The Integration of Seismic Resistant Design & Construction into the Diploma of Associate Engineering DAE (Civil) Curriculum in Pakistan.

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1 Abstract

The 8th October 2005 Kashmir Earthquake exposed the vulnerability of Pakistan's building stock with the collapse of both public and private buildings. Whilst appropriate building codes are now being developed and introduced, the codes alone are not going to solve the problem unless (and until) technicians and masons develop the knowledge, skills and appreciation for the design and construction of buildings in a seismically safe manner. The importance of these two groups of people is much of that vulnerability was in rural housing and it is these two groups (and in particular masons) who will deal directly with this issue.

This paper outlines the development of a seismic module to assist Pakistani Educational Authorities to integrate seismic resistant design and construction components into the curricula of the Diploma of Associate Engineering DAE (Civil) and in particular how the curricula addressed:

- the need to make houses and buildings actually conform to the codes.
- the need for seismic resistant design and construction components for mainly non-engineered buildings in Pakistan.

The process and strategy used for this module in Pakistan will have applications in other earthquake prone developing countries.

2 Introduction

It sounds easy and straightforward but it isn't. With the emergency and recovery phases essentially completed and reconstruction from the Oct 2005 Kashmir Earthquake will under way attention was then focused on the training given to those that would be responsible for the design and construction of Pakistan's future buildings. Despite it's known seismic hazard Pakistan did not have any explicit seismic code nor did it's technical training institutes include seismic design and construction in their curricula (except for the Diploma in Architecture which touched on the geological aspects of earthquakes). This vulnerability was exposed by the 2005 Kashmir Earthquake with the significant proportion of that vulnerability being borne by those in provincial and rural areas typically living in "non-engineered" houses. Government figures as at the 12 November 2005 (1 month after the earthquake) showed there were 272,019 buildings that completely collapsed in the affected areas of North West Frontier Province (NWFP) and Azad Jammu Kashmir (AJK). And of that number, 261,990 (or 97%) were houses. In addition, of the 182,886 buildings that partially collapsed 177,890 (or 98%) were again houses. The fuller break down of the data is tabulated in appendix B. Still further, as disturbing as the "non engineered" house figures were, there was also the complete collapse of 3,424 educational buildings, 262 medical facilities and 341 Government buildings that were presumably "engineered" buildings.

As a consequence, the Diploma level Associate Engineers (DAE) qualification was targeted because of their involvement in the design and construction of such "non engineered" and "engineered" buildings that are characterised by:

- Their rural/remote nature. Much of the housing affected were in mountainous areas often above the winter snowline.
- Typically 1 to 2 storey typology for public buildings.
- The observed and reported need for improved site construction, quality control and seismic detailing.

Local masons (or artisans as they are referred to in Pakistan) are predominantly used for house construction in rural areas. The artisan tag is because their knowledge is handed down usually from within their family or as apprentices and they are not likely to have received any formal building training. What they have learnt they have learnt on the job. And hence, UNESCO targeted both groups but this paper deals with the integration of seismic design and construction into the DAE.

3 The Stakeholders

How do you go about such integration?

The first step that was taken was to talk to all the stakeholders involved and there were many that included the following:

- UNHABITAT is the agency of the United Nations responsible for housing and urban development
- ERRA (Earthquake Reconstruction & Rehabilitation Authority for the Kashmir Earthquake).
- NAVTEC (National Vocational & Technical Education Commission)
- NISTE (National Institute of Science Technical Education)
- Education Boards
- Board of Engineers Pakistan
- Contractors Association
- University of Peshawar Earthquake Laboratory
- Government Colleges of Technology (GCT)
- The students themselves.

Meetings were set up with various groups in Islamabad, Peshawar and Lahore. There were a few areas of general agreement but more differences of opinion over the aim and process of how this was to be achieved. The main areas of agreement were as follows:

- There was agreement that a seismic component was needed (and moreover that the DAE curricula needed a full review).
- There was general agreement that the seismic module should be largely "details" centred to establish best practice.

While the areas of disagreement were as follows:

- There were divisions over the mix of theory and practical content. The engineering consultants and contractors felt that there should be no theoretical background in the module and that DAE graduates were solely on site to make sure what was on the drawings was built. Hence, their view as that there should be 100% practical. On the other hand, those involved in the reconstruction work following the Kashmir Earthquake felt that there should be around 60-80% practical and 20-40% theoretical content which reflected the potential involvement of DAE graduates.

- The engineering consultants and contractors felt that the module should concentrate on 4 storey building construction and above while those involved in the reconstruction felt that they should concentrate on buildings 2 storeys and below.
- This size factor was also reflected in the type of building materials to be covered. There was agreement that the main materials of concrete, steel and timber should be covered but those involved in the reconstruction and those from educational institutes felt that brick masonry, rock, mud bricks and adobe should also be included. The latter materials tend to be used for non-engineered buildings and hence do not involve consultants or contractors.
- Those involved in the reconstruction felt that the DAE course also needed to address seismic retrofitting and building seismic assessment.

