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Earthquake Resistant Design of Masonry Buildings in Kashmir

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Abstract
The valley of Kashmir lies in the seismic zone V as per IS 1893 (part 1): 2002. As such it is the hot spot for occurrence of earthquakes not only mild ones butalso very severe ones. However the people here are sleeping in a deep slumber andthey keep on constructing buildings which are no more than death traps consideringtheir Earthquake susceptibility. Leaving alone proper earthquake design of buildings,even the earthquake resistant guidelines or tips are not even followed properly here.It is same for both private residential buildings with lesser Importance factor andgovernment constructed public buildings (like schools and colleges) with high value ofImportance factor.Since most of the construction in Kashmir is still done in brick masonry, our project isintended to check out the earthquake resistance of various ongoing masonry buildingconstruction (mostly important buildings like school) and to point out flaws in designand construction that result in poor seismic performance of such structures and tosuggest adequate measures to curb this practice.

Keywords
Earthquake, Masonry Buildings, Seismic resistance, Important structures, design flaws

Introduction
Earthquakes are natural hazards under which disasters are mainly caused by damageto or collapse of buildings and other man-made structures. Experience has shown thatfor new construction, establishing earthquake resistant regulations and theirimplementation is the critical safeguard against earthquake-induced damage. As regards existing structures, it is necessary to evaluate and strengthen them before anearthquake based on evaluation criteria.Earthquake damage depends on many parameters, including earthquake ground motion characteristics (intensity, duration and frequency content of ground motion),soil characteristics (topography, geologic and soil conditions), building characteristics,and quality of construction, etc. Building design must be such as to ensure that thebuilding has adequate strength, high ductility, and will remain as one integral unit,even while subjected to very large ground motions.

Social and other factors are also important, such as density of population, time of dayof the earthquake occurrence and community preparedness for the possibility of suchan event.Up to now we could do little to diminish direct earthquake effects.However we can do much to reduce risks and thereby reduce disasters provided wedesign and build or strengthen the buildings so as to minimize losses based on theknowledge of earthquake performance of different building types. Observation of thestructural performance of buildings during an earthquake can clearly identify thestrong and weak aspects of designs, as well as the desirable qualities of materialsand techniques of construction, and site selection. The study of damage thereforeprovides an important step in the evaluation of strengthen measures of different typesof buildings.Leaving alone proper earthquake design of buildings,even the earthquake resistant guidelines or tips are not even followed properly here.It is same for both private residential buildings with lesser Importance factor andgovernment constructed public buildings (like schools and colleges) with high value ofImportance factor.

Since most of the construction in Kashmir is still done in brick masonry, our project isintended to check out the earthquake resistance of various ongoing masonry building construction (mostly important buildings like school) and to point out flaws in designand construction that result in poor seismic performance of such structures and tosuggest adequate measures to curb this practice.

What our team found out was shocking, the earthquake resistant features were eithernot incorporated or their construction was inadequate or was done in a raw fashion which would render them incompetent during earthquakes. All this could be attributedto one or more of these reasons:

1. Lack of attitude of people towards making Earthquake resistant structures.
2. Lack of skilled labor.
3. Lack of resources both financial as well as material.
4. Lack of knowledge of the earthquake engineering among the practicing engineers.

So the need of the hour is to take steps to educate people about the possible hazardsduring earthquakes and benefits of making earthquake resistant structures overaesthetically pleasing weak structures, making some sort of technical qualificationnecessary for people to fetch them suitable for practicing masonry and to provide somecourses that will give substantial knowledge to practicing engineers about earthquakeengineering.

The Problem
Most of the loss of life in past earthquakes has occurred due to the collapse ofbuildings, constructed in traditional materials like stone, brick, adobe and wood, whichwere not initially engineered to be earthquake resistant. In view of the continued use ofsuch buildings in most countries of the world, it is essential to introduce earthquakeresistance features in their construction.

Important Parameters In Seismic Design
The following properties and parameters are most important from the point of view of
seismic design.

a) Building material properties
   - Strength in compression, tension and shear, including dynamic effects
   - Unit weight (density)
   - Modulus of elasticity
b) Dynamic characteristics of the building system, including periods, modes ofvibration and damping.
c) Load-deflection characteristics of building components.

