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Behaviour of Unreinforced masonry

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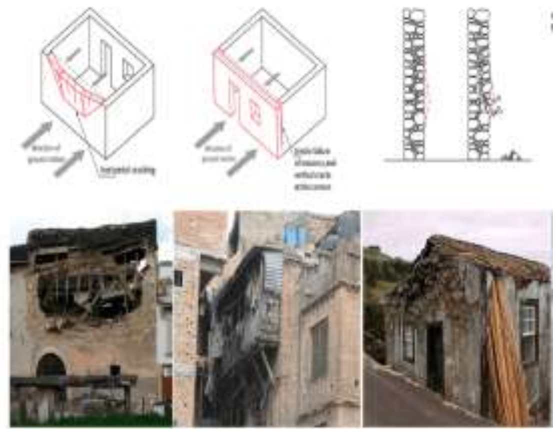
A B S T R A C T
Structures made of unreinforced masonry (URM) are simply those that lack reinforcement. URM is a typical building material, however, because of its enormous weight, high stiffness, and minimal strength, it is renowned for being seismically vulnerable. In underdeveloped nations like India, URM constructions are often employed for low-rise buildings up to two floors in rural regions. Loss of life and destruction of cultural heritage occurs from damage to such buildings.
The primary goals of the current thesis are to comprehend the idea of comparable frame modelling and the lateral behaviour of URM structures. In the current work, the nonlinear behaviour of masonry is investigated using uniform distribution lateral and inverted triangular loads. Static Pushover analysis of URM may be done in a number of ways, but Equivalent Frame Modeling is the most straightforward. By including shear and flexural hinges in the model, EFM is utilised to simulate the non-linear behaviour of masonry. Simply supposing a wall with an opening and a combination of vertical and horizontal elements is what equivalent frame modelling is all about. Since they enable users to precisely track the structural performance beyond the elastic limit at each stage of the incremental analysis, plastic hinges were employed in Static Pushover studies. As suggested in literature evaluations, perfectly hard plastic hinges were taken into consideration during modelling.
Sensitivity analysis is done to determine which masonry property is sensitive to lateral behaviour. All parameters were varied for sensitivity analysis using 5 percent, mean, and 95 percent values. The output of sensitivity is represented as a TD diagram. Except for compressive strength, it was discovered that every other parameter affected lateral behaviour.
One of the most crucial instruments in performance-based based structure design is fragility. The AZUS approach is used to create the fragility curves. Different damage levels, including minor, moderate, substantial, and total damage states, were assumed to indicate variations in the building's seismic performance and finally, based on damage probability and spectral displacements, fragility curves for three damage state quality levels of masonry were constructed. It has been noted that the building is more likely to sustain moderate damage. For comparing the pushover outcomes, different brick masonries are taken into consideration.
Keywords: Masonry,structural behaviour,Piles,Masonry stress

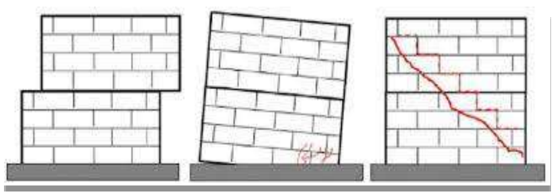
I. INTRODUCTION:

Piers and Spandrel Failure

Vernacular buildings have typically show a poor structure behaviour of unreinforced masonry after a recent earthquake such as in 1998 in azores , in 2009 in ITALY ,2011 in Sikkim INDIA or in 2015 in INDIA/NEPAL



Various types of failure in masonrypier:-
(a)sliding shear
(b)rocking
(c)diagonal shear cracking



There is a great threat of earthquake damage to the Un-Reinforced masonry building since it is weak in carrying lateral loads. There are many Un-Reinforced masonry historical important structures as well as housing units in India which may damage due to the earthquake. Still, it is difficult to predict the post-earthquake performance of such structures. Static Pushover analysis is an important tool to evaluate the seismic performance of the building

II. LITERATURE REVIEW

Push-over analysis is an approach of non-linear static analysis. Several literature research have focused on pushover analysis of RCC and steel constructions, while unreinforced masonry buildings have received far less attention. The pushover analysis is a crucial technique for the building's seismic assessment. This chapter reviews seismic assessment techniques found in the literature as well as a few analytical and experimental studies on unreinforced masonry structures. In this chapter, some findings from earlier SPO analysis research are discussed.

