# A REVIEW ON ANALYSIS OF MAJOR INTERNATIONAL CODAL DESIGN PROVISIONS FOR OPEN GROUND STOREY BUILDINGS

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## ABSTRACT

*In this paper enlightening the problem 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. "Open Ground Storey" (OGS) buildings are those types of buildings in which the ground storey is free of any infill masonry walls. These types of buildings are very common in India for parking provisions. The strength and stiffness of infill walls in infilled frame buildings are ignored in the structural modeling in conventional design practice. The design in such cases will generally be conservative in the case of fully infilled framed building. But the behaviour is different in the case of OGS framed building. OGS framed building is slightly stiffer than the bare frame, has larger drift (especially in the ground storey), and fails due to soft storey-mechanism at the ground floor.*

***Keywords****— Fragility curves, Open ground storey (OGS), Multiplication Factor (MF), Peak Ground Acceleration (PGA), Probabilistic Seismic Demand Model (PSDM)*



## INTRODUCTION

Need of space became very important in urban areas due to increase in population especially in developing countries like India. Need of parking space takes important vital role while planning a building. To provide adequate parking spaces, ground storey of the building is utilized. These types of buildings (Figure 1.1) having no in filled walls in ground storey, but in-filled in all upper storey's, are called Open Ground Storey (OGS) buildings. The majority of apartments are of this type and the infill walls used are of mainly brick masonry.

Upper stories of these buildings are stiff and the inter-storey drifts will be small, resulting in large curvatures, shear forces and bending moments of the ground storey columns. Hence, the strength demand on the columns in the ground storey of the buildings is very high. The majority of this type of buildings had collapsed in the past earthquakes in many countries. The failure of OGS buildings is observed to be due to storey mechanism in the ground storey. The sudden reduction in lateral stiffness and mass in the ground storey results in higher stresses in the ground storey columns under seismic loading. In most cases, ground-story columns were either damaged severely or failed completely, thereby damaging the buildings. Due to the presence of infill walls in the entire upper storey except for the ground storey makes the upper storey's much stiffer than the open ground storey. Thus, the upper storey's move almost together as a single block, and most of the horizontal displacement of the building occurs in the soft ground storey itself. Figure 1.2 distinguishes the behaviour of a full in filled frame and a OGS building during the Bhuj earthquake (2001). It can be seen that the building which is on the left has survived with minor cracks in the infill walls in the ground storey. The building on the right side is an OGS frame, completely collapsed due to soft-storey mechanism in the ground storey due to the absence of infill walls.

***OBJECTIVES***

The salient objectives of the present study have been identified as follows:

I. To study the seismic performance of typical OGS buildings designed as per applicable provisions in international codes in a Probabilistic Frame Work
   - Indian
   - Euro
   - Bulgarian
   - Israel

J. To develop Probabilistic Seismic Demand Model for the designed buildings

K. To develop fragility curves for the designed OGS buildings

**NEED FOR THE PROPOSED WORK**

The multiplication factors proposed by selected international codes and recent research works are not consistent as discussed in previous sections. The performance of the buildings designed by the various MFs proposed by the international codes may be different.

The motivation for the present study is to compare the relative performances of OGS building designed using the multiplication factors proposed by international codes and its major implications.

**LITERATURE REVIEW**

The literature review is divided into two parts. The first part of this Chapter deals with an overview of seismic behaviour of infill walls and open ground storey building. The second part of this chapter deals with the Previous Studies on the development of Seismic Fragility Curves.

Under lateral loading, the frame and the infill wall stay intact initially. As the lateral load increases, the infill wall gets separated from the surrounding frame at the unloaded (tension) corner. However at the compression corners the infill walls are still intact. The length over which the infill wall and the frame are intact is called the length of contact. Load transfer occurs through an imaginary diagonal which acts like a compression strut. Due to this behaviour of infill wall, they can be modeled as an equivalent diagonal strut connecting the two compressive corners diagonally. The stiffness property should be such that the strut is active only when subjected to compression. Thus, under lateral loading only one diagonal will be operational at a time. This concept was first put forward by Holmes (1961).

Rao et. al. (1982) conducted theoretical and experimental studies on infilled frames with opening strengthened by lintel beams. It was concluded that the lintel over the opening does not have any influence on the lateral stiffness of an infilled frame. Karisiddappa (1986) and Rahman (1988) examined the effect of openings and their location on the behaviour of single storey RC frames with brick infill walls.

The behaviour of RC framed OGS building when subjected to seismic loads was reported by Arlekar et. al. (1997). A four storied OGS building was analyzed using Equivalent Static Analysis and Response

Spectrum Analysis to find the resultant forces and displacements. It was shown that the behaviour of OGS frame is quite different from that of the bare frame.

The effect of different parameters such as plan aspect ratio, relative stiffness, and number of bays on the behaviour of infilled frame was studied by Riddington and Smith (1997).

Scarlet (1997) studied the qualification of seismic forces in OGS buildings. A multiplication factor for base shear for OGS building was proposed. This procedure requires modeling the stiffness of the infill walls in the analysis. The study proposed a multiplication factor ranging from 1.86 to 3.28 as the number of storey increases from six to twenty.