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Effects of Site Conditions on Building Damage

Past earthquakes show that site conditions significantly affect building damage.Earthquake studies have almost invariably shown that the intensity of a shock is directly related to the type of soil layers supporting a building. Structures built on solid rockand firm soil frequently perform far better than buildings on soft ground. This was dramatically demonstrated in the 1985 Mexico Earthquake, where the damage on softsoils in Mexico City, at an epicentral distance of 400 km, was substantially higher thanat closer locations.

From studies of the 1957 Mexico Earthquake, it was already known that the damageon the soft soils in the center of the city could be 5 to 50 times higher than on firmersoils in the surrounding area. Another example occurred in the 1976 TangshanEarthquake, China in which 50% of the buildings on deep soil sites collapsed, whileonly 12% of the buildings on the rock subsoil near the mountain areas totally collapsed.

Rigid masonry buildings resting on rock may on the contrary show more severe damagethan when built on soft soil during a near earthquake, as in the 1967 Koyna Earthquake,India and the 1980 North Yemen Earthquake.

Nature of Seismic Stresses

Horizontal seismic forces are reversible in direction. Structural elements such as walls, beams and columns that were bearing only vertical loads before the earthquake,have now to carry horizontal bending and shearing effects as well. When the bending tension due to an earthquake exceeds the vertical compression, net tensile stress willoccur. If the building material is weak in tension such as brick or stone masonry,cracking occurs which reduces the effective area for resisting bending moment, asshown in Fig. 1. It follows that the building material strength in tension and shear isimportant for earthquake resistance.

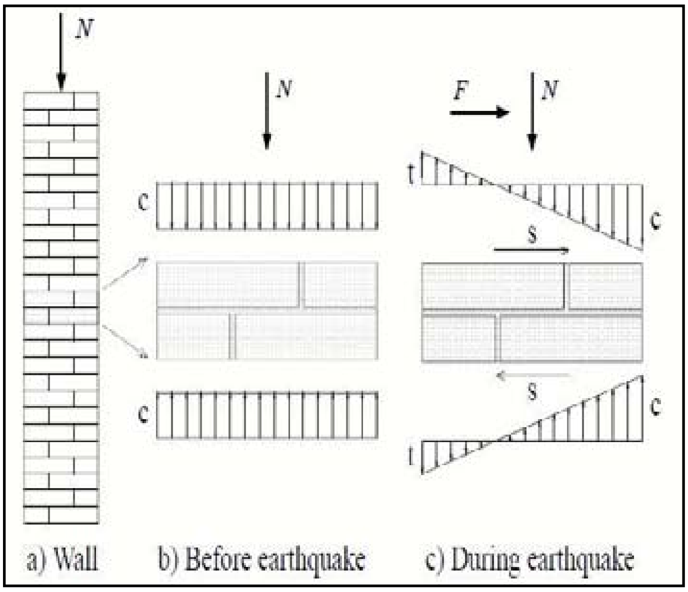

Fig.1: Stress condition in a wall element
N: vertical load, F: seismic force, c: compressivestress, t: tensilestress, s: shearing stress

Factors Affecting The Seismic Coefficient

The normalized design acceleration Ag is the design ground acceleration divided bythe acceleration due to gravity. It may be expressed as the product of the seismiczoning factor Z and the normalized standard ground acceleration ag of a seismicregion (zone) of a country. The seismic zoning factor Z depends upon the relativeground intensity of the earthquake, and it is usually plotted on maps in terms of seismicintensity isoseismal lines or maximum acceleration contours. Obviously, the higher theintensity or acceleration, the larger will be the seismic force. The normalized design response spectrum S depends mainly upon the fundamentalnatural period of vibration of a building T and the soil profile (see Fig. 2).The structural factor D is a factor depending on the ductility and dam ping of thestructure. The larger the ductility of the structure, the more energy the structure canabsorb and smaller the value of D. Damping is the energy dissipation property of thebuilding; the larger the damping, the smaller the value of D.

