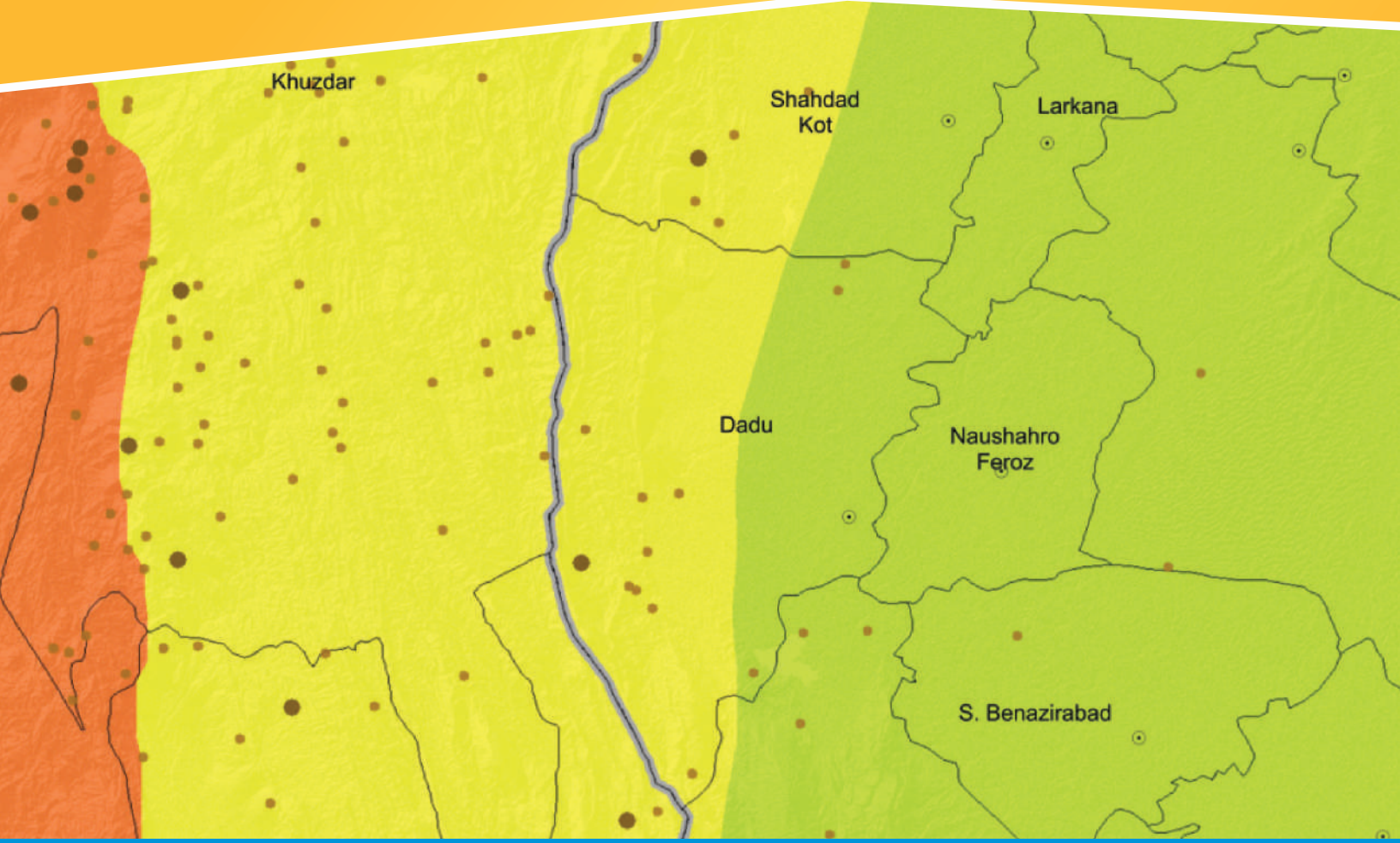


Seismic Design in Pakistan: The Building Codes, Bylaws and Recommendations for **EARTHQUAKE** Risk Reduction



United Nations Development Programme
Islamabad – Pakistan



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Seismic Design in Pakistan:

***The Building Code, Bylaws, and
Recommendations for Earthquake Risk Reduction***

**United Nations Development Programme
Islamabad-Pakistan**

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Foreword

On October the 8th 2005, the Mw 7.6 Kashmir earthquake in northern Pakistan caused 73,338 casualties, affecting about 3.5 million people and cost the country around US\$ 6 Billion. This devastation as a result of the earthquake alerted the country to many mitigation efforts that could be put in place to reduce future damages and deaths. The occurrences of earthquakes cannot be prevented, but their impacts on life, property and the economy can be managed and minimized.

Despite the death and devastation, the 2005 earthquake has been considered as an opportunity to build back better. Many positive actions were undertaken after the event to reduce the risks associated with earthquakes. The Building Code of Pakistan – Seismic Provisions 2007 is a concrete example of this. It is the first earthquake design code to be referenced in national policy, and it provides a strong platform for a potential advance in earthquake engineering practice nationwide. It is considered an important milestone in mainstreaming earthquake risk reduction.

UNDP Pakistan has taken the initiative to explore in more detail, the practical implications of the Building Codes and Bylaws and how it is enforced at the sub-national level. This publication explores how to translate policy into practical actions for better earthquake risk reduction initiatives. As one of the front campaigners of preparedness, UNDP believes that for every US\$1 invested in resilience and prevention, between US\$4 and US\$7 are saved in response.

We are hoping that this publication will bring more awareness of the importance of enforcing and implementing the Building Codes and Bylaws in Pakistan. The risk reduction measures and recommended activities must be translated into positive actions which will save lives, prevent more losses and damages and - in the long term - build a more resilient Pakistan.



Marc-André Franche
Country Director

Acronyms and Abbreviations

| | |
|-----------|--|
| ACEP | Association of Consulting Engineers Pakistan |
| ADPC | Asian Disaster Preparedness Center |
| AJK | Azad Jammu and Kashmir |
| ASCE | American Society of Civil Engineers |
| BCP | Building Code of Pakistan – Seismic Provision 2007 |
| CDA | Capital Development Authority |
| DA | Development Authority |
| DMA | Disaster Management Authority |
| DHA | Defense Officers Housing Authority |
| EEC | Earthquake Engineering Center |
| EMI | Earthquakes and Megacities Initiative |
| ERRA | Earthquake Reconstruction and Rehabilitation Authority |
| IEP | Institution of Engineers, Pakistan |
| NDMA | National Disaster Management Authority |
| NED | NED University of Engineering and Technology |
| NESPAK | National Engineering Services Pakistan |
| PDMA | Provincial Disaster Management Authority |
| PEC | Pakistan Engineering Council |
| PGA | Peak Ground Acceleration |
| PMD | Pakistan Meteorological Department |
| QTA | Quetta Development Authority |
| RDA | Rawalpindi Development Authority |
| SBCA | Sindh Building Control Authority |
| TMA | Tehsil Municipal Administration |
| UBC | Uniform Building Code |
| UET | University of Engineering and Technology |
| UNDP | United Nations Development Programme |
| UNHABITAT | United Nations Human Settlements Programme |
| USAID | United States Agency for International Development |
| USGS | United States Geological Survey |

Introduction

This publication discusses earthquake risk reduction in Pakistan and its relationship to building codes, building regulation, and structural engineering.

Part 1 reviews the status of building codes and bylaws, with a focus on the 2007 Building Code of Pakistan, or BCP. The BCP represents Pakistan's first nationwide policy for earthquake-resistant construction. While its publication in 2007 was an essential step forward, this report shows that local building regulations, or bylaws, still do not cite it and are not coordinated with it. Further, the BCP's effectiveness is limited by pre-existing challenges in the implementation of most bylaws.

Even where it is adopted and enforced, the BCP applies only to new construction. Part 2 of this publication discusses earthquake risk reduction more generally, considering also the status and opportunities related to building inventory, repair, loss estimation, and retrofit, especially for the existing building stock and for the many small or vernacular structures typically exempt from building bylaws. In many parts of the country, valuable work was done after the 2005 earthquake to understand the existing building stock, and this work should be continued. In the major cities, certain vulnerable structure types deserve similar attention. Nevertheless, in the cities where development and building replacement is rampant, retrofit seems less important and less effective than implementing the BCP on the new construction. There are more opportunities to avoid adding to the risk than to reduce existing risk.

Finally, Part 3 offers a set of recommendations based on the findings in Parts 1 and 2. The technical recommendations involve building code updates and continuation of inventory and retrofit studies. Just as important, however, are the less technical recommendations involving professional development for engineers and regulatory procedures for building officials.

Part 1. Status of Building Codes and Bylaws

The *Building Code of Pakistan – Seismic Provisions 2007* (BCP), represents a potential advance in earthquake engineering practice nationwide and, more importantly, a crucial step in the mainstreaming of earthquake risk reduction. Still, all stakeholders recognize that regulation of building design and construction throughout Pakistan still lacks certain essentials; chief among these are the capacity to enforce the code for new buildings and provisions of any kind to regulate risks posed by existing buildings.

