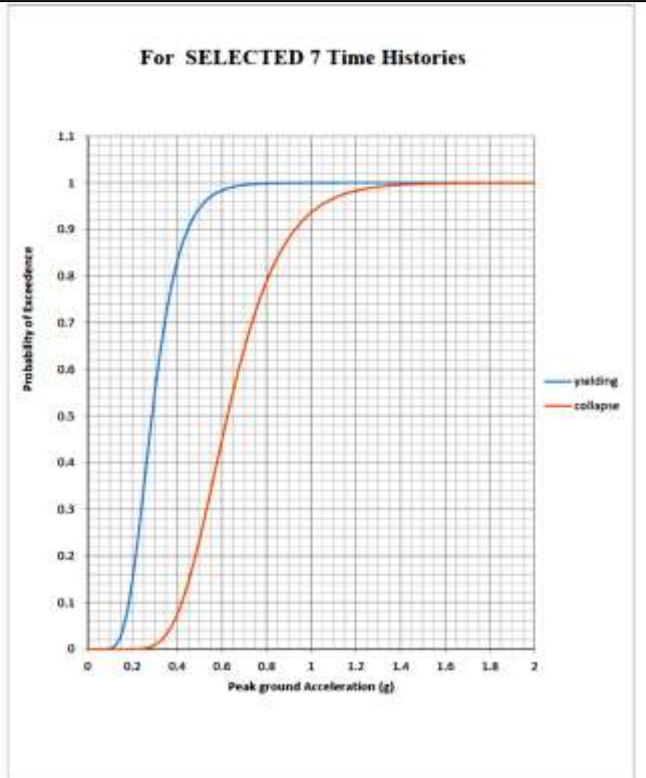

Fig. 7: Fragility Curve for Selected Ground Motion

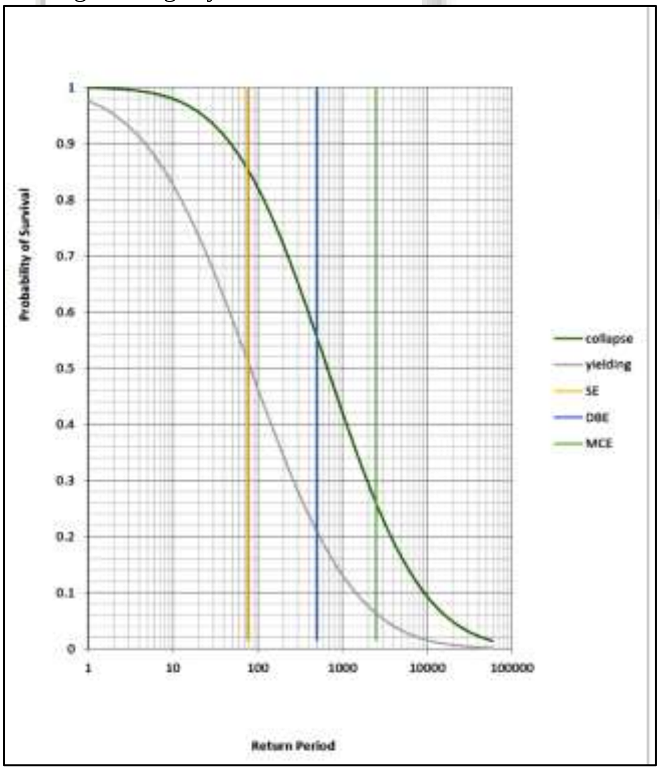

Fig. 8: Hazard Survival Curve

V. CONCLUSIONS

Based on the conclusions drawn from the Fragility Analysis of Masonry Buildings, the following statements can be made:

1) Masonry infill frames without openings have a higher peak ground acceleration (PGA) compared to frames with openings.
2) The earthquake with a PGA of 0.72g (2MCE) poses the highest vulnerability to masonry infill frames, resulting in more than 90% damage.
3) Considering the recent earthquake scenarios, it is crucial to perform seismic evaluations of existing masonry frames based on Incremental Dynamic Analysis (IDA).
4) The Indian seismic code should incorporate the effect of infill masonry material by introducing improved seismic design coefficients, as the presence of infill has a significant impact when compared to bare frames.
5) Infill masonry material significantly enhances the lateral resistance capacity of buildings in comparison to bare frames.
6) It is necessary to include nonlinear seismic analysis methods in the Indian seismic codes to enable realistic performance-based earthquake design of structures.

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