The responses from the students were also interesting and from what appeared to be a lone perspective with none of their concerns being raised by any of the other stakeholders. Most had selected the DAE because they felt it had good employment opportunities. Both groups in Peshawar and Lahore knew to expect around 12,000 rupee/month in the private sector with a little less for the Government sector. But perhaps more importantly, 25% of students in the Peshawar group and 45% in the Lahore group planned to go to the Bachelor of Technology Degree. This meant that any seismic integration module should staircase into the Bachelor's degree and some broad mapping should also be done for the degree to support the integration into the diploma.

Finally, it was noted that the DAE (Civil) is male dominated and while there were suggestions of a DAE (Civil) course for women in Karachi the only other educational route into construction was through the DAE (Architectural). This was outside the focus of this paper but it should also be noted that the vulnerability mentioned earlier was substantially women who were in and around the houses at the time of the earthquake. Moreover, despite the sense from the above meetings that construction was not for women gender equality and the realisation of the Millennium Development Goals MDG's remains on the agenda for education in Pakistan (MoE, 2005).

4 The Proposed Seismic Module

The present curriculum for the DAE (Civil) was formulated in 1996 (and is shown in Appendix A below) and given the changes in construction since then the call for an overall review seemed warranted. However, any review of the full curriculum for the DAE (Civil) would not be quick and therefore, the suggested seismic integration was designed as a module slotted into two topics selected by those teaching the present DAE (civil) course. The modular nature would also allow a stand alone presentation for those students who had already graduated.

A provisional idea of the seismic course content was then developed (and later accepted at a separate and subsequent workshop of stakeholders) based on the author's experience and "Seismic Design for Architects" by Andrew Charleson (Charleson, 2007). The book's non-mathematical and visual approach makes it ideal for Associate Engineers as well as Architects. The proposed module starts in year 2 of the DAE with "Earthquakes and Ground Shaking" which outlines where and how seismic forces are generated. It then moves on to "How Buildings Resist Earthquakes" and discusses how buildings at the same site will modify and respond differently to the same ground shaking. And then in year 3 this will be followed up with "Seismic Design Approaches" which is not about how to apply the code but the rational behind the approach in the code. For example, it would define and discuss the notion of "ductility" and its importance in seismic design. Different codes interpret this in different ways and the approach would be for Associate Engineers to understand the reasoning and background to the detailing and construction they would be inspecting. The module would then look at the "Vertical Structure" and in particular the detailing for timber, steel and concrete vertical resisting systems. And finally the "Horizontal Structure" and the role of diaphragms, ties and struts to transfer seismic induced loads to the vertical resisting elements. This is shown in figure 1 below together with a proposed possible course structure for the B. Tech Degree. Timber, steel and concrete together with brick masonry, rock, mud brick and adobe materials were included.

5 How Does the Curriculum Conform to the Code?

Better seismic codes are very important to improve seismic safety but how does the curriculum encourage code compliance of houses and buildings? It does this via the 5 following ways:

- Links and references to the code are incorporated into the module material
- Textual material specific to Pakistan

- A computer based code checking programme modified to the new Pakistani Seismic code.
- The compilation of an electronic library collection of codes, manuals, papers, video's and books.
- The provision of testing equipment

Figure 1: The Proposed Seismic Module for the DAE (Civil)

DAE (CIVIL)			**B. TECH (CIVIL)**			
YEAR			**YEAR**			
1	**2**	**3**	**1**	**2**	**3**	**4**
	1. Earthquakes and Ground Shaking **2. How Buildings Resist Earthquakes**	**1. Seismic Design** **2. Vertical Structure** **3. Horizontal Structure**	**1. DAE COURSE**	**1. Vertical Configuration** **2. Horizontal Configuration** **3. Non Structural- Causing Structural Damage** **4. Non Structural- Not causing Structural Damage** **5. Foundations**	**1. Retrofitting** **2. Professional Communications** **3. New Technologies**	**1. Seismic Project covering (DRR, Seismic Assessment, Special Issue for Pakistan)**
	T 0.4 **P 0.1**	**T 0.4** **P 0.1**				

The above resources would be provided to all Government educational institutes providing a DAE (civil) course and the literature based material to all teachers and lecturers. A 6th approach called "Professional Communications" was suggested for the DAE course (later shifted to the B Tech, refer to figure 1 above) that recognised that many/all DAE graduates would be "junior" when they were on site and trying to convince a mason with 20+ years of experience that what he has been doing needs to be changed for better seismic performance would be problematic but was central to the achievement of better buildings and code compliance albeit that several of the non engineered materials do not have codes.

