Why is Quality critical in Earthquake-Resistant Buildings?

Quality and Earthquake Safety

Quality is critical for ensuring safety of buildings during earthquakes. Appropriate measures are required to control quality in *all activities* related to development of *earthquake-resistant* buildings; if not, the weakest link will fail. While quality control is important also for buildings meant to resist effects other than those meant to resist earthquake shaking, there is a difference. Buildings meant to resist only *gravity loads* are designed to resist loads *much higher* (say about 2 to 3 times more) than the gravity loads that may arise during lifetime of the building. And hence, no damage occurs in buildings with minor structural deficiencies in individual members, because of availability of adequate margin in design. Thus, some error can be tolerated in design or workmanship without serious consequences or getting noticed.

On the other hand, buildings meant to *resist earthquake effects* are designed for lateral earthquake loads *much smaller* (up to about 10 times smaller) than what may be experienced during severe shaking, if the building were to sustain no damage during severe earthquake shaking. This is because earthquakes occur rarely. Hence, ordinary buildings are *expected* to undergo damage during strong shaking. Every structural element is expected to respond in a certain way, and is tested to its limit when strong shaking is experienced. Thus, deficiencies in structural elements can result in premature, unwanted or unwarranted failures. Because there is no margin, effects of poor quality are clearly noticed; the negative consequences of *poor quality* are most visible during severe shaking. Therefore, quality is *far more important* in buildings exposed to *earthquake effects* than in those exposed only to *other load effects* (*e.g.*, gravity loads).

What is Quality Control?

Quality control means *adopting and ensuring* formal procedures and processes that are based on scientific principles and professionally agreed norms. The need to ensure quality arises at every step of the building development process. These steps include:

(1) *Conceptualizing* structural configuration – *Architects* and *Structural Engineers* need to work together to adopt a good configuration;

(2) *Designing* the structure – *Structural Engineers* need to take utmost care while performing required calculations as per sound *structural safety concepts* and *relevant design standards*;

(3) *Preparing* structural drawings – *Structural Engineers* and *Draughtsmen* need to comprehensively and accurately present structural design intent in well detailed drawings;

(4) *Selecting* construction materials - *Contractors* need to take utmost care in selecting the *intended* construction materials, and adopting construction procedures as per standard specifications;

(5) *Converting* structural drawings at site – Competent *Site Engineers* need to faithfully follow structural drawings to ensure that the design intent is actually realized in the building working with *Certified Artisans*, as per good construction practices laid down in standards and specifications; and

(6) *Undertaking* post-construction activities – *Maintenance Engineers* need to embed long-term maintenance steps (like preventing leaks), thereby avoiding structural damage) in post-construction handling of structures, and preventing damage to buildings (especially to *critical structural members*).

What is Quality Assurance?

Rigorous, independent monitoring and correction need to be undertaken by competent *third party* professionals or professional agencies (other than those involved in the *Quality Control* effort) to ensure that the design intent is actually realized in buildings. This is referred to as *Quality Assurance*, and is required in each of the activities mentioned above.

How Quality can be Ensured

Owners and developers have the responsibility of ensuring that their buildings are *functional*, *safe* and *durable*, in addition to being *economical* and *aesthetic*. Quality must be ensured by all stakeholders involved in the building delivery process, including architects, structural engineers, draughtsman, contractors, site engineers, artisans (*e.g.*, bar benders, carpenters and masons), and maintenance engineers. Each activity needs to adhere to a pre-specified procedure laid down in design codes and standards. There is no single activity that is more important than the others, which alone determines the quality of the building being built. For instance, just designing the building for a higher seismic lateral force to compensate for poor quality in construction will not ensure a safe building. Even if *one* of the key stakeholders fails to deliver quality, overall earthquake safety of building may be jeopardised.

Building owners *need to* seek professional services that comply with: (1) proper understanding and estimation of earthquake *hazard* at the site, (2) rigorous design, compliance with prevalent standards, specifications and bye-laws, (3) independent design review (peer review), (4) procurement of intended quality materials, (5) careful construction of the building, (6) independent construction audit, and (7) approved occupancy and use of buildings. Any shortfall in understanding or implementing (to the fullest) any of these aspects leads to compromising safety of life and property in the building.