Experimental Research

Chandra and Krishna (2018) and Krishna (2021) conducted SPO analysis. Walls with and without reinforcement's static in-plane strengths were compared. In order to identify the lateral behaviour, different masonry characteristics must first be identified. Failure causes are then determined, and various ways for reinforcing masonry structures are used. Important findings include the fact that URM structures collapse brittlely and that their ability to absorb energy is limited by elastic deformation. Higher mortar grade provides greater earthquake resistance.

The damage to historic URM work buildings in seismic zones throughout the globe was reviewed by Scrivener (2019). Results indicate that monotonically increasing loads, such as those used in SPO analyses, can provide some insight into the deformation and initial strength of URM, but that dynamic loading can provide more precise information about stiffness reduction, ductility, and energy dissipation for detailed seismic analyses.

After researching the different earthquakes that occurred in Turkey, Anadol and Arioglu (2015) concluded that simple URM structures are the most vulnerable to destruction. To prevent the collapse of URM constructions, which perform better during earthquakes than typical masonry construction, it was advised to put horizontal wooden elements on both sides at various vertical intervals. Such traditions have historically been common in Turkey.

Under monotonic and cyclic stress, Abrams investigates unreinforced masonry components' in-plane lateral load behaviour. Although masonry is brittle, he argues that it has a significant potential for deformation after the first crack appears. Many pieces of advice have been offered to assess the features of masonry strength under lateral stress.

Bruneau derives a number of conclusions regarding the seismic performance of unreinforced masonry structures using the theoretical framework to evaluate URM-bearing wall structures developed in California and lately included in the new Canadian Rules for the seismic evaluation of existing buildings. One of the main reasons URMs fail when joists are secured to a wall is because the anchoring failed or there was insufficient anchorage between the wall and the floor. Bruneau provides the following list of various failures:

a) Out-of-plane failure, In-plane failure, Combined in-plane

Goel and Rai: The pier and spandrel, which are primarily responsible for the URM structure's lateral behaviour, may be successfully enhanced by adding a steel frame around the wall with vertical and horizontal components and openings. According to the findings, a pier with steel members has a displacement increase of 2.5%, with crumbling exhibiting a ductile response. In the present work, only the behaviour of masonry piers in plane was taken into consideration and the ductility and stiffness of the strengthened structures improved.

According to research by Navalli in Uttaranchal, using flat wood groups at specified vertical intervals will improve the structural integrity of the brickwork. In comparison to masonry buildings without horizontal timber bands, these homes sustain less damage during the October Uttarkashi earthquake. Such approaches are mentioned in a work by Anadol, Arioglu, Arya, and Jai Krishna as well.

Tianyi et al. analysed a two-storey, full-scale URM building to look at its lateral resistances and results, which revealed that although the test URM construction initially had a high initial stiffness, it quickly decreased with a slight increase in lateral deformation. He led to the important findings that damage to URM was discovered as a result of significant fractures developing at the masonry mortar and brick interfaces. The first-story piers' sliding and rocking failure mechanisms have an impact on the collapse of the first storey. This study also came to the conclusion that the FEMA 356 approach requires significant changes.

Analytical Research

Pappin and Duan (2018) provide a method based on the findings of the nonlinear push-over analysis for creating the necessary fragility curves for the different damage levels, especially for the more extreme damage levels. The problem of finding

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the median spectral displacements for the more extreme damage levels is addressed, and a solution is suggested. To demonstrate the full procedure, an example is presented. The authors' recent investigations of seismic loss estimates of contemporary cities with densely occupied structures in areas of moderate seismicity successfully used the proposed method.