Development of the 2007 BCP

The 2007 BCP, the country's first earthquake design code to be referenced in national policy, was plainly motivated by the catastrophic 2005 earthquake (MOHW, 2007; Shabbir and Ilyas, 2007).¹ Before its adoption in 2008, guidance for earthquake-resistant design and building regulation developed through the following broad phases (Shabbir and Qadeer, 2009):

- Pre-Partition: Seismic design provisions were added to the building code of the municipality of Quetta after a damaging earthquake there in 1935 (Quetta, 1937).
- 1947 through the 1970s: British building codes remained in use after partition. Outside of Quetta, however, careful earthquake design was rare. Some government agencies continue to use British codes even today, though not necessarily for earthquake design of building structures (Qadeer, 2013).
- 1970s to 1986: Trained engineers began applying American codes, especially the *Uniform Building Code* (UBC). Until the *International Building Code* (IBC) replaced it in 2000, the UBC was the leading model code throughout California and the U.S. west coast. It was updated on a three-year cycle through its final edition in 1997.
- 1986 to 2007: Pakistan's first national building code was published in 1986 as "an advisory document" with seismic provisions modeled on contemporary editions of the UBC (Rossetti and Peiris, 2008). Though perhaps intended for adoption by local bylaw, the 1986 code was not officially adopted or enforced (Shabbir and Ilyas, 2007). Neither was the 1986 code regularly updated. While sometimes used as a reference, trained engineers continued to use the triennially updated UBC (Lodi et al., 2013).

Soon after the 2005 earthquake, the Ministry of Housing & Works hired National Engineering Services Pakistan (NESPAK) to develop seismic hazard maps and earthquake design provisions for a thorough update of the 1986 code. Ultimately, NESPAK would collaborate with a committee of experts convened by the Pakistan Engineering Council (PEC), mostly academics, to produce a consensus document that would become the 2007 BCP (MOHW, 2007, Preface; Shabbir and Ilyas, 2007).

The 2007 BCP comprises eleven chapters:

- Chapter 1 clarifies that the BCP applies only to building and "building-like" structures, as opposed to bridges, dams, tunnels, and other civil or industrial facilities. It claims applicability to "reinforced concrete, steel and masonry" structures, which account for nearly all engineered buildings in Pakistan. As noted below, the BCP has no chapter for timber structures or for light gage steel framing, but its masonry chapter does provide guidance for empirical, or prescriptive, design. Importantly, Chapter 1 makes no exemption by building size, location, use, or occupancy. Unless exempted by local bylaws, the BCP would apply even to one-story buildings and single-family residences (assuming the BCP is adopted locally in the first place).
- Chapter 2 quantifies the seismic hazard for design at a given building site, breaking the country into five mapped zones and providing a table of parameters by tehsil. The zones generally match those used in the 1997 UBC; each represents a level of expected ground shaking characterized as having a 10 percent probability of

¹ The earthquake of October 8, 2005, together with its aftershocks and effects, is cited variously as the Pakistan earthquake (for example, in UNDP and USGS reports), the Northern Pakistan earthquake, the Kashmir earthquake (Wikipedia), the Muzaffarabad earthquake, the AJK earthquake, etc. For clarity and simplicity, this report refers to the event by its date as the 2005 earthquake.

exceedance in any 50-year period (or a return period of about 500 years). As with the design procedures in Chapter 5, this reflects the pre-earthquake practice of many Pakistan engineers, but it is obsolete with respect to the current American practice the BCP generally intends to follow. BCP Appendix A explains the derivation of the hazard values, referring to separate reports for details (see, for example, PMD, 2007). As discussed below, the code's seismic hazard values reflect contemporary local practice, and some have characterized them as unconservative.

- Chapter 3 addresses site selection. For “important” buildings the BCP prohibits locations close to active fault traces and requires mitigation of liquefiable soil, but it does not define what counts as an “important” building. The chapter also requires investigation, and potential mitigation, of slope stability for all buildings on sloping sites “in mountainous terrain.” It is possible that adequate local practices already account for these site issues, but if not, the various undefined terms and vague criteria make this chapter practically unenforceable, if well-intended.
- Chapters 4 through 11 present technical code provisions on various topics, largely reprinting criteria from American codes and standards (MOHW, 2007), principally:
 - 1997 UBC, for soils and foundations related to earthquake design (Chapter 4), structural design criteria and load combinations (Chapter 5 Division I), snow loads (Chapter 5, Division II), wind design (Chapter 5, Division III), earthquake design (Chapter 5, Division IV), structural tests and inspections (Chapter 6), and design of engineered masonry (Chapter 9 through Section 9.8).
 - ACI 318-05, the 2005 edition of *Building Code Requirements for Structural Concrete*, for concrete structures. In particular BCP Chapter 7 follows ACI 318-05 Chapter 21, “Special Provisions for Seismic Design” instead of 1997 UBC Chapter 19. By doing so, the BCP might be missing some of the ACI and UBC quality assurance provisions.
 - AISC 341-05, the 2005 edition of *Seismic Provisions for Structural Steel Buildings*, for steel structures in Chapter 8. In general, as long as the BCP incorporates appropriate quality assurance provisions, this represents a substantial improvement over 1997 UBC Chapter 22 in terms of both content and presentation.
 - ASCE 7-93, the out-of-print 1993 edition of *Minimum Design Loads for Buildings and Other Structures*, for seismic anchorage of architectural components (Chapter 10) and building services equipment (Chapter 11). Presumably this obsolete document was selected because it represented the state of practice in Pakistan in late 2005. (As noted below, either this source document or its transcription into the BCP appears to be in error, with criteria prescribed for the wrong occupancy categories.)
 - ASCE 7-05, the 2005 edition of *Minimum Design Loads for Buildings and Other Structures*, sporadically. For example, the load combinations in Chapter 5 generally follow the 1997 UBC but include some revisions per ASCE 7-05. It is possible that this standard is listed as a source document only because it was the latest update to ASCE 7-93 available at the time. In any case, ASCE 7-05 is substantially different in terminology and even in substance from both the 1997 UBC and ASCE 7-93.

In addition, BCP Section 9.9 provides criteria for empirical, or prescriptive, design of “simple residential buildings,” without restriction by seismic zone. The criteria are similar, but not identical, to those found in *Guidelines for Earthquake Resistant Non-engineered Construction* (IAEE, 1986), which the BCP lists as a source document. Section 9.9 covers both general masonry construction and so-called “confined masonry,” an idea that has received growing attention in the last decade (Brzev, 2007; Meli, et al., 2011; Build Change, 2012).

The nature of the 2007 BCP as an amalgam of American standards reflects the speed with which the document was compiled. Specific shortcomings and opportunities for improvement are discussed below. Here, with respect to the code's overall development, the essential point is that the BCP remains, six years after its publication, limited to structural design and devoted almost entirely to earthquake design of new buildings. Key participants from NESPAK and the PEC committee agree that the sense of urgency after the 2005 earthquake led to decisions that might have been made

differently had more time been available (Gilani, 2013; Lodi et al., 2013; Qadeer, 2013). The 2007 BCP is not the comprehensive building code – with provisions for fire safety, exiting, mechanical and electrical design, etc. – that some NESPAK staff had hoped and even planned to produce (Shabbir and Ilyas, 2007; Qadeer, 2013).

But even with respect to the seismic provisions, some experts and agencies, including the National Housing Authority, have expressed regret that the development schedule required wholesale incorporation of American source documents and prevented the creation of a truly Pakistani code, one suited specifically to the country's established practices and particular needs (NHA). In this regard, the 2007 BCP is unlike the building codes of India, Japan, or New Zealand (or, for that matter, the U.S.), each of which is unique and reflective of its own history and society.

One unfortunate result of a “borrowed” code is that it might not give due attention to conditions endemic to Pakistan, such as the ubiquitous use of masonry partitions and infill. More important, the American codes presume certain materials and practices that might be missing in Pakistan. Borrowing source documents therefore calls for careful customization to local conditions. But that effort would have been needed to produce a uniquely Pakistani code in any case. Meanwhile, the use of borrowed American codes and standards might actually have some benefits: They provide a now familiar model, or framework, for future code development in Pakistan to follow. They reference new material standards and structural systems that can help advance Pakistani practice. The latest American codes, published by the International Code Council, are themselves built from independent standards that each address a specific topic, giving them a modular structure that can be developed or customized piece by piece. Finally, even as country-specific codes in India, New Zealand, etc. continue to develop, they are coming closer to each other in concept. After all, the fundamentals of earthquake science and engineering are the same everywhere.

Implementation through bylaws

As the new code was being completed and introduced in August 2007, the Prime Minister himself was encouraging local adoption, asking provincial governments to enact bylaws and regulations to ensure compliance (Shabbir and Ilyas, 2007; APP, 2007). Nevertheless, the current status of the 2007 BCP within actual building control regulations is unclear.

While the 2007 BCP is a document of national scope produced by national organizations, design and construction of private buildings in Pakistan is regulated by local bodies through local regulations traditionally known as bylaws.² Most current building bylaws are a vestige of British rule and have little to say about earthquake design or vernacular construction. (The Quetta building code, discussed below, is a notable exception.)

In the major cities, most regulation is done by development authorities (DAs) with jurisdiction over the city and suburbs, though specific parts of a city might be overseen by a Defence Housing Authority, a Cantonment Board, or a Tehsil Municipal Administration (Dowall and Ellis, 2007). Government decentralization in 2001 was meant to distinguish the responsibilities of provinces, districts, and tehsils, but overlaps remain and sometimes lead to conflicts, as a DA and a TMA might both claim building control jurisdiction and issue contrary rulings (Dowall and Ellis, 2007; Memon, 2010; Habib, 2011; Hanif, 2012). This report considered primarily the bylaws promulgated by DAs in the major cities. These DAs, created to help manage rampant urban population growth after partition, now function as owner, developer, planner, and regulator, performing functions that in most U.S. cities would be handled by separate planning, public works, and building departments.

