BEHAVIOUR OF MASONRY BUILDINGS UNDER SEISMIC ACTION – A REVIEW

Neethu Gopal[1], Sankaranarayanan K.M[2], Sivan P.P[3]

[1]*PG Student, Department of Civil Engineering, Sreepathy Institute of Management and Technology, Vavanoor, India*

[2]*Assistant Professor, Department of Civil Engineering, Sreepathy Institute of Management and Technology, Vavanoor, India*

[3]*Assistant Professor, Department of Civil Engineering, Govt.Engineering College Thrissur, India*

---***---

Abstract - *There are different types of studies carried out based on the seismicity. The structure shows different types of damage pattern for low to severe earthquake conditions. The masonry structures are commonly classified as unreinforced, reinforced and confined masonry structures. These buildings belongs to the most vulnerable class of structure have experienced heavy damage or even total collapse during earthquakes, so their analysis is a difficult task. Generally three types of failure mechanism define the behaviour of masonry structures namely, sliding shear failure, diagonal shear failure and rocking flexural failure. This paper focused on the analytical study of different masonry buildings under various seismic conditions and the mitigation practices.*

Key Words: Masonry buildings, analytical study, failure mechanism

1. INTRODUCTION

Masonry walls are used in almost all parts of the building construction due to the low cost of materials, good sound and heat insulation properties, easy availability, and locally available materials and skilled labour. Generally, masonry is a nonelastic, non - homogeneous and anisotropic material composed of two different materials, bricks and mortar. It is very weak in tension due to the weak bond between them.

To understand the significance of the properties of the materials and structural characteristics specific for masonry structures which influence for the response of masonry structures to seismic action, the observed behaviour of the masonry buildings, as well as causes of any damage that occurred to building during earthquakes, should be analyzed carefully. Most of the data needed for structural verification and design can be obtained from ground acceleration records. The analysis of seismic behaviour of masonry buildings gives the values of effective peak ground accelerations are in correlation with the induced seismic forces and observed damage to the building.

The availability of masonry model for the seismic analysis of masonry structure would represent a critical step towards a proper assessment of new and existing masonry buildings. The aim of this project is to present an innovative model and safety measure of such building structures.

1.1 Masonry Structure

Masonry construction is one of the oldest construction techniques that are still used in the building industry. It is mostly used for the walls of the buildings. Bricks and the concrete blocks are most common types of masonry units. The masonry structures are easy to construct and are inexpensive to maintenance. The most common masonry types includes:-

- Unreinforced masonry
- Confined masonry
- Reinforced masonry

Generally, masonry buildings are built based on tradition and experience. Masonry buildings were classified depend on the use of materials (adobe, stone, brick…etc.). The structural typology of the buildings differs in different regions. The damages caused due to the earthquakes can be classified in a uniform way. The following are the typical damages identified by the analysis of observed earthquake damage pattern:

- Cracks between walls and floors
- Cracks at the corners and at wall intersection
- Out – of plane collapse of perimetral walls
- Cracks in spandrel beam or parapets
- Diagonal cracks in structural walls
- Partial or complete collapse of the building
- Partial disintegration or collapse of structural walls

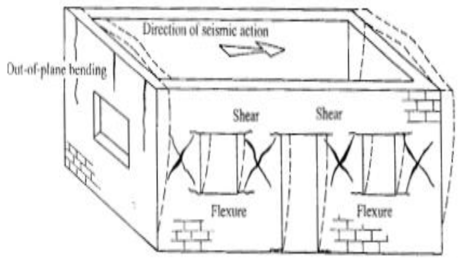

Fig - 1:deformation of the building and typical damage to the structural wal[15]

2. LITERATURE REVIEW

The detailed review of literatures related to seismic analysis of structures is very vast area. This literature review point out the brief review of the seismic analysis of masonry structures.

Krishna Naraine and Sachidanand Sinha 1989[1] studied the behaviour of unreinforced masonry under compressive cyclic loading both perpendicular and parallel to the bed joint. The specimens were instrumented for the measurement of axial and lateral displacements along the fixed gauge lengths. The experimental results have a major drawback that the readings were not consistent in the case of loading parallel to the bed joint; it causes the formation of wider cracks near the edge of the specimens. In the three types of tests, at the first time the load increased steadily to failure and then the specimen tested under cyclic loading. In the final case loading and unloading was repeated several times. The failure mode varies depends on the orientation of the bed joint.