Services of *competent* professional architects and engineers are essential to incorporate the above aspects in buildings; these professionals need to have past experience of having successfully provided such services. Building owners are faced with many challenges in *earthquake-resistant design* and *construction*. These include:

(1) *Identifying competent architects and design engineers*: There are many standards and specifications for *earthquake-resistant* design and construction of buildings, which architects and design engineers need to be conversant with. The mandatory curricula in architecture and engineering colleges often do not ensure that the required background is provided to graduates. Thus, it is unlikely that *all* architects and engineers practicing today understand earthquake behavior of structures, and the design techniques required to incorporate earthquake-resistance in them. So, building owners face a challenge related to selecting *competent* professionals to undertake earthquake-resistant design of their buildings. Governments need to establish robust systems for identifying competence-based *licensing of engineers*, who could assist building owners;

(2) *Complying with Building Codes & Municipal Controls*: Local governments require architects and design engineers to ensure safety of buildings through faithful compliance with various *building codes* and *municipal bye-laws*. This cannot happen only on the basis of voluntary effort by professionals – it is the responsibility of municipal authorities to enforce compliance. But, a severe shortage of suitable adequately trained personnel in municipal offices can be a bottleneck for ensuring compliance on part of local governments. Alternate strategies are required to build a robust system for *Enforcement of Earthquake Safety*, *e.g.*, independent peer review by consulting engineers of good standing; and

(3) *Undertaking hazard estimation studies*: Seismic hazard assessment must consider many uncertainties. For ordinary buildings, it is best to adopt seismic design codes of the country. But, for projects of importance, site-specific studies are required, for which owners will require services of *competent earthquake geologists*, *seismologists*, *earthquake geotechnical engineers* and *seismic structural engineers*.

Faithfully converting construction drawings of buildings into actual structures is critical for ensuring earthquake safety of buildings. *Competent* contractors must be appointed by building owners to implement formal construction strategies and construct earthquake-resistant buildings. Quality control needs to be exercised at all stages of construction by *Contractors*. But, independent agencies need to test quality of all construction materials before accepting them. Similarly, independent competent engineers employed for site-supervision need to examine that work being is done as intended. These independent engineers employed for site inspection need to have requisite *competence*. Therefore, *Competence-Based Licensing of Construction Engineers* and *Certification of Artisans* are essential.

Professional Ethics

Earthquake-resistant design and construction is possible only with high ethical standards employed by all personnel involved. A project can be successfully executed only by avoiding all three types of errors – *Error of Intention*, *Error of Concept* and *Error of Execution*. Error of *intention* is really an issue of *ethics*, while errors of *concept* and *execution* are of *competence*. For instance, a professional accepting an assignment beyond one's competence is indulging in unethical practice. Similarly, if a professional realizes that one is unable to follow correct procedures and still proceeds with the project, it is an unethical practice. And finally, an engineer not following code provisions to reduce structural cost, indulges in unethical practice.

In civil constructions, society takes performance of a structure for granted. For instance, one drives over a bridge unconsciously, assuming it is safe. Hence, it is critically important to ensure and enforce highest levels of ethical standards in the practice of engineering. It is not possible to legislate virtues. But, the situation can be alleviated to some extent by putting in place systems and procedures, *e.g.*, (a) *competence-based licensing*, wherein license to practice is given only after establishing that the person has at least a minimum set of skills required to practice design and construction, which may be revoked in case of a malpractice, and (b) a robust regulatory legal system, with a rigorous enforcement protocol and implementation mechanism that allows for swift penalties and punishments to erring individuals. Such systems have been effective in many countries, and must be established in countries like India.

Related IITK - BMTPC Earthquake Tip

Tip 9: How do make buildings ductile for good seismic performance?

Resource Material

Bellet,D., (2006), *Fundamental Concepts and Principles for Assuring Acceptable Performance of Schools and the Education System*, Chapter 10, *Keeping Schools Safe in Earthquakes*, Overseas Press India Private Limited, New Delhi

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