With respect to the BCP and structural or earthquake design issues, the bylaws of leading DAs are inconsistent, incomplete, often obsolete, sometimes overlapping, and sometimes contradictory. The lack of a clear authority on such basic questions as where, and to what buildings, the BCP applies, was confirmed in multiple interviews (Qadri, 2013; Qadeer, 2013; Lodi et al., 2013; Basit, 2013; Aziz, 2013). Indeed, as shown below, no major jurisdiction actually cites the BCP by name in its building control bylaws. This does not necessarily mean that design and construction are proceeding entirely without oversight, or even that the BCP is being ignored; rather, it suggests only that responsibility for structural design remains largely with the design professional, while legal precedents covering building code enforcement are not yet as ingrained as long-standing rules covering planning and zoning.

² Described in this report as “bylaws,” the actual documents use a variety of spellings, some archaic or British, including by-laws, bye-laws, and byelaws, and are sometimes titled simply as “regulations.”

At least two pieces of national legislation reference the 2007 BCP directly. First, about a year after the BCP was published, the PEC-maintained bylaws governing the practice of engineering (PEC, 1986) were modified (PEC, 2008a) to include a new three-part bylaw number 10:

10. *Application of Building Code of Pakistan (Seismic Provisions – 2007)*. (1) The provisions of the Building Code of Pakistan (Seismic Provisions – 2007) shall apply for engineering design of buildings, building like structures and related components.

(2) Construction of buildings in violation of the Building Code shall be considered as violation of professional engineering work as specified under clause (xxv) of Section 2 of the Pakistan Engineering Council Act, 1975 (V of 1976).

(3) The provisions of the Building Code shall be revised by the Pakistan Engineering Council after every five years or earlier if so required by circumstances.

The obvious first question is whether this national bylaw is intended to supersede local regulations that, as noted below, do not cite the 2007 BCP. A close reading raises a few additional questions:

- Since this modifies only the bylaws governing the “conduct and practice of consulting engineers,” does it put the burden of implementing the BCP on the design professional, as opposed to the development authority or jurisdiction? Does this mean that application of the BCP is merely a matter of professional conduct, as opposed to a law affecting owners?
- Part (1) refers to “engineering design.” Does this mean the bylaw does not apply to empirical, prescriptive, vernacular, or otherwise non-engineered construction (such as that envisioned by the IAEE source document for BCP Section 9.9) or to owner- or contractor-designed buildings? Section 2 of the 1975 PEC Act includes engineering design under “engineering services,” which it seems to limit to registered or qualified persons. However, Section 2 also defines “professional engineering work” rather broadly, to include both “residential and non-residential buildings.”
- By contrast to part (1), part (2) refers to “construction of buildings,” without limitation. Does this make engineers responsible for the work of contractors? Or is it meant to extend the engineers’ bylaws to contractors? Under this bylaw, who precisely is in violation when a non-compliant building is built?
- Part (3) would have required a code update around 2012; the five-year cycle matches the intent stated in the BCP preface. Does the fact that this update did not occur have any effect on the liability of engineers to apply the BCP, especially if newer codes and standards are available?

Two years later, the 1987 national bylaws governing “construction and operation of engineering works” added an identical three-part bylaw (PEC, 2010). However, those same construction bylaws (Section 1, part (2)) exempt any project valued at less than four million rupees. On one hand, this would (even in 2013) exempt many houses and small commercial buildings. Is a small building not in compliance with the BCP considered a violation under the bylaws for engineering practice, or is it exempt under the bylaws for engineering works? On the other hand, despite the wording of the new bylaw, “engineering works” are normally considered to include industrial facilities, not buildings with residential or commercial occupancy. Again, the question of when and where exactly the BCP is meant to apply remains unanswered.

In late 2010, the Government of Pakistan Planning Commission issued a decision that “all development projects requiring approval of Government should ... incorporate measures of disaster risk reduction at the project design, planning and implementation stages” (Kayhar, 2010). The Commission developed checklists to be incorporated into existing project *pro forma* documents; one checklist item asks, “Is the project prepared keeping in view the Building Codes [sic] of Pakistan 2007?” Aside from the likely ineffectiveness of this simplistic approach, three years later the *pro forma* documents posted on the Commission’s website still date from 2005 and do not mention the BCP or, for that matter, earthquake risk reduction measures more generally (Planning Commission, 2013).

The local bylaws are more concerned with planning and zoning than with the design of the structure itself. A review of readily available bylaws finds a range of requirements for structural design and certification, but not a single mention of the 2007 BCP. The closest reference comes from model regulations produced by the Punjab provincial government for adoption by cities and towns (Punjab, 2007a). These model regulations are discussed in more detail below, but the key provision is found in an otherwise administrative chapter about plan review procedures, effectively hidden in a section on “Special Conditions” near the very end of the document:

10.11.2 Safety and Stability of Buildings. Every builder who carries out building works shall use sound building material, of good quality and properly put together so as to ensure safety and stability of the building and in accordance with Uniform Building Code, 1997, USA & International Building Code, 2006 or Building Code of Pakistan, 1986 till the revised Building Code are notified [sic].

While this paragraph does mention the 1986 BCP, along with two more recent (though rather different) codes, and while it applies to all buildings regardless of size or occupancy, as written it applies only to builders, not engineers, and only to the quality of construction, not design. Structural and earthquake design provisions, which do not cite the BCP, are given elsewhere in the model regulations, where they apply only to larger buildings.

Except in Quetta, where earthquake design provisions have been in place since 1937, local regulations can be expected to require code compliance in a general way, and to require a brief certification of adequacy by an architect or engineer, but far more attention is given to lot setbacks, floor area ratios, and allowable uses (see, for examples, CDA, 1993, or Punjab, 2007a). Indeed, the more complete bylaws address a number of topics typically covered in a comprehensive building code, including height and area limits, fire safety, and administrative procedures. As a result, approval processes spend far more time on those issues than on vetting the structural design, and professionals charged with obtaining such approvals will devote their professional effort accordingly (Qadri, 2013; Lodi et al., 2013).

Following are notes regarding seismic and structural criteria referenced in a selection of provincial and city bylaws:

- For Islamabad, the Capital Development Authority was expected to produce new building regulations along with recent fire and life safety regulations (NDMA, 2012a, p37), but the Authority still posts online only its prior residential regulations, now twenty years old (CDA, 1993). Section 6.01, regarding “Construction of buildings,” states only that “No building or structure shall be constructed ... except ... [i]n accordance with the building and zoning regulations, or instructions issued by the Authority in this behalf from time to time.” No specific building codes or structural design criteria are given.
- Perhaps the most complete and current bylaws are the model regulations produced by the provincial government of Punjab (Punjab, 2007a) for adoption by cities and development authorities. Section 10.1 clarifies that the model regulations are intended to cover all new buildings including those developed by government agencies, except for minor agricultural and temporary structures. As noted above, Section 10.11.2 references the 1986 BCP pending an update (which has since occurred) but is not specifically about design. Despite their thoroughness, the model regulations’ structural provisions, in Chapter 7, apply only to multi-story buildings, defined as buildings taller than three stories or 38 feet. The requirements include:
 - 7.1.1 Earthquake Resistant Design: “The structural design ... shall conform to the requirements of the applicable codes such as UBC 1997, for resisting earthquake forces. ... The seismic zone factor for buildings shall be based on the Seismic Zone Map of Pakistan.” Presumably, this map would now refer to 2007 BCP Figure 2.1, titled “Seismic Zoning Map of Pakistan.”
 - 7.1.3 Compliance to Design Codes: “The structural design of buildings shall meet the requirements of the current edition of the following design codes: i. Uniform Building Code, 1997 Edition ... ii. International Building Code, 2006 Edition ... iii. Building Code Requirements for Structural Concrete (ACI 318-99) ...” This provision resolves the vagueness of Section 7.1.1, but as written, it requires compliance with *both* the 1997 UBC and the more current 2006 IBC, which the BCP does not reference. Also, since the 2006 IBC already adopts the 2005 version of ACI 318 (as does BCP Chapter 9), the reference to ACI 318-99 is either contradictory or, if intended as an option, obsolete.