The occupancy importance factor or hazard factor I depends upon the usage of thebuilding. The higher the importance or larger the hazard caused by the failure of thebuilding, the greater the value of the factor I.

In some recent building codes, the term "occupancy importance" factor has changed
to "risk" factor. The term "occupancy"as used by older building codes relates primarilyto issues associated with fire and life safety protection, as opposed to the risks associated with structural failure. The term "RiskCategory"was adopted in place ofthe older Occupancy Category to distinguish between these two considerations

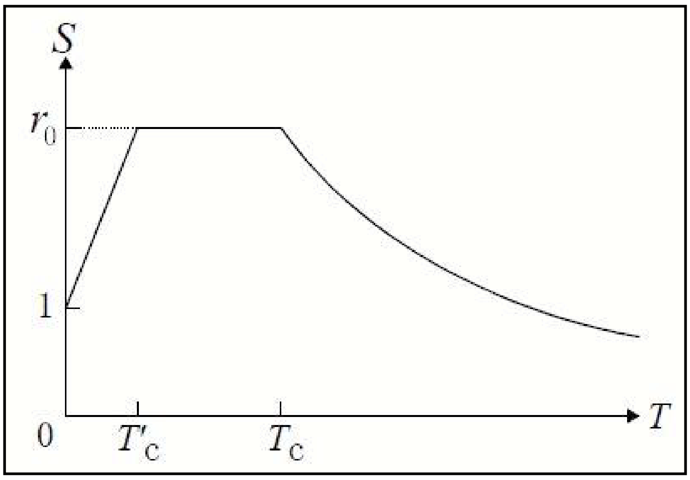

Fig. 2: Normalized design response spectrum S
(T_c, T_c' and r_0 dependupon the soil profileand the magnitude ofdesign earthquakes)

Openings in bearing walls

Door and window openings in walls are big and many and are not centrally placed. The ratio of total width of openings to the total width of wall is 0.51 which is greater than 0.42 permitted by IS 13828:1993. The openings particularly doors are not centrally placed as well mainly due to functional restrictions.

The presence of so many openings in the bearing walls reduce their strength andalso can cause local failure of thin and long piers in between the openings a asshown in fig.3. Openings have their top at the same level which has facilitated the provision of
continuous lintel bands throughout the building.

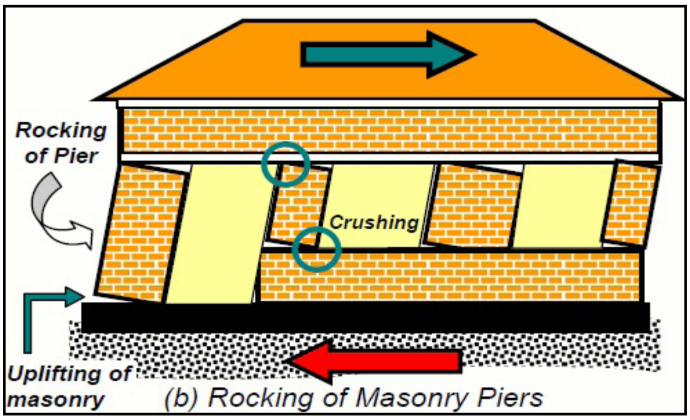

Fig.3: Damage due to presence of openings

Guidelines For Earthquake Resistant Construction

In addition to the main earthquake design code 1893 the BIS(Bureau of Indian Standards)has published other relevant earthquake design codes for earthquake resistant construction

Masonry structures (IS-13828 1993)

1) Horizontal bands should be provided at plinth ,lintel and roof levels as per code
2) Providing vertical reinforcement at important locations such as corners, internal and external wall junctions as per code.
3) Grade of mortar should be as per codes specified for different earthquake zones.
4) Irregular shapes should be avoided both in plan and vertical configuration.
5) Quality assurance and proper workmanship must be ensured at all cost without any compromise.