Yan Zhuge et al.1998 [2] conducted nonlinear dynamic analysis of unreinforced masonry. Developed an analytical model and study the response of unreinforced masonry to in – plane dynamic loads including earthquake loading. This analysis is considered as a nonlinear finite element program. The model is able to performing both static and time history analysis. The global behaviour of the building is studied by the use of a SDOF model, which is a FEM of masonry under dynamic loading. The analytical model has been developed for carrying out the time history analysis of the URM under seismic loads. At the time of testing, the vertical compressive stress is taken as constant and the horizontal loads increased gradually up to failure. All the failures depend on the stress state acting on the joints.

Milad M.AIShebani and S.N.Sinha 1999[3] carried out several laboratory tests on half – scale sand plast brick work panels under uniaxial cyclic loading. Then conducted the monotonic uniaxial, cyclic uniaxial loading and repeated loading and unloading were carried out. The changes in the aspect ratio affect the cyclic behaviour in the case of loading parallel to the bed joint. The failures are occurred by total splitting in vertical bed joint.

Guido Magenes2000 [4] this paper describes a method for the nonlinear static analysis of masonry building suitable for the seismic assessment based on pushover analysis. This method is based on the equivalent frame idealization of the structure. Here several basic ideas of the storey mechanism approach have been used in which the resisting mechanism is governed by in plane response of walls. This model does not considering the collapse mechanism due to dynamic out of plane response. In the SAM method an assumption is made that an elastic – brittle behaviour of the spandrels falling in shear. The evaluation is carried out for the deflected shape of the building at peak response. The experimental responses have been evaluated in terms of an equivalent SDOF structure. SAM method is very attractive and need less computation.

Asterisis.P.G.2003[5] made an attempt to analyze the brick work in filled plane frames under lateral loads. This investigation is based on the lateral stiffness of brick masonry in filled plane frame using a finite element technique. Here present a method to define the general anisotropic failure surface of masonry under the biaxial stresses, and propose an analytical methodology to describe the masonry failure surface under plane stress. The failures happens due to the crushing of the in filled corner. The main drawback of this study is the research of infill wall with opening is analytical and limited, and bears no comparison due to the different materials used and the different type of opening.

Bosiljkov,V et al.2005[6] made an attempt to find out stiffness of masonry wall. Here conducted experimental test with the basic definition of stiffness as the action that causes unit displacement. The main aim of this work is to re – evaluating the values for the shear modulus in the different national codes considering different experimental techniques for its determination.
In seismic analysis of laterally loaded walls, the resulting deformation is combined action of bending and shear. Each specimen was subjected to lateral displacement under a constant vertical load. Analytically calculated elastic stiffness was compared with effective stiffness obtained experimentally. The elastic stiffness is an approximation of the effective stiffness for laterally loaded masonry element.

Pere Roca et al.2005[7] studied the strength capacity of masonry wall structures. They used the equivalent frame method which is to be developed for efficiently simulating the service and ultimate response of structural system of masonry load bearing wall. The non – linear response are find out by the use of biaxial equations. This method helps to the prediction of overall response of the masonry buildings and their failure conditions. It shows compatibility between wall panels and the transverse members connecting them. The constitutive equations for the non – linear analysis of the masonry element have been implemented for allowing the use of the method for the assessment for the ultimate capacity of masonry construction including the load bearing or shear wall.

Tianyi Yi et al.2006 [8] conducted different analytical approaches to investigate the response of unreinforced masonry. A nonlinear discrete crack finite element model was adopted. The nonlinear analytical methods are used for the analysis includes; a rigid body analysis, a two-dimensional nonlinear pushover analysis, and a three-dimensional nonlinear finite element analysis. This method predicts the nonlinear behaviour of the structure. Out-of-plane walls are considered for their additional vertical load capacity to resist overturning moments. The building is assumed to be dominated by shear deformations where flexural deformations are neglected. The rigid body analysis is good for a quick estimate, that the 3D nonlinear FE model is suitable for in-depth investigation of important projects, and that the 2D nonlinear pushover method is best for the seismic evaluation and retrofit of existing structures. The 3D nonlinear FE analysis is very time consuming, and thus is not suitable for daily design or evaluation projects. The rigid body analysis cannot recognize toe crushing and diagonal tension failure modes, and cannot predict deformations.

Shakeri K. et al. 2008[9] proposed an advanced spectrum based multimodal adaptive procedure for pushover analysis. The lateral load pattern is based on the assumed fundamental mode shape and the response of a multi degree of freedom system is directly related to the response of an equivalent single degree of freedom system with a fundamental mode shape assumed to be constant in elastic and inelastic deformation. In regular and low-rise buildings in which the response is governed primarily by fundamental mode, this procedure provides a good estimation of the global deformation response. The resulting capacity curves depend to spectra acceleration which is according to the structural behavior in inelastic phase.