Low-rise, unreinforced masonry constructions' seismic potential was examined by Park et al. in 2019. Create a fragility curve for a southern US region, two-story URM. They provide a method for structural modelling that may be used to fragility analysis successfully while without appreciably lengthening computation times and maintaining a respectable degree of accuracy in describing the nonlinear behaviour of the structures. The HAZUS method and the developed fragility curve are compared.

For the purpose of generating fragility curves for URM structures, Rota et al. (2020) have proposed a novel analytical method. This probabilistic method is the one that treats mechanical characteristics as random variables. For seismic performance, masonry property variation is also crucial. This strategy is based on stochastic nonlinear evaluations of prototype building. Assuming that they fluctuate within appropriate ranges of values, the mechanical features of the prototypes are processed as random factors. Then, input variables are produced from the mean and coefficient of variance using Monte Carlo simulations. Nonlinear studies are carried out after the model has been developed. Non-linear static analysis is applied, non-linear dynamic studies enable us to ascertain the probability density function of the displacement demand corresponding to various degrees of ground motion, whereas linear dynamic studies enable us to ascertain the probability distributions of each damage scenario. Fragility curves may be derived for various damage states by employing a complicated convolution technique that combines the probability density function and cumulative demand distribution.

Lagomarsino et al. (2021) conduct a nonlinear study of unreinforced masonry structures using the TREMURI program's equivalent frame modelling technique. They observed that the equivalent frame technique is fundamental and easy since it allows for the quick and easy examination of a whole 3D URM structure while requiring little computing effort. This approach is suitable for real-world engineering applications. He discusses the procedures used to create the corresponding frame model for the TREMURI program's non-linear analysis of masonry buildings.

In a paper by Bakre and Sonekar (2020), Masonry frame constructions are studied in relation to their non-linear response to seismic excitation and various lateral loading conditions. By include flexural and shear hinges, the non-linear behaviour of brickwork is simulated using the EFM. Estimates of the structure's strength are improved when the loading pattern is uniform throughout the height of the building, as opposed to the other two lateral loading patterns, mode and parabolic, which are always equivalent (i.e., about 15 percent higher). Shear failure is discovered to be the primary factor in the failure of URM frame constructions. Stronger and stiffer structure moves less than weaker because spectral displacement is observed to be less in the strong direction (i.e., around 64 percent less) than the weak direction.

Structures with masonry infill are subjected to sensitivity analysis by Bhosale et al. in 2021. The structure's seismic performance is significantly impacted by the variance in material qualities. They discovered how responsive certain masonry characteristics are to lateral behaviour. The primary goal of this analysis is to discover the parameter that most significantly impacts the building's lateral reaction. To obtain a suitable set of findings that adequately reflect the large range of potential circumstances that might be encountered in practice, sensitivity analysis is performed in this paper by taking into account a random variable's mean and coefficient of variance, as well as its 5 percent mean and 95 percent probability value on the basis of coefficient of variance and mean. They employed base shear at yield and the pushover curve as sensitivity parameters. While the tensile strength of the concrete figure used to illustrate the sensitivity analysis findings did not substantially alter the lateral structural performance, all other mechanical strength-related elements of masonry and concrete did.

The "Department of Homeland Security Federal Emergency Management Agency (FEMA)" created the technical and user documentation known as Hazus - MH 2.1 (2021). It outlines the process for creating damage that is particular to a building and working with cutting-edge engineering construction components. The probabilistic approach for developing the fragility curve, which is based on a number of variables for various damage stages, is also provided by this code. It provides uncertainty related to various damage conditions. Hazus has provided pre-calculated values for total variability utilised in the production of fragility for various damage levels, saving us the trouble of the difficult convolution approach.