- 7.3.3 Structural Calculations: “The builder shall submit structural calculations and a certificate from a qualified engineer to verify the structural stability of foundations and super structure [sic], if required by the Authority.” Forms BR-6 through BR-9 are provided to meet the verification requirement.
- In addition to Chapter 7, but still applicable only to multi-story buildings and “buildings of public assembly,” Chapter 9 requires the builder to engage the services of a design Structural Engineer to provide compliance with Section 7.1.3, a vetting Structural Engineer to review the work of the designer, and a Resident Engineer to supervise construction. The Resident Engineer must also “cause such testing and inspections to be carried out as are required, in his opinion, but such testing shall in no case be less than prescribed by the Uniform Building Code, 1997, USA.” Contrary to the wording in Chapter 9, Section 10.3.4 indicates that the vetting Structural Engineer is to be employed by the development authority.
- Section 9.6 covers the responsibilities of the development authority, including the following: “The structural engineering staff shall ensure that the construction is taking place as per approved structural designs and specifications and as per good engineering construction practices to ensure quality of construction.”
- Although no specific structural design criteria are given for other than multi-story buildings, Section 10.5.1 requires that apartment buildings, buildings of public assembly, and commercial and industrial buildings on large lots must have plans approved by a committee including the Director Structural Engineer.
- As noted above, Section 10.11.2 requires builders to “use sound building material, of good quality and properly put together so as to ensure safety and stability of the building and in accordance with” the 1997 UBC, the 2006 IBC, or the 1986 BCP pending its revision. This provision is not limited to buildings of a certain size or occupancy, but as written it addresses only construction quality, not design.
- In 2007, the Punjab provincial government directed the city governments of Lahore, Rawalpindi, Multan, Gujranwala, and Faisalabad to adopt the model regulations described above (Hanif, 2007). Lahore and Rawalpindi have each adopted the model regulations with minor procedural amendments (Punjab Gazette, 2008; RDA, 2007). (The other cities might have adopted the model regulations as well, but their versions are not available online.) In 2011, Punjab province took steps to create a Divisional Building Control Authority that would regulate construction throughout its 36 districts (Pakistan Today, 2011; Pakistan Observer, 2012). In all likelihood, this province-wide DA will adopt the model regulations.
- For Karachi, the Sindh Building Control Authority posts the city’s 2002 bylaws online, in 25 chapters with updates through January 2013 (SBCA, 2013). Per Chapter 1, the bylaws do not apply to the cantonment area or to security-related federal projects. They may also be replaced by “special low cost housing codes” in some cases. The structural design criteria, given in Chapter 11, are vague but generally consistent with the intent of the 2007 BCP. The scope of the regulations is set by the approval rules in Chapter 3, which distinguish between buildings of different sizes and uses.
 - Table 3.1 categorizes buildings by size and use, from modest houses and buildings up to 33 ft tall (Category I) to large public buildings and “essential facilities” (Category IV). Seismic design is not explicitly waived for any category, but the professional responsibility and approval process varies by category per Tables 3.2 and 3.3.
 - For houses (referred to as bungalows, in Category I or II), Table 3.3 suggests that an engineered structural design is required in all cases, but plans signed by the engineer need only be submitted for bungalows on lots larger than 400 square yards. The same rule applies to other buildings whose size or use does not put them in Category III or IV.
 - Category III buildings have floor area greater than 20,000 square feet or height greater than 50 ft. Category IV buildings include public buildings with floor area exceeding 10,000 square feet, “essential

facilities" (not defined), and "public sale buildings." For Category III and Category IV buildings, plans must be signed by a structural engineer *and* vetted by a "proof engineer" hired by the developer. Section 3-2.2.3 reads, in part, "The proof engineer will be equally responsible in case there is any error in design, drawing and/or calculations."

- 11-1. Loads and Design: "Structure analysis, design, detailing and loading shall be in accordance with the requirements of current Uniform Building Code (UBC) and American Code or British relevant Code or any other Code. Structure shall however be designed by only one approved Code." Unlike the Punjab regulations, this requirement appears to apply to all buildings. However, the specific criteria are to some degree left to the discretion of the owner or permit applicant. This provision also clarifies that only one code need be satisfied; the Punjab provision was less clear.
- 11-2. Seismic Design: "Seismic Risk Zone for Karachi will be zone~2B (with reference to UBC-97) which is equivalent to Peak Ground Acceleration (PGA) of 16% g to 24% g." This is consistent with the 2007 BCP.
- Sections 11-8, 11-9, and 11-10 address quality assurance with provisions for material specifications, testing, and construction supervision, respectively. The language is vague, however, with options and overlaps that could allow either very loose or very strict application. Effective quality assurance will rely greatly on the discretion and diligence of the developer, the engineer, the builder, and the DA staff.
- Construction in the Defence section of Karachi is regulated separately, by the Defence Officers Housing Authority (DHA). DHA regulations are posted online in 11 chapters (DHA, 2011). Among the relevant provisions are:
 - Chapter II, Section 6.b: "Every person intending to erect, re-erect or demolish, or carry out additions or alterations in a building shall engage an architect or structural engineer as applicable, for residential building and for high-rise flat sites, residential- cum-commercial and commercial buildings." This is followed by requirements for the architect or engineer to submit relevant forms, but these merely record the design criteria that were applied and do not themselves make any requirements. Thus the adequacy of design is made a matter of professional responsibility more than one of public policy.
 - Chapter II, Section 9.n: "Detailed structural drawing and calculation, on the basis of soil investigation report prepared by registered geo tech [sic] consultant, are required for residential and commercial projects taller than G+2 height duly prepared and vetted by the licensed and registered structural and vetting engineers respectively on *Form 4* as required under these regulations." Thus, the submittal of structural drawings and calculations is apparently not required for any residential or commercial building up to three stories.
 - Chapter III, Sections 30 through 33, cover residential structures, with requirements for everything from heights and areas to permissible uses and the width of car gates. But the only mention of structural design, in Section 33.r, relates to the installation of generators, which are "subject to sound structural design duly verified/certified and documented by registered structural engineer." Similar provisions are made for commercial structures in Section 37.n and for amenity buildings in Section 39.e.
 - Chapter III, Sections 34 through 37, cover commercial structures. Section 37.h: "Structural design and vetting is compulsory for all types of buildings higher than G+2 floors and for all amenity buildings irrespective of height." So-called amenity buildings, per the Chapter I definition of "amenity plot," include those housing "government offices, health, welfare, education, worship places, burial grounds, parking and recreational areas." Thus, DHA makes a procedural distinction by building use. The amenity buildings are generally public facilities, but the list does vary somewhat from the occupancy categories in BCP Table 5.10 that set importance factors for earthquake design.
 - Chapter III, Section 37.y: "Structure of commercial buildings to have inbuilt safety features against seismic threat, basing on the applicable seismic zone parameters eg [sic] Karachi lies in 2-B seismic zone, as such the building should be safe against an earth quake [sic] of 6.5 Richter Scale intensity. An

endorsement on the right margin of the submission drawing shall be made by the structure engineer duly signed by him as follows: - "The structure can withstand the seismic vibration upto [sic] 6.5 Richter Scale". However well intentioned, this is an ill-advised provision, full of undefined terms and inconsistent with DHA's own seismic criteria (in Section VIII, as described below). To the extent that it contemplates a design basis earthquake larger than that implied by UBC provisions for Zone 2B, it should be stated in more practical and enforceable terms.

- Chapter III, Sections 38 through 43, cover various amenity buildings but make no specific structural or earthquake design requirements.
- Chapter VIII, Sections 80 and 81, give structural design criteria with provisions essentially identical to those in Sections 11-1 and 11-2 of the SBCA regulations described above: "current Uniform Building Code ... and American Code or British relevant Code or any other Code," and "Seismic Risk Zone for Karachi will be zone-2B (with reference to UBC-97)."
- Chapter VIII, Sections 87 through 89, restate the vague provisions for material specifications, testing, and supervision from Sections 11-8, 11-9, and 11-10 of the SBCA regulations described above.
- The most recent building regulations available for Peshawar date from 1985 and apply to the "urban areas of the North-West Frontier Province" (PUDB, 1985). These bylaws have essentially no requirements for either structural or earthquake design. The most relevant provisions include:
 - Chapter 2, Section 7: Every building with more than 150 square meters of floor area must be designed by an architect, but only buildings with more than 500 square meters of floor area or taller than 13 meters require an engineer as well, "for the supervision of the buildings." The regulations thus imply that smaller buildings are exempt from a specific design and presumed to be adequate based on traditional or common practices.
 - Chapter 2, Section 8: Of the buildings larger than 500 square meters or taller than 13 meters, only "commercial, industrial and public buildings" require the submittal of "detailed drawing [sic] and structural calculations duly signed by the Civil Engineer." Fully residential buildings appear to be exempt, regardless of their size.
 - Chapter 5, "Building Structures – Constructional Requirements," deals mostly with site preparation and drainage. The only structural requirement is in Section 43, which requires foundations to properly resist dead load, live load (called "imposed load") and wind load but does not mention earthquake load.
- Quetta was famously destroyed by an earthquake in 1935. In 1937, a building code was introduced with "rules regulating the construction of private buildings within the limits of Quetta Municipality" intended to "afford a reasonable degree of safety both to the occupants and to passers-by in the event of an earthquake" (Quetta, 1937). The provisions, while thoughtful for their time, are obviously out of date with respect to multistory concrete construction, but it is not clear that they have been replaced by more current codes or bylaws (The Nation, 2011), and relatively recent legal decisions have confirmed that they still apply (High Court Balochistan, 1997). While a Quetta Development Authority was created in 1978, its jurisdiction appears limited to "public amenities" and "QDA's own housing/commercial schemes" (Government of Balochistan, 2013).

The 1937 code's primary technical focus is on limiting the use of unreinforced masonry construction. In addition, and in contrast to the more recent bylaws of other jurisdictions outlined above, the Quetta code emphasizes the role of the building official (called the Municipal Engineer) as an authority, as opposed to the role of a designer as a certifier. Specific design requirements include the following:

- Rule 7(b) requires submittal of "stress diagrams, computations, and other data" normally produced by an engineer for all concrete and steel buildings, as well as any other building at the discretion of the Municipal Engineer.

- Rules 12, 15, and 25 specifically regulate work on existing buildings in ways that most municipal bylaws do not. These rules raise questions of structural adequacy at appropriate points in the life of the building, such as when additions, alterations, repairs, or changes of occupancy are proposed.
- Rule 18 provides an early version of a tested principle of earthquake resistant design: “Every building shall have its parts tied together in such a manner that the structure will act as a unit.” Rules 30, 31, 32, 34, and 39 apply the same principle for earthquake safety of ornamentation, parapets, chimneys, “verandahs,” and stairs.
- Rule 19 specifies a base shear coefficient of 12.5% for use in an early version of an equivalent lateral force procedure.
- Rule 21 provides an early version of increased allowable stresses for load combinations that include earthquake effects.
- Rule 44 sets design criteria for eight “types of earthquake proof buildings.” Despite the unfortunate obsolete term “earthquake proof,” this is a thoughtful provision for its time, one that acknowledges engineered and vernacular construction types so as “to give sufficient variety in cost and quakeproof to suit the pockets of all classes.” Interestingly, Rule 52 exempts “government buildings” from the prescriptive requirements of Rule 44 as long as they are “safe against an acceleration of 4 feet/sec²,” approximately one eighth the acceleration of gravity. This indicates an intent to set a minimum design base shear similar to Rule 19, but from a modern perspective the two rules would only be consistent for buildings with certain structural systems and dynamic properties.