J.Snoj et al.2012[10], the seismic performance of existing masonry buildings were affected by different uncertainties. The experimental setup based on the measurement of ambient and forced vibrations on an old two storey masonry building. The vibration periods are estimated and which is based on two type of measurement, these are compared and seismic performance of the building is assessed for the near – collapse limit state. An existing masonry building's seismic analysis is very difficult criteria. The possibility to reduce the uncertainty in modeling is to measure ambient or forced vibrations. Time or frequency domain techniques are based on the estimation of natural frequencies. The empirical estimation of natural frequencies are based on the ambient vibrations and the forced vibrations. It evaluates the vibration of building caused by trains. The Centre of the three corners of the roof storey contains 3D velocity sensor, which measures the vibrations. Then carried out the Fourier spectra analysis. In this experimental approach, the wider frequency range of the forced vibrations estimates the higher frequencies while considering the small amount of time, the first natural frequency is not clear. Here by using 3Muri program, developed a pseudo 3D non – linear structural model. Its research version(TreMuri) is used for the analysis. The non – linear time history and pushover analysis is used. The building's uncertain modeling parameters have large impact on the computed vibration period.

3. SUMMARY AND CONCLUSION

From the previous studies, it is clear that there are different types of studies were carried out in the masonry buildings based on the seismic action. The following conclusions are drawn from these studies:

- Masonry buildings belong to the most vulnerable class of structures which have experienced heavy damage or even total collapse in earthquakes.
- Non – linear seismic analysis is useful for assessing inelastic strength and deformation of the structure
- The strength capacity differs depends on the masonry parameters

REFERENCES

[1].Krishna Naraine and SachidanandSinha , "Behavior of brick masonry under cyclic compressive loading compressive loading", Journal of Construction Engineering and Management, 1989,Vol. 115, pp1432-1445.

[2]. Yan Zhuge, David,T and CorderoyJ, "Nonlinear dynamic analysis of unreinforced masonry", Journal of Structural Engineering, Vol. 124, pp 270-277, 1998

[3]. Milad M. AlShebani and S. N. Sinha, "stress-strain characteristics of brick masonry underuniaxial cyclic loading", Journal of structural Engineering, Vol.125, pp 600-604, 1999

[4]. Guido Magenes, "A method for pushover analysis in seismic assessment of masonry buildings", Proceedings of 12th World Conference on Earthquake Engineering, Auckland, New Zealand, 2000

[5]. P. G. Asteris, "Lateral Stiffness of Brick Masonry Infilled Plane Frames", Journal of Structural Engineering, Vol. 129 , pp 1071-1079, 2003

[6].Bosiljkov.V, Totoev.Y.Z and Nichols.J.M. , "Shear modulus and stiffness of brickwork masonry An experimental perspective", Structural Engineering and Mechanics,2005

[7]. Pere Roca.,Molins,C., and Antonio,R.M, "Strength Capacity of Masonry Wall Structures by the Equivalent Frame Method", Journal of Structural Engineering, Vol. 131, pp 1601-1610, 2005

[8]. Tianyi,Y., Moon,F.L, Leon,R.T and Lawrence,F.K., "Analyses of a two-story unreinforced masonry building", Journal of Structural Engineering, Vol. 132, pp 653-662, 2006

[9]. Shakeri,K., Shayanfar,M.A, and Asbmarz,M.M, "A spectra-based multi modal adaptive pushover procedure for seismic assessment of buildings", Proceedings of 14th World Conference on Earthquake Engineering, Beijing, China, 2008

[10].J.Snoj,M.Osterreicher and M.Dolsek, "Experimentally supported modeling of an existing masonry building by measuring ambient and forced vibrations", Proceeding of

15th World Conference of Earthquake Engineering,LISBOA2012
[11].Anil K. Chopra, Dynamics of structures Theory and application to Earthquake Engineering, Pearson Education, Third Edition, 2007
[12]. S.R.Damodarasamy and S.Kavitha, Basics of Structural Dynamics And Aseismic Design, PHI Learning Private Limited, Eighth Edition,2014
[13].PankajAgarwal and Manish Shrikhande, Earthquake Resistant Design of structures, PHI Learning Private Limited,Fourteenth Edition, 2015
[14].Ray W.Clough and Joseph Penzien, Dynamics of Structures, CBS Publications, second edition, 2015
[15].Thomazevic ,Earthquake resistant design of masonry buildings, series on innovation in structures and construction vol.1, 1999