Sensitivity Analysis

Introduction

Sensitivity analysis, as its term suggests, is the process of determining which input parameter is sensitive to a structure's output behaviour. The parameter might be one or more mechanical or physical characteristics, such as Young's modulus, density, or compressive strength. Identifying the modification in response to the structure means changing one property while leaving the others unchanged. Sensitivity analysis is research that determines how input factors influence output parameters. In this research, ultimate and yield base shear are used as sensitivity factors to investigate the effect that masonry properties like compression strength and shear strength have on the lateral behaviour of URM during an earthquake. This analysis is the term used to describe the search of output uncertainty in relation to input uncertainty. Sensitivity analysis has a number of benefits, some of which are given below:

- To lessen the model's uncertainty by being aware of the variables (inputs) that have a substantial impact on output.
- Understanding the sensitive parameters allows one to concentrate on them, which reduces computing effort and saves time.
- To understand how input and output variables are related.
- To evaluate the model's dependability in the face of uncertainty.
- Reliability may be improved by reducing uncertainty during the assessment of inputs that significantly affect output uncertainty and, as a result, should be the focus of attention.
- Errors in the model may be anticipated by identifying the abrupt link between output and input.
- To fix the model inputs by fixing the non-sensitive variables, which will simplify the model.

A main sensitivity test, which focuses on the sensitive parameters, might make the calibration step easier when calibrating models with many parameters. When parameters' sensitivity is unknown, time may be wasted on insensitive ones.

Sensitivity Analysis of URM Wall

This lateral behaviour of the structure is affected by variations in the material parameters, such as physical and mechanical properties. Sensitivity analysis is done to determine which URM parameter is sensitive to the earthquake reaction. The probability values of the input masonry qualities used in the current work's sensitivity analysis are 5 percent and 95 percent. The model's mistakes may be anticipated by understanding the rapid changes in output brought on by changes in the input. The sensitivity analysis presented in this chapter was done to provide a realistic range of findings that represented a broad variety of potential circumstances that may be handled in practise using pushover analysis.

Selected URM Wall

The a single, double-story URM wall with a 0.25 m wall thickness is considered for sensitivity analysis. This analysis was done on the same wall while taking alternative masonry into consideration (CLC, Clay, and AAC). For sensitivity analysis, the masonry's compressive density, strength, modulus of elasticity, shear strength, shear modulus, as well as Poisson's ratio are all taken as random factors

III. RESULT

The general definition of sensitivity analysis and its benefits are provided in this chapter. Later, sensitivity analysis is performed by taking into account a random variable's probabilities of 5 and 95 percent for the qualities of masonry. Tornado Diagrams show the sensitivity's outcome. The results show that ultimate base shear is sensitive to all factors except for the compressive strength of the masonry, whereas base shear at the yield level is vulnerable to the density and shear strength of the brickwork.

IV. CONCLUSIONS

These are the main findings from the research that are derived:

- Pushover curve: According to the results of the SPO research, clay masonry will respond to an earthquake better than Fly Ash, AAC, and CLC masonry. The responsiveness of a URM construction will increase with a better grade of cement mortar. In comparison to an inverted triangular load distribution, a stronger strength estimate is achieved with a uniform load distribution. The creation of shear hinges in the structure was the primary cause of URM's collapse. When the weight is distributed in an inverted triangular fashion, as in the upper storey, the storey mechanism kicks in, and when the load is distributed uniformly laterally, as in the lower level. Both distributions end up moving around the same amount.
- Sensitivity analysis: According to the findings, the density and shear strength of the brickwork affect the base shear at the yield level, whereas all other factors except the compressive strength of the masonry affect the base shear at the ultimate level.
- Fragility curve: It is only created for CLM walls for the three damage levels in this work. It has been

shown that the likelihood of moderate damage is higher than the likelihood of full damage. With an increase in injury severity, the likelihood of harm will drop.

V. LIMITATIONS AND FUTURE SCOPE

In the current research, one wall is examined while taking into account various masonry qualities. The current work may be strengthened by taking into account various walls with various geometries and various orientations in openings. The research is only focused on in-plane strength (2D). This modelling must take the influence of 3-D out-of-plane strength into account for more accurate results. This study is covered by a whole wall with no openings. Because there is a significant of regional variation in the mechanical and physical characteristics of URM, it is crucial to properly determine these characteristics to get more accurate findings. Only clay masonry is utilized to develop the fragility curve.

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