Table 1 summarizes the bylaws outlined above. Even with a limited review of provincial and local policies, it is easy to draw two important lessons about the BCP and its adoption through bylaws:

- Where bylaws cite structural or earthquake design criteria from a model building code, they do not cite the BCP. Instead they directly cite the 1997 UBC or a more recent edition of the IBC. Further, the cited code might only be required for buildings taller than three stories. Thus the BCP’s influence is immediately limited by current bylaws, not supported by them.
- Local bylaws regulating design and construction and national bylaws regulating professional practice appear to be in conflict. While the local bylaws fail even to mention the BCP, the national rules require its use. This reflects the emphasis of local bylaws on design certification by professional consultants, as opposed to design approval by public officials.

These lessons indicate how the content of local bylaws relates to their implementation.

Table 1. Structural and earthquake design codes cited by various bylaws

| Jurisdiction and Bylaws reference | Building codes and standards cited | Scope and applicability | Specific exemptions |
|---|---|--|--|
| National, “Conduct and Practice of Consulting Engineers” (PEC, 2008a) | BCP | “Engineering design of buildings, building-like structures and related components” | None |
| National, “Construction and Operation of Engineering Works” (PEC, 2010) | BCP | “Engineering design of buildings, building-like structures and related components” | Projects valued at less than four million rupees |
| Islamabad (CDA, 1993) | None | Residential buildings | None |

| Jurisdiction and Bylaws reference | Building codes and standards cited | Scope and applicability | Specific exemptions |
|---|--|--|---|
| Punjab province model regulations intended for adoption by local development authorities (Punjab, 2007) | UBC 1997, IBC 2006, ACI 318-99 | All "multi-story" buildings (at least 3 stories or 38 ft tall), including those built by government agencies | Small agricultural buildings, temporary buildings |
| Lahore (Punjab Gazette, 2008) | Adopts Punjab model regulations | | |
| Rawalpindi (RDA, 2007) | Adopts Punjab model regulations | | |
| Karachi, except for cantonment (SBCA, 2013) | "[C]urrent Uniform Building Code (UBC) and American Code or British relevant Code or any other Code" | All buildings | None |
| Karachi Defence (DHA, 2011) | "[C]urrent Uniform Building Code ... and American Code or British relevant Code or any other Code" | All residential buildings. All commercial buildings "higher than G+2 floors." All "amenity buildings." | None |
| Peshawar (PUDB, 1985) | None | "Commercial, industrial and public buildings" larger than 500 sq. meters or taller than 13 m | None |
| Quetta (Quetta, 1937) | Building Code for Quetta Municipality, 1937, with amendments | All buildings | None |

Implementation in practice

The 2007 BCP is widely recognized as a major step forward for earthquake engineering practice in Pakistan. If it has not yet had a major impact on risk reduction, and if its future impact is limited, the reasons will fall in several categories related to the code itself, professional expertise, formal adoption, and implementation.

- As described above (and itemized below), the current code is an amalgam mostly of recent (but not current) American codes and standards. While reflective of leading practices in place in Pakistan in 2007, it does not focus on specific characteristics of Pakistani construction, it might be un-conservative with respect to the presumed seismic hazard, and it lacks provisions for mitigating risks posed by existing buildings. But all these issues can be addressed through continuing research and regular revision cycles. Certainly Pakistan's academics and practicing engineers, including several interviewed for this report, are motivated to update and enhance the code (TCDPAP, 2007; Gilani, 2013).
- As a new document, the BCP provisions might be unfamiliar to some engineers, builders, and regulators, leading to ineffective or inconsistent application. But this is merely a learning curve issue; the situation will improve with time. Indeed, the universities have been teaching the codes referenced by the BCP for years already, and their graduates have been applying its concepts on real projects (Lodi et al., 2013). Professional development among motivated practitioners, facilitated by communications tools far newer than the code itself, can bridge any anticipated education gap.
- The code cannot be effective where it is not adopted or not applied. As shown above, six years after publication the BCP is still not cited in the bylaws of any jurisdiction, and the codes that *are* cited are waived for most

buildings up to three stories. This is a fundamental gap in application, but with organizations like the Planning Commission, PEC, NHA, and NDMA as solid supporters of the BCP, it's a gap that could be filled through straightforward legislation and revision of model bylaws. Alternatively, if the involvement of a licensed engineer on smaller projects is still considered economically infeasible, specialized or simplified design guides can perhaps be produced to encourage code-based designs for common engineered structures. Perhaps this is what NDMA has in mind for the US\$10M program it describes in its recent plan to "enforce the building code" through "preparation of guidelines for housing construction in the areas vulnerable to disasters" (NDMA, 2012b, Table 10).

But the most important issues involve implementation within Pakistan's challenging legal and economic context. Simply, a building code cannot be effective if implemented through bylaws that are routinely ignored, skirted, or violated. That this happens is not news to Pakistan's citizens or engineers. Shortly after the 2005 earthquake, the *Dawn* newspaper ran a series of articles highlighting obsolete bylaws in Quetta and Islamabad, feckless inspection in Lahore, dangerous buildings in Karachi, inadequate DA staffing in Peshawar, and violations and bribery in Faisalabad and Hyderabad (*Dawn*, 2005).

The problems are recognized by public officials as well. Indeed, most DAs have bylaws for "regularization" of discovered violations, and some maintain full time offices to remove or improve squatter communities known as *katchi abadis*. Sindh province even implemented a one-time amnesty program for building control violations (SBCA, 2013). The national government's own 2007 DRM framework, produced in the same post-earthquake period as the 2007 BCP, put Institutions and Legal Arrangements at the top of its priority list. It called for a strategy to implement building codes but also characterized that implementation as a "major challenge:"

The urban housing and infrastructure suffers from lack of implementation of building codes. The mushrooming of slums and urban poverty has further compounded unsafe construction practices. Even a city like Quetta that was devastated by an earthquake in 1935 doesn't follow safer construction practices. Reasons lie in lack of political will, business interests, corruption, lack of information and trained man-power. ... Pakistan lacks application of building codes for construction of housing and infrastructure in hazard prone areas. This could be attributed to lack of political will, lack of trained construction workforce, lack of monitoring and evaluation mechanisms, corruption, and apathy. (NDMA, 2007, p7; p15)

Corruption, often in the form of bribes or "speed money" to expedite approvals or ignore violations, has enabled a variety of illegal practices directly and indirectly linked to the quality of construction (Dowall and Ellis, 2007; Inskip, 2011; Aziz, 2013). These include:

- Land grabbing, often by so-called "land mafias," who simply claim an open plot, or raze an existing structure, then build without oversight, sometimes relying on a corrupt regularization process to obtain permits after the fact (Hanif, 2007; Inskip, 2011).
- Building more than the approved design, either by extending the structure in plan (in violation of setback requirements) or building additional stories (Saleem, 2010). Usually the motivation is to increase the floor area, but other violations have been noted. Substantial water tanks built into the structure without approval are suspected to have played a role in the collapse of one of the Margalla Towers in the 2005 earthquake, the only major collapse in Islamabad (Kayani, 2013).
- Changing the building use during or after construction (High Court Balochistan, 1997). This allows a developer to qualify for certain design allowances when seeking approvals, then sell or lease spaces for more lucrative commercial uses. In doing so, the design live loads might change, and masonry partitions might be moved or added, changing their effect on building mass and story stiffness (Badrashi et al., 2010).
- Ignoring details on the construction documents. Detailing of steel reinforcing bars in concrete structures can be expensive when done properly but is hidden once the concrete is in place, making it easy for unscrupulous builders to cut corners.

To be sure, not every violation of the bylaws, with or without “speed money,” results in an unsafe building. In fact, practicing engineers report that they are sometimes commissioned to produce two safe designs and two sets of plans, one of which (they suspect) will be used to secure permits, while the other is used to guide the actual construction (High Court Balochistan, 1997, p4; Lodi et al, 2013; Basit, 2013). Still, the corrosive effect of corruption is not just obvious to the layman, but documented. Multiple studies have shown that where corruption thrives, new or additional regulations are ineffective (Kenny, 2009). Ambraseys and Bilham (2011) have shown that perceived corruption correlates with earthquake deaths; over the last three decades, countries that are more corrupt than their national income would predict, including Pakistan, have suffered 83 percent of all earthquake deaths worldwide.

Further, corruption limits the effectiveness of mitigation by prolonging ignorance and uncertainty and by negating the benefits of regulation that would otherwise accrue over time. Thorough codes and standards are valuable at least in part because of the record they provide when applied consistently. Without that record, without knowing what is actually being built, one cannot apply some basic tools of earthquake risk reduction – inventory, loss estimation, structural evaluation, and retrofit.

