MULTI DIMENSIONAL BUILDING PLANNING FOR SAFER TOMORROW

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ABSTRACT :

An architectural drawing of plan in two dimensions is actually a final overlay of various layers. These layers may include soil characteristics, slope analysis, climatology, site study, functional requirements of the structure, acoustics and illuminations, services, vegetation and many more. The inferences from performance of buildings during past earthquakes add another layer to the architectural drawing plan as ‘Safety’. Every building is unique in its nature and complex due to the incorporation of various aspects. This addition of another layer ‘safety’ is not to restrict the wings of imagination in planning, but to unclip them to fly high in a safer environment. However, the most commonly faced challenge to achieve seismic safety along with desired architectural plan is to choose the architectural planning phases where experts from other disciplines needs to interact. This paper addresses innovative resultants where expertise from other engineering discipline (e.g., structural engineering) and architectural creativity need to be together to prepare/enhance a safe structural design with a sustainable approach. The fundamental deficiencies in planning are explored in this paper, such as; a) where architects have forgotten their basics, b) when an engineer and an architect can come together to find a better and safer solution that has not been thought before in isolation and c) how it helps in changing building’s response during severe seismic shaking.

KEYWORDS: Architectural planning, Seismic safety, Multidimensional building planning

1. INTRODUCTION

Over the past 100 years, architects and engineers have developed tools to assess the earthquake hazard, as well as the stability of individual design. Building codes provide normally the key policy mechanism for regulating a standard of safety. However, the death toll and heavy economic losses in recent earthquakes in many developed and developing countries like, Japan, United States, India, China, Pakistan, Iran, Turkey, etc., suggest that the technical capacity to design buildings to withstand earthquake forces may not fully satisfy the societal need of earthquake safe built environment.

Since the beginning of 20th Century the development of earthquake engineering conceived to study devastating effects and to produce recommendations for the design and construction of tougher structures that guarantee life safety. However, as mentioned by Teresa (2005), the design and control of contemporary cities in Seismic zones still follows the same architectural planning, urban design and regulations as those in non-seismic zones.

During the initial phases of planning in construction industry, the prevailing practice is to produce all architectural drawings based on multiple thoughts, building codes and clients’ requirements. After final decision and approval, these drawings are sent to Structural Engineers for consultation, addition of another layer, i.e., structural detailing. Mostly, the seismic code requirements by structural engineers are for single buildings. Whereas, architects, urban designers/planner and politicians unknowledgeable of the disastrous consequences that those modern building configurations can produce in seismic zones, take the main decisions regarding construction pattern, urban zoning and building regulations. For effective performance of building during an earthquake, intervention of Structural engineer for addition of last dimension as structural grid is not sufficient, but the incorporation of knowledge for seismic design in many phases is requisite. The planning in collaboration needs to be extended for construction sites, building envelope, inside of the envelope (non structural elements), core of the structure (structural elements), and for services. This collaboration will continue forever as design ideas are neither restricted by structural elements nor the structural elements hampered by design ideas. This study is an attempt to bring architects and engineers on the same platform, to achieve multidimensional building planning and eventually to seek simple answer as design solution to very complex problems raised by earthquakes.

The following sections include a brief discussion on how important it is to bridge the gap between an architect's decision and structural engineer's recommendations for a safer tomorrow.

2. PHASES IN ARCHITECTURAL PLANNING AND THE MISSING LINK "SEISMIC DESIGN"

2.1. Site analysis

For any site small or large, the data is same to analyze but the perspectives are different for an engineer and for an architect. A structural engineer is concerned about depth of footing or type of foundation whereas an architect is worried about effective use of slopes and carving out spaces into it. Due to lack of communication often lead to difficult situations, for an example, the architect never knows about torsion induced during shaking, neither the civil/structural engineer has a chance to avoid the complication by simply reallocation of larger spaces or distribution of masses before final plan sanction for buildings on slopes. An example of such a situation can be seen in Figure 1a.