Deodhar and Patel (1998) pointed out that even though the brick masonry in infilled frame are intended to be non-structural, they can have considerable influence on the lateral response of the building.

Davis and Menon (2004) concluded that the presence of masonry infill panels modifies the structural force distribution significantly in an OGS building. The total storey shear force increases as the stiffness of the building increases in the presence of masonry infill at the upper floor of the building. Also, the bending moments in the ground floor columns increase (more than two fold), and the mode of failure is by soft storey mechanism (formation of hinges in ground floor columns).

Das and Murthy (2004) concluded that infill walls, when present in a structure, generally bring down the damage suffered by the RC framed members of a fully infilled frame during earthquake shaking. The columns, beams and infill walls of lower stories are more vulnerable to damage than those in upper stories.

**DESCRIPTION OF STRUCTURAL MODEL**

Open ground storey buildings are considered as the vertically irregular buildings as per IS 1893: 2002 .In the present study, a typical ten storied OGS framed building is considered and the building considered is located in Seismic Zone-V. The design forces for the ground storey columns are evaluated based on various codes such as Indian, Euro, Israel, Bulgarian codes and Kaushik et. al (2009) suggested approach. Various OGS frames are designed considering MF as 1.0, 2.1 (Israel), 2.5 (Indian), 3.0 (Bulgarian), 3.79 (Kaushik et. al, 2009) and 4.68 (Euro). The performance of each building is studied using the fragility analysis method introduced by Cornell et. al (2002). Uncertainty in concrete, steel and masonry walls are accounted. Thirty computational models are developed in the program Seismostruct (2012) for nonlinear dynamics analysis for each case. For the analysis, a set of thirty natural time histories is selected and modified to match the Response spectrum as per Indian code (IS 1893-2002). In the present study, fragility curves are generated for each building, by developing a Probabilistic Seismic Demand Model (PSDM) according to power law. The relative performances of each building designed as per various codes are compared using fragility curves.

**RESULTS AND DISSCUSSIONS**

The seismic performance assessment of typical open ground storey 2-D frames designed with Multiplication factors as per various codes is carried out with the help of fragility curves. A method introduced by Cornell et. al (2002) is used in the present study for fragility curve development. The PSDM models are developed for each frames selected. It is found that as MF increases the inter-storey drift at the ground storey reduces. The inter-storey drift for OGS 1.0 is found to be the largest. The inter-storey drift decreases for the building frames in the order, OGS 1.0, Israel (MF =2.1), OGS 2.5, Bulgarian (MF = 3.0), Kaushik et. al, 2009 (MF = 3.97) and Euro (MF =4.68).

It is found that the inter-storey drift at ground storey of OGS frame designed using MF = 2.5 is reduced by 80% compared to that of OGS frame designed using MF = 1.0. Similarly, it is also found that, the inter-storey drift at ground storey is reduced by 66% for frame designed using MF = 2.1, 83.3% for frame designed with MF = 3.0, 94.6 % for frame with MF = 3.97 and 96% for frame designed with MF = 4.68 with reference to OGS frame designed using MF =1.0.

The first storey of OGS building is found to be more vulnerable when the ground storey columns alone are designed with a MF of 2.5, 3.0 or more. This implies that performance of the above storeys also to be checked while using multiplication factors to the lower storeys. The Israel code applies MF of 2.1 to both ground storey and first storey, which make all the storeys to behave more close to a uniform strength distribution across the storeys in a seismic loading.

Except Israel code, no other code considers MF for first storey. In other words, the first storey of all the frames designed by codes other than Israel code remains same to yield same exceedance probability.

***CONCLUSIONS***

Followings are the salient conclusions obtained from the present study:

- The performance of typical OGS buildings designed considering various magnification factors according to different codes are studied using fragility curves.
- Uncertainties in concrete, steel and masonry are incorporated using LHS scheme. It is found that the performances of the OGS frames, in terms of ground storey drift is increasing in the increasing order of magnification factors used by various codes for all the performance levels.
- In all the cases of the buildings designed using various codes, the first storey is about 80% more vulnerable than the ground storey except for Israel code.
- It is found that relative vulnerability of first storey increases due to strengthening of the ground storey.
- Except Israel code, no other code considers MF for first storey. In other words, the first storey of all the frames designed by codes other than Israel code remains same to yield same exceedance probability.
- Application of magnification factor only in the ground storey may not provide the required performance in all the other stories. It is found from the study that the OGS buildings designed using Israeli code, which considered the magnification factor in the adjacent storey, performed better compared to that of others. This indicates that the implementation of magnification factor in the adjacent storey's may be required to improve the performance of OGS buildings.

**FUTURE WORK**

- The present study is based on a case study of a ten storey six bay RC framed building that are regular in plan and elevation (with open ground storey). This study can be extended considering buildings having irregularity in plan and elevation. This involves analysis of three dimensional building frames that accounts for torsional effects.
- OGS buildings with basement, shear walls and plinth beams are not considered in this study. The present methodology can be extended to such buildings also.
- Soil - structure interaction effects are also ignored in the present study. It can also be extended to study the response of the OGS buildings considering the soil - structure interaction.

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