And corruption, or ineffective regulation generally, continues in part because there is no market for reliability or accountability. One indirect effect of strong regulation and documented compliance in countries like the U.S. is that it lets stakeholders determine where to place blame, or whom to sue. But in Pakistan, some have asserted, buildings are not thoroughly insured, so claims and lawsuits are few, so there is less demand for a full accounting of the design and construction defects when failure does occur, so there is no pressure on regulators to ensure accurate records (Inskeep, 2011, p208). For rare failures like the Margalla Towers in 2005, investigations are made, and the findings might even become public, but they do not lead to changes in regulatory practices (Khan, 2010; Kayani, 2013). And the cycle continues from there: if corruption inhibits insurers’ confidence in the quality of construction, they might never enter the market (Kenny, 2009, p19).

But corruption is not a problem that a short-term DRR intervention can solve. As many interview subjects noted, corruption and legal opportunism are endemic in Pakistan, affecting far more than building design and construction. Though unfortunate, they are part of the culture, and “everyone’s fault.” In all likelihood, substantial change will require not just procedural improvements in civil service rules and legal accountability, but generational changes in attitudes about health and safety, social equity, and the rule of law. Meanwhile, the question is whether any systemic attributes of the regulatory process might be identified as especially in need of reform.

In its 2007 plan, NDMA’s strategy was to involve a consultation process with “relevant agencies.” The idea of working with local governments showed self-awareness and foresight, since proposals for reform will need to respect the institutional cultures of development authorities as agencies historically separate from even District and Municipal DMAs. But six years later, the plan to use NDMA’s National Institute of Disaster Management to execute that outreach has published no results, and the NIDM website, while heavy on response and preparedness, lists no DAs among the target audiences for its training sessions. The site indicates only one workshop on earthquake mitigation, in March 2010 (NDMA, 2010).

So improving implementation of building control regulations remains a “major challenge.” But our review of existing bylaws and implementation measures did find two differences between Pakistani and American practice that might be significant.

First, as noted above, local bylaws for structural design emphasize certification by the owner’s consultants, as opposed to approval by the development authority on behalf of the public. The ultimate intent is the same – compliance with applicable codes and bylaws – but the shift in responsibility and accountability suggests an unfortunate “hands off” approach by the one agency charged with representing building users: potential tenants, neighbors, patrons of the building’s shops, emergency responders who might have to fight fires or perform search and rescue in the building, or just anyone who happens to be inside it when the earthquake comes. This is not to suggest that DA officials and plan checkers never care about safety, only that the bylaws encourage them to measure compliance by affidavit, not by calculation or test. For example, of the hundred pages in the Punjab model bylaws, twenty-four are given to forms and certificates, including template affidavits both to undertake the design and to withdraw from the design team. Four different “structural stability certificates” collect the engineer’s signature and license number at various stages of construction, but none records the actual design criteria, design calculations, material test data, or numerical proof of compliance (Punjab, 2007a).

Second, the development authorities that enforce the bylaws act both as regulators and as developers, approving submittals for private sector projects but also planning, designing, building, and maintaining public projects. Mingling regulatory and development functions can lead to a potential conflict of interest, since a regulator tends to seek sometimes costly or time-consuming quality assurance, while a developer tends to prefer minimal soft costs and less regulation. When both functions are performed by the same agency, the regulatory effort will suffer if development is prioritized. Further, a DA might be comfortable, as an owner-developer, with its own established practices, not seeing the need for complicated new standards. A similar conflict exists with some public agencies in the U.S., but they tend to control relatively few buildings within any city. DAs in Pakistan, by contrast, are among the largest urban landowners and are the primary developers of urban and suburban housing (USAID), so their influence is pervasive.

These circumstances tend to make earthquake safety in Pakistan a question of professional conduct (for private development) or economic expedience (for public works) rather than a priority of public policy. Professionalism and economic progress are important, but building control regulations – especially those that consider natural hazards that affect whole regions at once – represent public policy and need to serve the general welfare. As the High Court Balochistan expressed it in confirming the applicability of the then 60 year old *Building Code for Quetta Municipality*, “The entire population of Quetta cannot be allowed to be put in danger for the benefit of few builders who are constructing plazas and multistoreyed buildings as against provisions of Building Code, 1937” (High Court Balochistan, 1997).

Certainly these two conditions – over-reliance on certification and conflicting priorities – do not explain Pakistan’s code implementation problems by themselves. But if they are significant factors, their effects might be tempered with relatively simple procedural changes (**See recommended activities 1 and 4**):

- The Ministry of Housing and Works, which publishes the BCP, could commission a series of design review checklists to accompany the code. The checklists would be completed by development authority officials and kept with project records. In substance, more paperwork is no substitute for careful vetting of calculations, but such tools (if they are not already in use by the leading DAs) would at least provide a consistent means of tracking submitted calculations and would perhaps shift some accountability from the designer to the DA. After the 1995 Kobe earthquake, Japan made a similar shift. If necessary, legislation could provide some immunity to the DA staff in exchange for the added responsibility. NESPAK has already produced a checklist for its own use on earthquake reconstruction projects that might serve as a model; the three-page checklist simply asks in a yes/no format whether certain specific code provisions are addressed in the construction documents (NESPAK undated-e).
- Each DA could (if they don’t already) separate staff that regulates private construction from staff that administers DA development projects. More important, the regulatory staff could be incentivized with measures of project compliance, as opposed to project completion. On its face, such a proposal would appear to add even more fragmentation to the country’s infamous bureaucracy, where securing development and construction permits can take up to a year and involve a stack of forms (not to mention bribes) submitted to a dozen or more authorities (Dowall and Ellis, 2007, p37). On the other hand, development agencies in the larger cities appear already to be in a constant state of reorganization, and a clean separation of regulation from development could offer the opportunity to consolidate certain functions as well. In any case, organizational change is never popular.

Finally, returning to the observation that corruption nullifies regulation, it may be that for the short term at least, the most effective risk reduction strategy regarding codes and bylaws is to empower enlightened owners and project funders to do as much of their own quality assurance as possible.

BCP revision and update

The 2007 BCP, as well as the professional practice bylaws that cite it, calls for an update every five years, so the first update cycle is already overdue. When the update process does begin, stakeholders should have the opportunity to correct errors, replace outdated reference standards, and add new provisions suited to Pakistan’s building stock and

construction practices. The update process might consider the following issues, among others³ (**See recommended activities 3 and 4**).

- Provisions for existing buildings. Interestingly, the 2007 BCP, though based on the 1997 UBC, does not include that model code's Chapter 34 for Existing Structures. Instead, the bylaws described above all contain provisions for eliminating imminently dangerous conditions. They also have basic provisions covering proposed additions, alterations, repairs, and changes of occupancy, but the provisions are almost entirely procedural. That is, they might require a permit or outline an approval process, but they say little about the degree of alteration, for example, that might be allowed within the existing building before unintended improvements are required. In other words, the bylaws lack the sort of triggers that current model codes use to regulate existing buildings. (The 1937 Quetta code is more substantive on these points.) Not surprisingly, the current bylaws also do not cite any reference standards that specifically deal with structural or seismic evaluation or retrofit of buildings with archaic or non-conforming conditions. Thus, they provide practically no policy or technical guidance for earthquake risk reduction.

When the BCP is updated, provisions with more substantive triggers, scopes, and criteria might be added. However, provisions from the current U.S. model codes (the 2012 or 2015 *International Existing Building Code* or Chapter 34 of the 2012 *International Building Code*) might not be a good fit for all of Pakistan at this time. The question in drafting existing building provisions is how to calibrate the seismic upgrade trigger: too lenient a trigger misses a rational opportunity to improve performance, but too harsh a trigger discourages building improvements and encourages work without permits. In Pakistan's major cities, where violations are routine and buildings are sometimes constructed from the ground up with no permits and no connection to infrastructure, it is folly to think that an owner would seek permits for a small addition or alteration just because a new bylaw requires it. One important purpose of an existing building provision – to trigger upgrades when the life of a building is extended – is thus lost. What remains is the opportunity to at least bring existing buildings into a regulatory process in order to correct egregious violations and to ensure some minimal oversight for the work that is going to be done regardless. Upgrade triggers could be set aside, and the scope of engineering work could be set simply to ensure that the proposed alteration, addition, or change of occupancy would not *increase* earthquake risk. Possibly, for certain buildings, a seismic evaluation or documentation could be required, but retrofit would remain voluntary. Such an approach could follow, as a model, current bylaws and amnesty programs for regularization of existing violations. In addition to avoiding increased risk, the goals would be to build trust and increase confidence for both owners and regulators.

- Coordination with bylaws. The 2007 BCP also does not incorporate 1997 UBC Chapter 1: Administration. This is appropriate, since building control bylaws generally cover the topics in that UBC chapter. Clarity and coordination could be improved in a BCP update, however, by providing model bylaws that ensure proper coordination between typical bylaws and the BCP as a referenced code. For example, if the BCP is intended to be referenced from local bylaws, those bylaws should include the scope material currently in BCP chapter 1, as well as new provisions clarifying application to existing and temporary buildings, work exempt from seismic design, and submittals relevant to earthquake design. As described above, a set of checklists to assist a DA official in confirming that the BCP has been properly applied could improve code implementation.
- Switching to the IBC. By design, and with permission, the 2007 BCP reprints large sections of the American codes and standards it relies on. In general, this will aid both the designer and the DA official by providing all the applicable requirements in a single volume. However, there are places where the BCP refers to other documents, such as material standards, that it does not reprint. If these are not readily available, users of the BCP might be discouraged from following those provisions. For example, BCP Chapter 8 refers to a separate AISC document and to several AISC 341-05 appendices that contain important quality assurance provisions.