Damage And Failure of Bearing Walls

1) Failure due to rackingshear is characterized by diagonal cracks mainly due todiagonal tension. Such failure may be either through the pattern of joints or diagonally through masonry units. These cracks usually initiate at the corner of openings and sometimes at the centre of a wall segment. This kind of failure can cause partial or complete collapse of the structure
2) A wall can fail as a bending m ember loaded by seismic inertia forces on themass of the wall itself in a direction transverse to the plane of the wall. Tensioncracks occur vertically at the centre, ends or corners of the walls. The longerthe wall and longer the openings, the more prominent is the damage. Since earthquake effects occurs along the both axes of a buildingsimultaneously, shear and bending effects acts often together and the twomodes of failures are often combined. Failure in the piers occurs due to thecombined action of flexure and shear.
3) Unreinforced gable end masonry walls are very unstable and the pushing actionof purloins imposes additional force to cause their failure. Horizontal bendingtension cracks develop in the gables.
4) The deep beam between two openings one above the other is a weak point ofthe wall under lateral in plane forces. Cracking in this zone occurs beforediagonal cracking of piers unless the piers are quite narrow. Inorder to prevent it and to enable the full distribution of shear among all piers,either a rigid slab or RC band must exist between them.
5) Walls can be damaged due to the seismic force from the roof, which can causethe formation of tension cracks and separation of supporting walls (see Fig 4).This mode of failure is characteristic of massive flat roofs (or floors) supported by joists, which in turn are supported by bearing walls, but withoutproper connection with them. Also, if the connection to the foundations is notadequate, walls crack there and slide. This may cause failure of plumbingpipes.

Fig. 4: Damaged brick masonry(2006 Central Java Earthquake, Indonesia)

6) Failure due to torsion and warping: The damage in an unsymmetrical buildingoccurs due to torsion and warping in an earthquake (see Fig.5). This mode offailure causes excessive cracking due to shear in all walls. Larger damage occurs nearthe corners of the building.

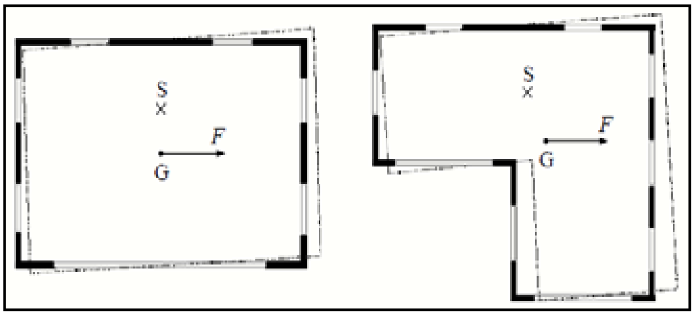

Fig. 5: Torsion or twisting of unsymmetrical plans

7) Arches across openings in walls are often badly cracked since the arches tend tolose their end thrust under in-plane shaking of walls.
8) Under severe prolonged intense ground motions, the following happens:

- Cracks become wider and masonry units become loose.
- Partial collapse and gaps in walls occur due to falling of loose masonryunits, particularly at the location of piers
- Falling of spandrel masonry due to collapse of piers.
- Falling of gable masonry due to out of plane cantilever action.
- Walls get separated at corners and intermediate T-junctions and fall

outwards.

- Roof collapse, either partial or full.
- Certain types of roofs may slide o the tops of walls and the roof beams fall

down.

- Masonry arches across wall openings as well as those used

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for roof collapse completely.

Conclusion

Earthquakes in Kashmir have been causing extensive damage to buildings and loss of many valuable lives since times immortal. Such devastations due to earthquake demand the need of making structures that are earthquake resistant. Since most of the construction in Kashmir is still being done in masonry, the aim of this project was to study various earthquake resistant measures in masonry buildings in context with Kashmir then point out the various flaws in construction practices in the current ongoing masonry constructions particularly important buildings like school buildings etc. and compare them with the actual seismic requirement.

It was found out horrible display of negligence of earthquake resistant construction not only by the people here but also by the government authorities. Some people prefer aesthetics over seismic resistance others fear of extra cost that may be added to the project cost if seismic features are incorporated in it.

The need of the hour is to get little serious about the Earthquake Resistant design and construction in Kashmir valley which is vulnerable to devastating earthquakes. It can be done only by the combined effort of the government authorities & common people.

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