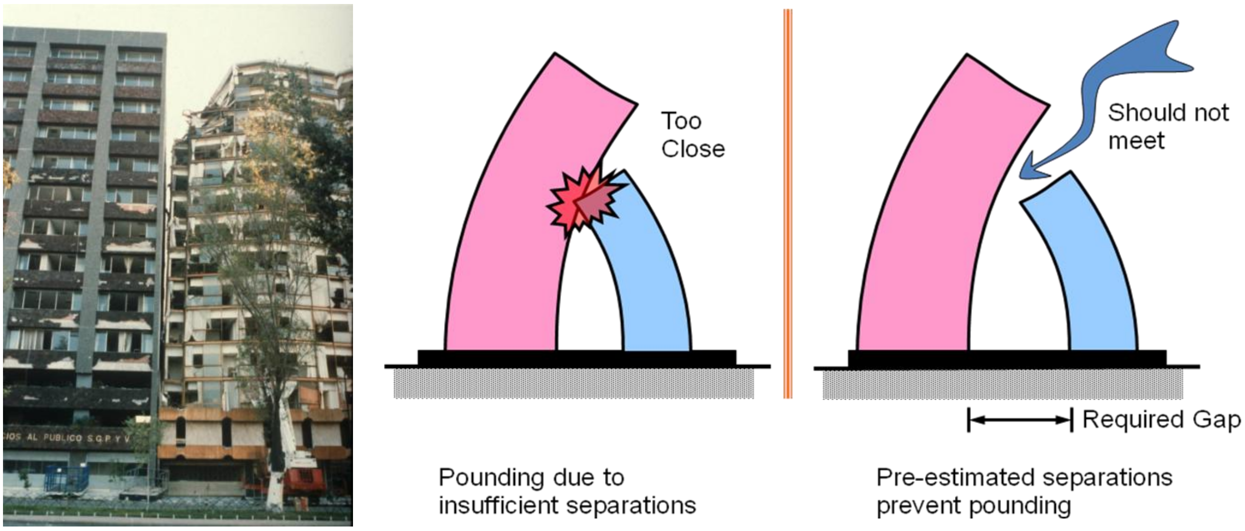
Considering larger scale of a site, often an entire city is considered as a site for urban designers. Urban zoning needs seismic design considerations based on site geology, soil and slope analysis. A deficiency of required site analysis leading to failure can be best explained by the well known case history of many crackless building blocks immersed into soil due to liquefaction in 1964 Niigata Earthquake (Figure 1b).

Figure 1 a) A building on slope failed due to excessive torsion during 2005 Kashmir earthquake (photo courtesy: Prof. C.V.R.Murty) . b) Failure of buildings due to settlement caused by seismic liquefaction during 1964 Niigata earthquake (NISEE).

2.2. Siting of buildings

The 'length of building' could be 'a cause of worry' is beyond imagination for an architect as incorporation of expansion joint according to building code is a simple solution. However, for a structural engineer to introduce a seismic joint within the allocated expansion joint is a tough challenge. These buildings with insufficient seismic gaps and improper detailing are getting ready to appear for another real shaking test in future to prove poor performance.

Building byelaws for front, rear and side setbacks are simply regulations for an architect while designing a structure and sometimes to tamper these regulations within Floor Surface Index (FSI Limitation) to achieve desired form. Architects hardly have the idea of 'pounding' during an earthquake caused by surrounding existing structures. On the other hand, the structural engineers are mostly concerned about erecting three dimensional frame for the given building and hardly have any concern with the site surroundings or thought for the 'time' as fourth dimension for future developments until and unless the structure comes down in an earthquake. One of the best example of this can be seen in figure 2a, where insufficient gap between two buildings caused failure during 1985 Mexico city earthquake. The simplest way to avoid these kinds of failures in future is to physically separate adjacent buildings with sufficient distance.



