ASPECTS OF EARTHQUAKE DISASTER MITIGATION - SPECIAL REFERENCE TO NON-ENGINEERED CONSTRUCTION

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ABSTRACT
Earthquakes have been a cause of major destruction and fatalities and as the process of urbanization continues at a much faster pace, the consequences of strong earthquake ground shaking are becoming more and more threatening to both life and assets. While earthquake prediction may be of some help, mitigation remains the main focus of attention of the civil society. The review presented in this paper identifies the salient features of earthquake mitigation aspects globally while specifically addressing the engineering aspects.

KEYWORDS
Disaster, Earthquake, Mitigation, Protection, Non-Engineered Construction

INTRODUCTION

Earthquakes are nothing but natural energy release driven by the evolutionary processes of the planet we live on. Earthquakes have caused massive destruction to human life and property, where these events have occurred near human settlements. Earthquakes, therefore, are and were thought of as one of the worst enemies of mankind.

Due to the very nature of release of energy, damage is evident which, however, will not culminate in a disaster unless it strikes a populated area. The twentieth century has seen an unparalled explosion in the world's population and an exponential growth in the size and number of villages, towns and cities across the globe. Various migration processes have led to abnormal densification of urban areas, surrounded by mushroom growth of squatter settlements specially in the developing third world. As cities increase in size, so the potential for massive destruction increases. The risk of earthquake disaster, therefore, is fast increasing, and is higher than at any time in our history.

It is primarily the loss of life and the human suffering after the occurrence that is most important, therefore, all those factors which contribute towards this are of vital importance. The main contributor and the principle cause of deaths in most large-scale disasters is the total or partial collapse of buildings. In earthquakes affecting a higher quality building stock, e.g., Japan and USA, more fatalities are caused by the failure of non-structural elements or by the earthquake induced accidents e.g. fire, over turning or collapse of free-standing walls etc. About 75% of fatalities, however, are caused by the collapse of buildings, which primarily are weak masonry buildings (adobe, rubble stone, or rammed earth) or unreinforced fired brick and concrete block masonry that can collapse even at low intensity of ground shaking. Unfortunately a very large proportion of the world's current building stock of such buildings resides in the developing third world or marginally developed world. On the other hand the increasing population in the developing countries will continue to be housed in these types of structures for a foreseeable future.

It is thus in this context the mitigation becomes utmost important.

EARTHQUAKE DISASTER MITIGATION

The word mitigation may be defined as the reduction in severity of something. Earthquake disaster mitigation, therefore, implies that such measures may be taken which help reduce severity of damage caused by earthquake to life, property and environment. While "earthquake disaster mitigation" usually refers primarily to interventions to strengthen the built environment, and "earthquake protection" is now considered to include human, social and administrative aspects of reducing earthquake effects, however, "earthquake mitigation" being more widely used and understood expression, it is used here as synonym to "earthquake protection"[1].

It should, however, be noted that reduction of earthquake hazards through prediction was considered to be the one of the effective measures, and much effort was spent on prediction strategies. While earthquake prediction does not guarantee safety and even if predicted correctly the damage to life and property on such a large scale warrants the use of other aspects of mitigation.

A flowchart in Fig.1 below shows how mitigation can be thought of globally [2].