This issue will become more acute if, as expected, the next version of the BCP drops its reference to the obsolete UBC and switches to the IBC, whose structural criteria rely almost entirely on separate reference standards. One reason the IBC does this is that it became impossible to do what the 2007 BCP tries to do: include everything in a

³ A complete review of the 2007 BCP is outside the scope of this report. This list is intended only to give a general sense of issues raised during the document review and interviews performed for this report. These should not be understood as code change proposals.

single volume. Pakistan's stakeholders will have to decide how best to balance the use of current standards with the convenience of an all-in-one volume. One approach worth considering would be to use the American model as a general code (that is, the BCP would adopt and amend the IBC and refer to separate reference standards as it does) but produce a more convenient standalone version to address only concrete structures, which continue to dominate construction in Pakistan.

- Concrete frames with masonry infill. Concrete moment frames with unreinforced (or nominally reinforced) brick or block infill are ubiquitous in Pakistan. Because these are not common structure types in the United States, however, the U.S. codes cover them only in general. The most applicable provisions from the 1997 UBC appear in the 2007 BCP as well, but again only in general terms in Chapters 5 and 10, not with material-specific guidance in either Chapter 7: Structural Concrete or Chapter 9: Masonry. The key provisions are:
 - Section 5.33.2.4.1 allows the relatively flexible concrete moment frame to be “enclosed by or adjoined by” (or, presumably, infilled by) more rigid elements such as masonry panels, as long as “failure” of the masonry does not impair the performance of the frame.
 - Section 10.2.3 requires that the effect of adjoining architectural components on the structural system be considered in the design of both elements.

Aside from these general rules, the BCP gives no quantitative provisions about how to analyze or design these potentially complex interactions, and conventional practice even among leading engineers in Pakistan has been to (improperly) ignore any effects of the masonry on lateral response (Lodi et al., 2013; Sharif et al., 2011). Recently, however, outreach efforts have developed educational materials and offered training on so-called “framed infill” (Rodgers and Deierlein; GHI-NED). Though focused on identifying deficiencies in existing buildings, the same ideas could be converted to design provisions or prohibitions for new construction and added to BCP Chapter 5. Such provisions, perhaps with commentary, could describe how to:

- Characterize a framed infill system's R value and other design parameters
 - Estimate story and wall line stiffness, and its effects on building period
 - Identify torsional and vertical irregularities related to the location of stiff masonry panels
 - Model the interaction between concrete frame and masonry infill as needed to comply with Sections 5.33.2.4.1 and 10.2.3
 - Detail the infill where it abuts the concrete
 - Predict or quantify the expected failure.
- Light gage steel partitions. Brick and block masonry remain the dominant materials for perimeter enclosures and interior partitions in Pakistan's concrete structures. This is a function of the region's history and economics (Inskip, 2011, p92), but the masonry no doubt remains popular also because of its thermal properties, given Pakistan's often extreme climate. Nevertheless, as engineers begin to consider the effects of this traditional construction on structural earthquake response and nonstructural earthquake risk, not to mention the simple availability of new and better materials from abroad, light gage steel partitions might become competitive or advantageous. The current BCP, because it has no chapter for wood construction, also has no provisions for light gage steel framing. The updated BCP might consider referencing standards for light gage steel design and detailing. NESPAK (undated-b) has done some preliminary research in this regard.
 - Material properties. Many design equations in the American codes adopted by the BCP are empirical; they apply only when the structural materials comply with specific reference standards. Products typically used in Pakistan might not meet those standards (Lodi, et al., 2013), so the BCP might need to adjust the empirical equations or add provisions constraining design assumptions regarding structural materials.
 - Seismicity. The 2007 BCP uses 1997 UBC parameters to define seismicity by zone, with tabulated values for every tehsil. However, the BCP zones differ from those specified in 1997 UBC Appendix Chapter 16. Both codes assign Lahore to Zone 2A, but while the BCP assigns Islamabad, Karachi, and Peshawar to Zone 2B, the UBC lists each of those cities as Zone 4. The lower zonation of the BCP reflects the engineering criteria used by leading Pakistani firms over the previous two decades. For Karachi at least, the assignment to Zone 2B was thus not a change relative to the UBC so much as a reluctance to follow the UBC's increase (Bilham et al., 2007).

The UBC allows for seismicity reductions based on “consideration of regional tectonics and up-to-date geologic and seismologic information” (ICBO, 1997, p2-404). Bilham et al. (2007) describe two more recent efforts to map the country’s seismicity: one by the Global Seismic Hazard Assessment Program (GSHAP, 1999) and one that resulted in the 2007 BCP seismic zone map. Both are necessarily imperfect, but the two together show differences that should be resolved at least for policy purposes in the next BCP update. In particular:

- The GSHAP map suggests higher seismicity than the BCP map along and south of the corridor between Peshawar and Islamabad.
- The GSHAP map and Bilham et al. (2007) both suggest that the BCP map underestimates seismicity along the coast south of Karachi. The latter note that the codified seismicity for Karachi and environs should almost certainly be higher than Zone 2B, despite the lack of recent large events there.
- In southwest Pakistan, where Balochistan province borders Iran, the GSHAP map shows significantly higher seismicity than would be indicated by the BCP map, which zones this area as 2A or 2B. The April 16, 2013 M7.7 earthquake in this area shook buildings enough to prompt evacuations in Karachi almost 400 miles away. This event produced peak ground accelerations of about 0.24g along the Iran border (USGS, 2013), yet the closest parts of Pakistan are all mapped as Zone 2A, where the 500-year peak ground acceleration is expected to be only about half as high.
- Prescriptive engineered design. Section 9.9 of the 2007 BCP masonry chapter provides prescriptive criteria for small residential buildings. Since then, a number of newer guides and manuals have been produced, so it would be especially useful if the updated BCP were to clarify (perhaps in commentary) whether any of these newer documents is considered equivalent or “deemed to comply” with Section 9.9. (Some of these newer documents are described in the following section on mitigation measures.)
- Flood design. The 2007 BCP has no provisions for flood-resistant construction. The updated BCP might incorporate some of the findings and recommendations produced in response to the 2010 and 2011 flood disasters.
- Importance factors and resilience-based design. The 2007 BCP mostly relies on the 1997 UBC but also lists ASCE 7-05 as a resource document. Among the differences, ASCE 7-05 applies different importance factors (I values). The BCP is consistent with the UBC, but based on priorities expressed by NDMA and others, Pakistan agencies and jurisdictions might prefer ASCE 7’s higher importance factor for school facilities, $I = 1.25$ for Occupancy Category III, as opposed to $I = 1.0$ for Occupancy Category 3 in the 1997 UBC (Table 16-K) and 2007 BCP (Table 5.10). (Terminology differences might also be resolved to reduce confusion. The UBC/BCP Occupancy Categories range from 1 to 5, with 1 for Essential Facilities, while the ASCE 7 Occupancy Categories range from I to IV, with IV for Essential Services. The IBC uses the ASCE 7 terminology, which changes to Risk Category in ASCE 7-10 and the 2012 IBC.)

This issue will be moot if the updated BCP adopts the IBC as a model code. Even so, the IBC and ASCE 7 continue to treat most occupancies, including housing, shops, offices, and even small schools or care facilities, as non-essential, meaning that damage should still be expected, and re-occupancy might be substantially delayed. If the BCP is to become a mainstreamed instrument of resilience-based mitigation (see the discussion of risk reduction programs in the next section), this approach might need to change. Many subjects interviewed for this report, especially DRM professionals who are *not* engineers, expressed the need to protect not just lives, but livelihoods. To do that, some enhanced design criteria might be needed. The model building codes do this largely through the use of importance factors and more thorough construction quality assurance. Whether to seek better performance from buildings traditionally deemed “non-essential” would be a policy decision, but it could find expression in, and would need to be supported by, the building code.

In addition, a BCP update should correct certain errors and inconsistencies in its references to the 1997 UBC, if these are not made moot by a shift to the IBC model code. These include:

- BCP Chapter 6 generally follows UBC Chapter 17 for tests and inspections, but modifies it in places by grouping Zone 2 with Zones 3 and 4. This modification is not made, however, in the concrete and masonry chapters. If the intent of Chapter 6 is to require the higher degree of quality assurance even in Zones 2A and 2B – which, significantly, include Islamabad, Lahore, Peshawar, and Karachi – the modification should be made throughout the code.
- BCP Chapter 9 misses some significant errata published for the 1997 UBC in 2001. For example, BCP Section 9.8.2.5.6 calls for $R = 1.5$, but the 2001 errata corrected this to $R = 1.1$. The change could make a significant difference in boundary member reinforcing for masonry shear walls. Similarly, in Section 9.8.2.6.2 item 3, $R_w = 1.5$ should be changed to $R = 1.1$.
- BCP Tables 10.1 and 11.1 give design criteria by Occupancy Category for architectural, mechanical, and electrical components. Presumably these criteria are adopted from ASCE 7-93. However, as published, the criteria are less conservative for Occupancy Category 1, Essential Facilities. This appears to be in error, possibly due to terminology differences between the UBC and ASCE 7.

Part 2. Earthquake Risk Reduction Measures

Earthquake risk reduction means more than retrofit. In fact, the first and most important step for Pakistan might not be to reduce the current risk, but to stop adding to it. In the short term, effective risk reduction measures are likely to include best practices for new construction, including capacity building for regulators and owner-builders, and selective retrofit for essential facilities. But the long-term strategies need to begin now as well, applying resilience-based thinking to traditional planning tasks such as inventories and loss estimation, already begun.