(a) (b)

Figure 2 (a) A RC building severely damaged due to pounding during 1985 Mexico city earthquake. (Photo Courtesy: EERI), (b) Schematic diagram showing separation of buildings to prevent pounding (Murty et al, 2006)

2.3. Building configuration

As quoted by Henry Degenkolb, a noted earthquake engineer of USA, if we have a poor configuration to start with, all that the engineer can do is to provide a band-aid to improve, basically a poor solution as best as he can. Conversely, if we start-off with a good configuration and reasonable framing system, even a poor engineer cannot harm its ultimate performance too much.

The well known truth comes out after each earthquake reconnaissance study is that the buildings with simple configuration in plan and elevation perform better (Arnold and Reitherman, 1982). The configuration means the layout of the building form and structure as seen in elevation and in plan. The behaviour of a building during earthquakes depends critically on its overall shape, size and geometry as well as the earthquake forces. Generally, the derivatives of the complex building forms are torsion, open ground storey, soft storey, re-entrant corners, etc. Hence, at the planning stage, architects and structural engineers must work together to avoid any unfavourable features by considering a good building configuration.

Another relatively new concept, performance based design (PBD), makes the structural engineers to predict the seismic performance of the building. This in turn facilitates many possibilities in planning and designing with respect to seismic safety. This challenges the policy-makers to rethink about the safety standards (PEER, 2004).

2.4. Interior of building: Non-structural element and involvement of structural engineer

Nonstructural elements in a building include staircases, parapets, glazing, cladding panels, suspended ceiling, mechanical services equipment, building contents, etc. Attention must be given to the seismic performance of these non-structural elements in order to limit the economic losses and reduce the risk of injury to people. Among these elements, for example, staircase is one of the most important elements as it can get damaged or can also cause damage to the structure. Where staircases are strongly built-in with the structure, they act as structural elements. Their inclination makes them to behave as bracing elements. These bracings are very stiff and strong against horizontal loads when compared to the frame action. Staircases attract loads in a manner unanticipated by structural engineers if these members are not included in the analytical model of the structure. On the other hand, where staircases are not separated from the primary structure they will act as braces, and because they have not been designed to resist large horizontal forces, they will get damaged (see for an example Figure 3a). If damaged severely, building occupants may face problem in evacuating during/after the earthquake and remain trapped in the building. One of the simple solutions structural engineers proposes in the seismic zones to avoid stair case failure during earthquakes is a slider at the base of the staircase (Figure 3b).