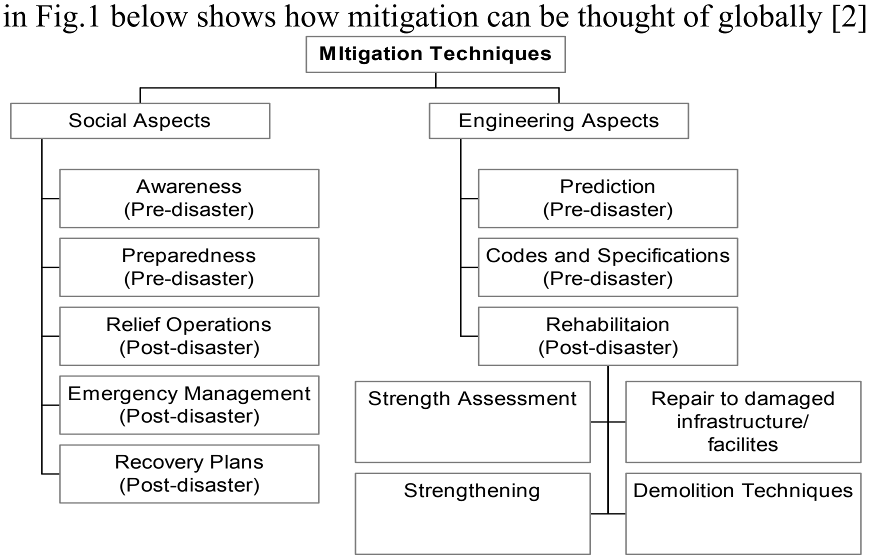

Fig.1: Mitigation aspect through flow chart

Following is the chart (Table.1) prepared at Cowasjee Earthquake Study Centre, Department of Civil Engineering, NED University of Engineering and Technology, Karachi (CESNED). The chart outlines the role and responsibilities of people belonging to different professions and agencies in order to effectively respond to the disaster [2].

Table.1. Role and responsibilities of different professionals in earthquake disaster mitigation process

Non Professional Groups	Pre-Disaster	Post-Disaster
Media	▪ Promoting awareness and preparedness programs for general public. ▪ Guiding government agencies in identifying existing hurdles, their possible causes and removal. ▪ Critical reviews on research directions, education and course of actions.	▪ Special news bulletins and programs related to happenings. ▪ Highlights of mitigation techniques. ▪ Realistic reporting and highly professional journalism
Government Organizations (GO) and Agencies	▪ National disaster preparedness plans. ▪ Code and specification enforcement. ▪ Building and infra-structure stock management. ▪ Collaboration with research organizations and universities. ▪ Budgeting and fund raising for protection.	▪ Developing contingency plans for immediate and long-term relief. ▪ Co-ordination between National and International relief agencies. ▪ Removing hurdles for immediate and emergency handling of issues.
NGO's	▪ Developing relevant data bank at local level. ▪ Imparting awareness and conducting workshops and training programs. ▪ Linkage with other GO's and NGO's.	Fire fight, controlling leakage of gases, epidemic diseases control, provision of food, water, medicine, clothes, temporary bridges, temporary roads, temporary shelters.
Civil Defence	▪ Preparing and training for post-disaster relief operation. ▪ Sharing training with civil administration.	
Rescue Workers	▪ Preparing for response to disaster. ▪ Developing skills to the best of abilities. ▪ Registering with local NGO or GO as trained rescue worker.	

Table.1. ------- cont'd

Professional Groups	Pre-Disaster	Post-Disaster
Engineers	▪ Developing insight into engineering aspect of earthquake resistant structures. ▪ Persuading clients to protect. ▪ Designing earthquake resistant structures. ▪ Seismic evaluation of building and its components. ▪ Improving earthquake resistance of existing buildings and infrastructure facilities.	▪ Classifying damaged structures. ▪ Demolition techniques for structures in a progressive collapse mode. ▪ Proposing choice of repair methods and strengthening techniques.
Urban and Regional Planners	▪ Micro-zoning and vulnerability mapping. ▪ Population density optimization. ▪ Protection strategies for infra-structure facilities and transportation.	▪ Learning from disaster and updating plans.
Medical Doctors and Paramedics	▪ Developing national data on medical resources . ▪ Categorizing nodes according to resources. ▪ Training allied professionals for preparedness and formulation of preparedness module. ▪ Linkage with international organizations for relief.	▪ Emergency mobilization of resources. ▪ Filtering affected people according to requirements and injuries. ▪ Epidemic control strategies.
Researchers and Academicians	▪ Strengthening understanding of regional seismicity, collecting and analyzing data and developing modules for mitigation. ▪ Developing guidelines for codes for local building materials and construction methodologies. ▪ Updating and transferring knowledge through mid-career training programs for professionals. ▪ Advising different agencies for developing contingency plans.	▪ Assessing extent of damage. ▪ Learning from disaster and reconsidering research options. ▪ Preparing post-disaster rehabilitation plans and imparting updated information.

NON-ENGINEERED CONSTRUCTION

While the global aspects of earthquake disaster mitigation have already been outlined, the obvious choice here is to look at engineering aspects. The main chart of Fig.1, therefore, is further expanded here, with the shaded boxes defining the focus of discussion of this paper, Fig.2 [3].