But the main issue was the lack of suitable textual material specific to Pakistan using examples and especially photographs from a Pakistani context and hence the following textual material was identified:

- A Teacher's Manual: This would be as a text book (though more compact) specifically designed for this seismic module. The text would follow the course content outlined earlier and would try to expand on material presented in class.

- Lesson Plan: Power point presentations of the theoretical material that teachers could use as power points or use as dot points for white boards or chalk boards. Lesson plans for the practical content should also be included that would cover simple experiments to high light the theoretical material. For example, the use of 2D paper representations of buildings to show the different seismic responses of buildings to shaking: or role plays showing the role of stiffness in seismic response of building elements are easily and intuitively understood by students.
- Detailing Guide: this guide should consist of engineering drawings of the relevant details for timber, steel and concrete structures as well as brick, rock, mud brick and adobe house construction. These should be in an engineering drawing format rather then solely photographs, as it would tie into the civil drafting component of the curriculum.

All of these would align with the intent of the Pakistan Seismic code and what was considered acceptable practice.

Suitable test equipment such as a scala penetrometer and a rebound hammer were also highlighted. Scala penetrometers are rugged, inexpensive, portable hand operated test equipment for ascertaining the bearing capacity of soils (NZ, 1988). Most/all of the houses and buildings in this rural context would not have had any foundation testing. And the intention of this equipment was to ensure good foundations as a starting point for any building. This would be backed up by rebound hammers for checking insitu concrete strengths. The advantage of this equipment over concrete test cylinders is that it can be done on site (and hence the location of good, poor or failed concrete is readily apparent), it is non destructive, it can be easily repeated and it can be shown directly to the contractor. It does not replace concrete test cylinders but in the vulnerable rural context would be an improvement on no testing. In addition, both sets of equipment could be used for others parts of the DAE curriculum

Finally, it was planned to include a Pakistan version of the RESIST programme. This programme is an intuitive straight forward lateral load code checking program and if building designs are under strength users can easily increase or change the bracing system till code compliance is achieved. This has proven to be a useful teaching tool in New Zealand and Indian Schools of Architecture.

6 How Does the Curriculum Address Non-Engineered Buildings?

The inclusion of seismic resistant design and construction components for mainly non-engineered buildings in Pakistan was problematic due to the lack of codes and industry standards but it clearly had to be incorporated into the seismic module. It starts with the meaning of "non engineered". The term suggests that no one qualified has been involved in the building's design yet the buildings could be considered as finely engineered taking into account the following (Shaw et al, 2008):

- Understandable to users
- Implementable (usable, doable)
- Originated within communities, based on local needs, and specific to culture and context (environment and economy)
- Provides core knowledge with flexibility for local adaptation for implementation
- Uses local knowledge and skills, and materials based on local ecology
- Has been proven to be time tested and useful in disasters
- Is applied or applicable in other communities or generations

And hence, the main difference between "engineered" and "non engineered" buildings is perhaps in the level of risk seemingly accepted by those commissioning masons? Nonetheless, vernacular houses such as the Dhajji that uses a diagonal weave of timber that is infilled with mud do meet the "engineered" level of risk but are probably still tagged as "non engineered". (Schacher T et al, 2009). But to unpick these non engineered buildings requires firstly significant social issues as alluded to by Shaw above, but also material supplies, cost structure, tools and building practices, all of which produces a potentially unsustainable situation. So how was any balance to be achieved?

The approach adopted within the module was to focus on practices that could increase seismic performance and safety using the same materials or innovatively apply others that were readily available in the rural context of Pakistan. The specific concepts highlighted in the module were the promotion of the following key features:

- The Dhajji house approach
- Maximum cross wall spacing
- The use of horizontal timber bands built into mud and rock walls
- Better ties between the roof/floors and the walls
- The use of through stones in walls

- A secondary propping system for roofs and floors that would allow people to escape but would not prevent structural collapse by the tying of timber beams and to additional timber posts using nailed plates formed from tin cans.
- And if possible the use of lightweight roofs.

7 Conclusion

It sounds easy and straightforward but it isn't. The integration of seismic design and construction into the DAE (Civil) in Pakistan required balancing several stakeholder differences, had a significant textual demand and trade offs to achieve the best outcome for the vulnerability identified by the 2005 Kashmir Earthquake. However, the issues faced can be expected to be similar in other developing countries and hence it's value.