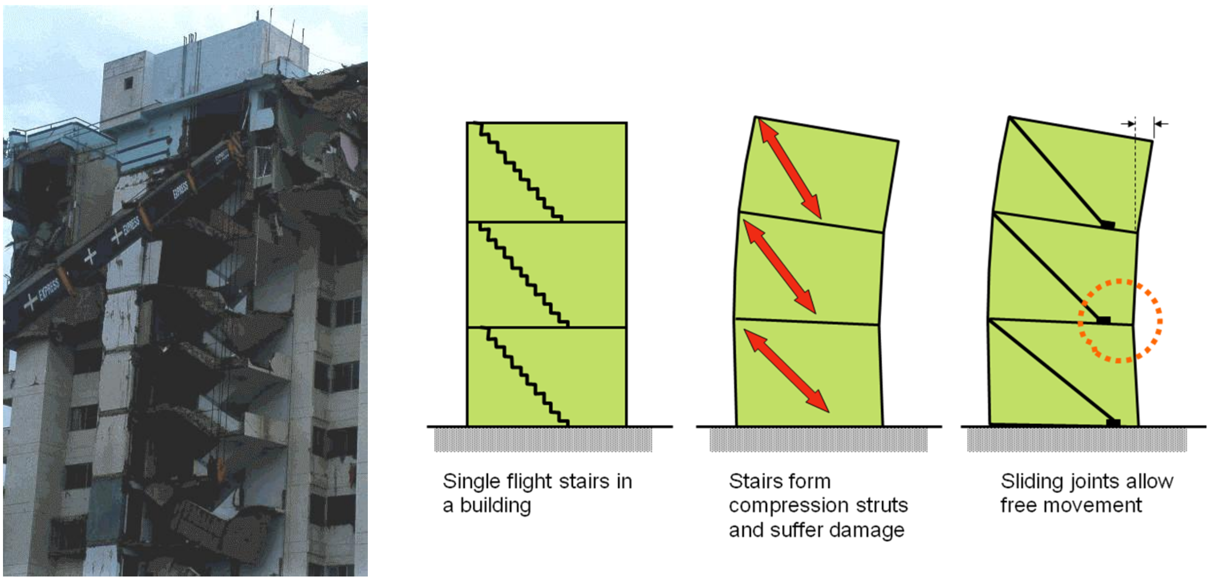


Figure 3 a) Mansi appartmet suffered damage due to stiff staircase failure (EERI 2001). b) Schematic showing the strut action of a normal staricase and its solution with sliders

Some of the solutions (Lagorio, H. J., 1990) to protect non structural elements during earthquakes and their seismic safety do have significant architectural implications. However, the architects and the structural engineers are responsible for making sure each of these elements shall perform well in an earthquake.

2.5 Building services and lifelines

Building services must be constructed to have no/minimum disruption of utilities, such as, water, electricity, gas and sewage/drainage (Murty, 2005). These days, long distance pipelines carrying crude oil, gas and water are becoming more common to meet the increasing needs of the urban population. When such pipelines pass through seismic areas, in particular fault zones, special design and detailing needs to be adopted to accommodate the expected differential ground displacements and seismic forces.

In metropolitian cities most of the buildings are now fitted with butane/cooking gas pipelines. Any kind of rupture to these pipelines during earthquake may trigger a catastrophic scene. However, this can be avoided by proper planning and construction detailing. The past earthquake surveys clearly show how a stitch at time is required by architect and structural engineer unanimously to keep ‘safety’ in high priority.

3. ADDITION OF NEW CONCEPTS TO ARCHITECTURAL PLANNING

There is a great need for incorporating different concepts from various fields to achieve a decent design solution along with functional efficiency. When an architect and a structural engineer come together to address the same problem, new ideas and innovative solutions evolve. Some of the concepts include:

a. strengthening of evacuation routes,
b. base Isolation as an answer to foundation strengthening,
c. effective use of building material to reduce the mass and to achieve desired strength,
d. introduction of performance based design,
e. incorporation of intelligent agents in design (Fruchter, 1996),
f. really simple and cost efficient solution to save non-structural material, and
g. need of architects and structural engineers coming together even for addition, alteration and extension of existing structures.

4. CONCLUSION

Most architects, city planners and urban designers as well as decision makers, unknowledgeable of the previous asseveration, have considered, since seismic codes come out, that the mitigation of urban seismic vulnerability is an exclusively responsibility of structural engineers. It has not been, it is not, and it will never be sufficient to apply seismic building codes to say the structure is 100% safe. It is necessary not only to develop and bring a multidimensional and interdisciplinary approach, but also to incorporate trans-disciplinary knowledge.

The seismic performance of a building will benefit greatly from timely interaction between architects and structural engineers. A building that is poorly configured will never perform well in a damaging earthquake. Unfortunately, many architectural decisions, such as the placement of infill walls, can have a huge and detrimental effect over building's performance. It is crucial that in the early stages of the building design, engineers and architects discuss issues that will determine largely how well a building will respond during an earthquake.

As we know, the structural mass is one of the major sources that attracts/develops seismic forces. Hence, the architect should consult a structural engineer as soon as the building massing has been established, and well before the detailed space planning is undertaken. Early consultation will avoid re-work and unduly expensive structural systems and detailing. The architect should have a preliminary structural concept in mind before meeting the engineer, so that the structure will be consistent, compatible, and hopefully reinforce the architectural concept. This preliminary structural concept will be a good basis from which to discuss with structural engineers in more detail.

The best architectural outcome will occur when there is a high level of cooperation and collaboration between architects and structural engineers at various stages of the project.

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