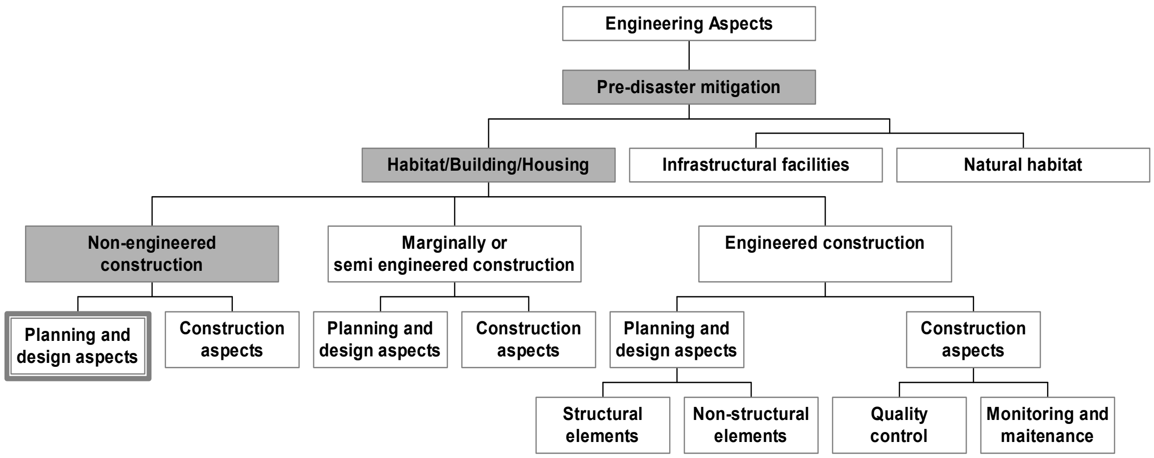

Fig.2: Engineering aspects of earthquake disaster mitigation

Non-engineered construction as opposed to engineered construction may be defined as buildings constructed without state-of-the-art application and which is merely based on experience of local masons, and skilled and semi-skilled workers. Since scientific consideration is absent, such construction lacks seismic load resistance. While such construction most of the time is prevalent in rural areas of the developing world, therefore, non-engineered construction is mostly referred to the construction in rural areas of developing countries. In the opinion of the author, however, the terminology should be extended to structures where state-of-the-art applications have deliberately or undeliberately been omitted, abused, misapplied or suppressed, specially after the experience of the 2001 Bhuj earthquake (Gujarat, India), and other major disasters in Iran and Turkey etc. and more recently the lethal Tsunami in the Indian Ocean. An example of the frequent recurrence of severe earthquakes in an area marked by prevalent non-engineered construction was seen on 1st Feb. 1991 in Chitral, Pakistan. The northern area of Pakistan stretching from Chitral to Gilgit was shaken up by an earthquake of magnitude 6.8 on the Richter scale. Approximately 100 villages were affected where almost 2900 houses were destroyed and almost 14786 houses were severely damaged, Figs. 3, 4 and 5. Intervention through engineering aspects of earthquake disaster mitigation helped in reducing the severity of damage, Figs. 6 and 7.

Fig.3: Destroyed village house in Chitral, 1991 earthquake

Fig. 4: Damaged village house in Chitral, 1991 earthquake

Fig.5: Destroyed village house in Chitral, 1991 earthquake

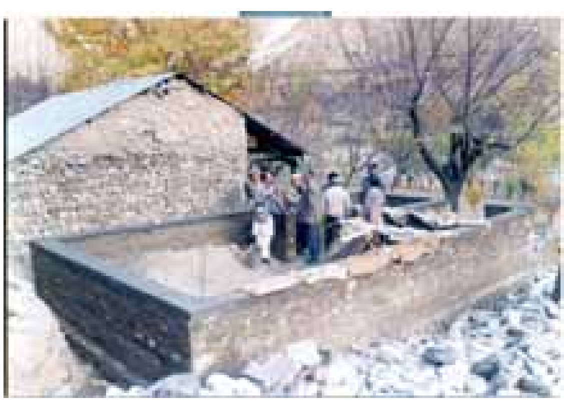

Fig.6: Improved construction techniques being implemented for earthquake resistant rural houses, after 1991, Chitral earthquake