8 References

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Appendix A

DAE (Civil)
Scheme of Studies

First Year

			T	P	C
Gen	111	Islamiat & Pak Studies	1	0	1
Eng	112	English	2	0	2
Math	113	Applied Mathematics-I	3	0	3
Ch	112	Applied Chemistry	1	3	2
Phy	122	Applied Physics	1	3	2
Shop	162	Workshop Practice	0	6	2
CT	114	Surveying-I	2	6	4
CT	123	Construction-I	2	3	3
CT	133	Civil Drafting-I	1	6	3
		T o t a l	**13**	**27**	**22**

Second Year

Gen	211	Islamiat/Pak Studies	1	1	0
Math	212	Applied Mathematics-II	2	0	2
Comp	122	Computer Applications	1	3	2
CT	212	Public Health Engineering-I	1	3	2
CT	224	Surveying-II	2	6	4
CT	233	Construction-II	2	3	3
CT	243	Civil Drafting-II	1	6	3
CT	253	Mechanics of Structures	2	3	3
CT	262	Quantity Surveying-I		1	3
	110				
		T o t a l	**13**	**27**	**22**

Third Year

Gen	311	Islamiat & Pak Studies	1	0	1
CT	312	Project Management	2	0	2
CT	322	Quantity Surveying-II	0	6	2
CT	333	Public Health Engineering-II	2	3	3
CT	344	Hydraulics & Irrigation	3	3	4
CT	353	Railways, Docks, Harbors and Bridges	2	3	3
CT	364	Concrete Technology and RCC Design	3	3	4
CT	373	Soil Mechanics, Highways and Airports	2	3	3
CT	381	Civil Engineering Project	0	3	1
		T o t a l	**15**	**24**	**23**

Appendix B

This data was as at Nov 12 2005 and was down loaded at http:/www.ajk.gov.pk

Table B1: Overall impact of the Oct 2005 Kashmir earthquake in Pakistan(WB-ADB, 2005)

Indicator	Latest estimate
Area Affected	30,000 sq km
Population Affected	3.2 to 3.5 million
Deaths	73,000
Injured	79,000
Houses	400,153 (damaged and destroyed)
Families Affected	500,000 (based on an average family size of 7)

Table B2:Overall Losses for the NWFP and AJK areas of Pakistan. This data was as at Nov 12 2005 and was down loaded at http:/www.ajk.gov.pk

District	Life		Buildings		Damaged length of Road (km)
	Deaths	Injured	Fully Destroyed	Partly Destroyed	
North West Frontier Province (NWFP)					
Shangla	423	957	15,880	11,087	405
Manshera	24,511	30,585	32,293	43,925	671
Kohistan	661	639	4,504	18,737	396
Abbottabad	515	1,730	7,267	27,813	306
Batagram	3,232	3,279	29,015	8,841	284
Sub Tot	29,342	37,190	88,959	110,403	2,062
Azad Jammu Kashmir (AJK)					
Neelum	447	1,013	3,692	8,991	
Muzaffarabad	33,724	21,374	115,211	17,209	1,237
Bagh	8,157	6,644	48,365	18,736	461
Rawalakot	1,025	1,909	15,362	25,770	667
Sudhnoti	4	16	430	1,777	
Mirpur	6	11	0	0	
Sub tot	43,363	30,967	183,060	72,483	2,365
TOTAL	72,705	68,157	272,019	182,886	4,427

Table B3: Building Type and Use Full Collapse and Partial Collapse Data. This data was as at Nov 12 2005 and was down loaded at http:/www.ajk.gov.pk

District	Housing		Education		Medical		Other Govt		Misc[1]		Sub Tot	
	Full	Part	Full	Part	Full	Part	Full	Part	Full	Part	Full	Part
North West Frontier Province (NWFP)												
Shangla	15,661	10,821	206	247	13	19					15,880	11,087
Manshera	31,323	43,282	935	624	35	19					32,293	43,925
Kohistan	4,350	18,395	154	320		22					4,504	18,737
Abbottabad	6,961	27,051	295	736	11	26					7,267	27,813
Batagram	28,712	8,656	268	180	35	5					29,015	8,841
Sub Tot	87,007	108,205	1,858	2,107	94	91					88,959	110,403
Azad Jammu Kashmir (AJK)												
Neelum	3,692	7,215	0	75	0	9	0	2	0	1690	3,692	8,991
Muzaffar.	108,157	17,120	929	0	103	0	77	89	5,945	0	115,211	17,209
Bagh	4,7619	18,226	511	240	49	40	186	76	0	154	48,365	18,736
Rawalakot	15,086	25,405	125	275	16	19	78	71	57	0	15,362	25,770
Sudhnoti	429	1,719	1	54	0	2	0	0	0	2	430	1,777
Sub tot	174,983	69,685	1,566	644	168	70	341	238	6,002	1,846	183,060	72,483
TOTAL	261,990	177,890	3,424	275	262	161	341	238	6,002	1,846	272,019	182,886

Note 1. includes shops and mosques