Fig.7: Newly constructed houses through technology transfer after 1991, Chitral earthquake

Rural construction in most parts of the third world is marked by its large dead weights, both for walls and for roofs. Such construction while may be good enough for gravitational forces and for thermal insulation, have to pay a heavy toll when it comes to the earthquake forces, as it generates high seismic forces which increases with weight and the height at which they occur. As most of the materials used do not possess the desired strength and ductility, the destruction leads to fatalities. Recent earthquakes in Iran, Turkey, India and Northern areas of Pakistan are a testimony to the vulnerability of such a construction [4].

As mentioned above, most attention is needed at the rural level, therefore, some aspects of rural construction in general and in Pakistan in particular are discussed in the subsequent sections.

The common modes of failure of such load bearing walls may be as follows:

For an adobe or stonewall construction as shown in Figs. 8 and 9, random rubble masonry walls may completely shatter away and would pile up in a heap of stone. This would happen when the mortar is weak or spaces in-between the stones are not completely filled, lack of through stones within the thickness of wall and inadequate connection at corners of the wall. If the above is adequately taken care of, the failure may be initiated by the failure of the roof as shown in Figs. 10 and 11.

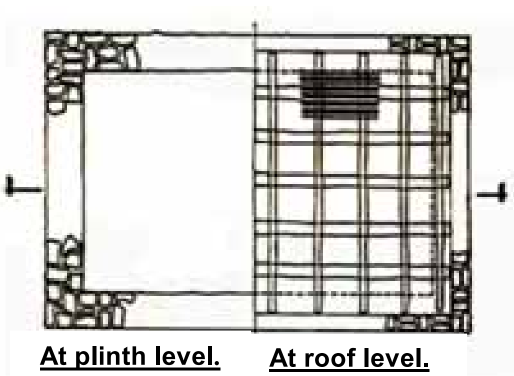

Fig. 8: Plan of adobe or stonewall construction (After Ref. 5)

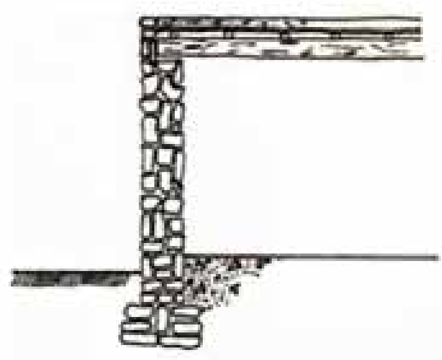

Fig. 9: Section of adobe or stonewall construction (After Ref.5)

Fig. 10: Cantilever wall collapse mode (After Ref.5)

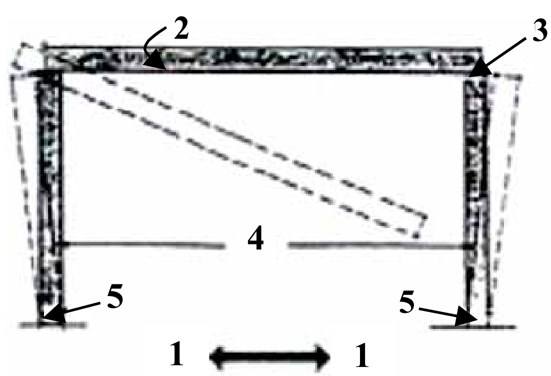

Fig. 11: Fall of roof because of Inadequate connection between roof and wall (after Ref.1). 1- Earthquake 2- Flat joisted roof 3- Fractional support, no connection 4- Out of phase motion 5- Crack

This failure is not caused by the failure of the spanning roof members, but by the dislocation of their connections at the support. Once the diaphragm action of the roof after dislocation of the connection is lost, the partly failed, damaged, or dislodged roof, leave the walls to act as isolated cantilevers, and as they possess very small flexural resistance, they fail by enlarging tensile cracks, causing the collapse of the entire system, Fig. 12. This mode of failure is characteristic of massive flat roofs (or floors) supported by joints that in turn are supported by bearing walls, but without proper connection with them. Also if connection with foundation is not adequate, the walls crack there and may slide [5].

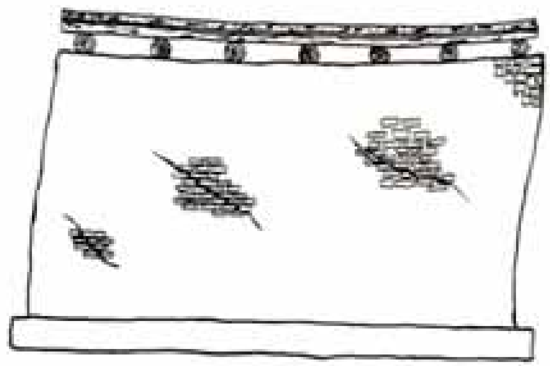

Fig. 12: Shear wall collapse mode (After Ref.5)

Wasti [6], while discussing safety of rural houses in Pakistan, identified that in Sindh, Baluchistan and Punjab, rural housing is basically of two types: (i) adobe buildings and (ii) brick masonry construction. Adobe buildings include structures of unburnt brick with mud mortar, rammed earth, and buildings of stone in a mud matrix, i.e. all types of earthen architecture, usually with a mud-plastered roof [6]. A typical rural adobe dwelling is as shown in Fig. 13.

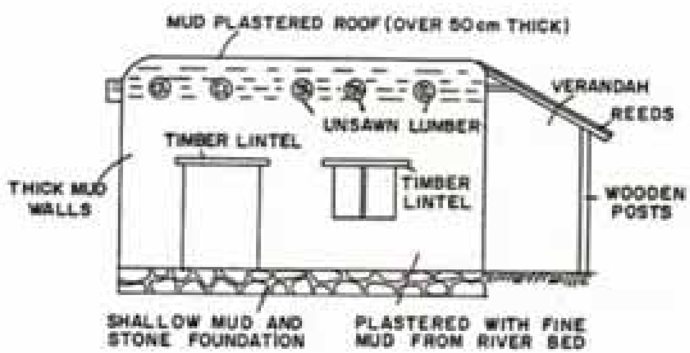

Fig. 13: Rural adobe dwelling (After Ref.6)

Brick masonry construction uses burnt brick with lime or cement mortar resulting in moderately well designed buildings with flat concrete slab roofs.

Current methods of construction for both types of rural construction in Pakistan, however, is said to incorporate few if any features for seismic safety. Rafay [5], while elaborating the construction techniques in rural housing to improve resistance to seismic forces, reported that materials used for rural housing in northern areas of Pakistan consist primarily of stone, wood and mud plaster [5]. These materials are locally available while the manufactured building materials such as cement and steel, which have to be transported from outside, over long distances, and, over tortuous routes, become too expensive. The construction techniques presently employed are quite adequate for gravity loads, but are poor for lateral forces. The walls and the roofs are thick and heavy, thereby leading to generation of large lateral forces even during moderate earthquake, to be resisted by structures lacking seismic resistance.

Mahmood et al. [7], while discussing the design and construction needs for rural structures, emphasized that the prevalent methods of rural construction in Pakistan results in houses and farm structures that are often primitive and afford little protection from natural hazards [7]. Because of poor construction methods and absence of planning, the whole pattern of rural settlement in Pakistan is unsatisfactory. All dwellings need frequent repairs because of crack formation and other damages. Very few rural dwellings can resist earthquakes, floods or other natural disasters and are usually built afresh by the villagers in the same traditional manner. This often results in a dwelling that is structurally even more unsound than the one destroyed.

Whatever has been discussed by renowned researchers in this area holds true for the majority of the rural construction in the Indian subcontinent, Iran, Turkey and probably in many other developed countries, pointing to a need of identifying technological errors in these types of construction and suggesting ways and means to rectify them. A concerted effort, therefore, is desired by planners, architects and structural engineers to mitigate the hazards that these structures pose during and after earthquake.

CONCLUSIONS

The above references have been made part of this review, to emphasize the need of identifying the responsibility that the engineers and planners have to play regarding mitigating efforts. It is not only the basic understanding of the phenomenon of earthquake, its resistance offered by the designed structure, but the understanding of the socio-economic factors, engineering properties of the indigenous materials, local skill and technology transfer models are also of vital importance. In conclusion, therefore, it is vital that the engineering aspects of mitigation should be made a part of public policy documents.

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