The risk reduction context

Earthquake risk reduction, or mitigation, is multi-faceted. While the process is straightforward – identify your risk, quantify it, reduce it – the most appropriate priorities and strategies will vary with circumstances: What is the nature of the potential loss, who is vulnerable to it, how does the mitigation benefit compare with the cost, what are the opportunity costs of planning for rare events, etc. Thus, while cities, neighborhoods, institutions, and even individual households can all address their own risks, there will be no single approach that suits all of them. The best mitigation measure for an institution, like a university or a housing complex, might have no relevance to a family across town or to the city as a whole. Scale and context are important in judging effectiveness.

This report considers the municipal or provincial context and addresses risk reduction measures primarily from a public policy perspective. From this perspective, the key issue is not how individual building losses might affect specific owners and tenants, but how aggregated losses, and aggregated effects on people, will affect the city's ability to function. Within this context, risk reduction efforts will generally take the form of programs, not individual projects.

From the perspective of an individual owner, earthquake risk reduction is often straightforward: simply retrofit the structure, or brace the nonstructural components, or buy insurance, or make a continuity of operations plan. From the public policy perspective, risk reduction involves more comprehensive planning and balancing of interests. The sections that follow therefore address the broad steps toward city- or region-wide risk reduction: inventory and risk assessment, resilience-based planning, and retrofit prioritization.

New thinking on earthquake risk reduction is resilience-based (SPUR, 2009; Bonowitz, 2012). That is, it supports mitigation and it measures success in terms of citywide resilience or recovery – whether key service sectors return to functionality within acceptable timeframes. It captures what DRM professionals mean when they speak of protecting livelihoods as well as lives. Still, while resilience-based DRM is a useful approach for Pakistan, and one advocated both in the Hyogo framework and the new National Disaster Management Plan (NDMA, 2012b), it is perhaps still something of a luxury reserved for the most developed and DRM-savvy countries. In developed countries, in cities like Los Angeles, Tokyo, or Wellington, it makes sense to worry about dollar and downtime losses, because what can be done to minimize deaths has almost all been done already; more focus on life safety, while vital, has marginal benefits at the city scale. In Pakistan, however, where the 2005 earthquake killed 73,000 people, and where reasonable speculation about a Karachi earthquake involves five or ten times that number (Berlinski, 2011; Abid, 2012), the resilience of commerce and industry seems secondary. For the short term, Pakistan's major cities, like Tehran, Manila, Istanbul, and other world capitals, would do well just to focus on life safety and the basics of response.

Nevertheless, long-term thinking is necessary too, and it needs to begin now. Without it, even great short-term successes might only move Pakistan from the list of countries with the deadliest earthquakes to the list of countries with the costliest earthquakes.

New and replacement structures

New construction is not normally thought of as a risk reduction strategy, but it applies in Pakistan's case in the sense that improvements in standards for new construction represent a reduction relative to the risk that would have *increased* otherwise. This is because even when the country is done rebuilding after the 2005 earthquake and the 2010 and 2011 floods, its cities will still be growing to accommodate staggering levels of rural-to-urban migration. Nearly every subject interviewed for this report, when asked whether an emphasis on retrofit or on new construction would most reduce risk, urged to focus on new construction (Gilani, 2013; Basit, 2013; Lodi et al., 2013). With rampant urban growth, old and substandard buildings, and even relatively new ones, are already being replaced regardless of their earthquake risk; if the

new and replacement buildings are not done right, they will only lengthen the list of buildings eventually needing retrofit.

So Pakistan’s first earthquake risk reduction challenge, paradoxically, is not to reduce risk, but to stop increasing it. How to do this? By consistently applying adequate standards for new engineered and non-engineered buildings.

The 2007 BCP, though already slightly out of date, represents the current standard for new engineered buildings in Pakistan. As discussed above, however, its effect on risk reduction is severely limited by conflicting references in national and local bylaws, by gaps in application to small buildings, and by inadequate implementation by local development authorities. Fortunately, a variety of alternative prescriptive guidelines were developed in response to the 2005 earthquake. Applied by NGOs, by government agencies such as the new Earthquake Reconstruction and Rehabilitation Authority (ERRA), and by trained owner-builders, these new guidelines fill the gaps and sidestep the worst implementation pitfalls of bylaw-driven design and construction. Tables 2 and 3 summarize some the post-2005 guidelines in roughly chronological order. (Tables 2 and 3 describe the English versions of available documents; in many cases Urdu or other non-English versions have been produced as well, but they have not been reviewed for this report.)

Table 2. Post-2005 guidelines for prescriptive engineered construction

| Title and reference | Scope and intent | Content notes |
|---|--|--|
| Interim Guidelines for Design and Construction of Buildings in Earthquake Affected Areas (ERRA, undated-a) | <ul style="list-style-type: none"> • All buildings and occupancies • Section 12, “Guidelines for Single to Two Storey Housing Units,” considers brick, block, or stone masonry walls structures with seismic bands at plinth, lintel, roof, and gable. | <ul style="list-style-type: none"> • 16-page narrative document with few details • Organized as code or bylaw • Section 12 written as recommended practices |
| Guidelines for Earthquake Resistant Construction of Non-Engineered Rural and Suburban Masonry Houses in Cement Sand Mortar in Earthquake Affected Areas (DRAFT) (ERRA, 2006b) | <ul style="list-style-type: none"> • Brick, block, or stone masonry wall construction with seismic bands at plinth, lintel, and roof • Stated intent: housing • Stated intent: For “government officials, partner organizations, and trainers”; intended as basis for capacity-buildings and training | <ul style="list-style-type: none"> • 34-page explanatory and background document • Organized as technical primer, not as practical step-by-step reference • Appears to be superseded by more direct, usable guidelines • Includes section on site issues • Includes sections on damage assessment, repair, and retrofit |
| Few Recommendations for Single Storey Masonry Houses in Cement Sand Mortar (ERRA, 2006c) | <ul style="list-style-type: none"> • Brick, block, or stone masonry wall construction with seismic bands at plinth, lintel, and roof • 1-story with pitched lightweight wood or metal roof • Stated intent: housing | <ul style="list-style-type: none"> • 1-sheet (front and back) poster or illustrated handout • Organized as practical reference; quasi step-by-step procedure • Uses same source material and illustrations as ERRA, undated-a, but in more concise, practical presentation |

| Title and reference | Scope and intent | Content notes |
|---|--|--|
| Field Practicing Manual (EEC, 2007) | <ul style="list-style-type: none"> • Brick and stone masonry wall construction with seismic bands at plinth, lintel, and roof • No occupancy limits stated • Rectangular plan up to 4:1 • No height or area limits, but 2-story building illustrated • Stated intent: For use by engineers, contractors, and masons | <ul style="list-style-type: none"> • 30-page English version of illustrated guide first published in February 2006 • Includes chapter on material quality control • Organized as practical reference; quasi step-by-step procedure • Does not distinguish between confined masonry and infilled frame; sequence shown as concrete frame first, infill masonry second; unlike recommended practice for confined masonry |
| Compliance Catalogue: Guidelines for the construction of compliant rural houses (ERRA, 2007b) | <ul style="list-style-type: none"> • Brick and block masonry with reinforced concrete bands at plinth, lintel, and roof • Confined masonry • Stated intent: housing • Rectangular plan up to 3:1 • Room dimension up to 15 ft • 1-story w/ pitched timber roof • Stated intent: For use by engineers, trainers, advisors, planners • Not for use by masons or owner-builders | <ul style="list-style-type: none"> • 120-page summary of poster reference guides; includes 1-page versions of posters • Organized as dos and don'ts • Includes section on site selection • Includes section on site improvements (retaining, etc.) • Includes section on material quality control • Includes section on retrofitting and correcting common defects, with details and procedures • Includes sections on traditional construction (see below) |
| Confined Masonry: An illustrated guide for masons (SDC, 2007a) | <ul style="list-style-type: none"> • Confined masonry construction with concrete bands at plinth, window sill, and door lintel, plus bond beam at roof bearing • Not for infilled concrete frames • One story building shown, with pitched roof or concrete flat slab roof • Housing or shops; includes section on storefront condition | <ul style="list-style-type: none"> • 16-page illustrated guide • Organized as practical reference; quasi step-by-step procedure • Does distinguish between confined masonry and infilled frame |
| Easily Understandable Guidelines on Earthquake Safer Construction (Confined Masonry) (Ali, 2009b) | <ul style="list-style-type: none"> • Brick or block confined masonry with seismic bands at plinth, lintel, and roof • Zone 3 or 4, with relaxed requirements for Zone 2 • No occupancy limits stated • Rectangular plan up to 4:1 • 1- or 2-story | <ul style="list-style-type: none"> • 40-page illustrated guide, update of EEC, 2007 • Includes chapter on material quality control • Organized as practical reference; final section illustrates construction sequence • Does distinguish between confined masonry and infilled frame |

| Title and reference | Scope and intent | Content notes |
|--|---|--|
| Technical Specification for masonry house in flood affected areas (seismic zone 2B and lower) (UN-HABITAT, 2010) | <ul style="list-style-type: none"> • Brick, block, or stone masonry wall construction with seismic bands at plinth, lintel, and roof • Stated intent: housing • Rectangular plan up to 3:1 • Room dimension up to 14 ft • 1-story w/ pitched timber or bamboo roof or flat mud or concrete roof on steel girders | <ul style="list-style-type: none"> • 7-page document w/ engineering drawings • Organized as tabular listing of materials and requirements by element (roof, walls, bands, etc.) • Includes guidance on site selection • Includes engineering details, no step-by-step guidance |
| Earthquake Data Manual (OPP, undated) | <ul style="list-style-type: none"> • Reinforced brick or block masonry with seismic bands | <ul style="list-style-type: none"> • 17-page illustrated guide, hand-drawn and handwritten in Urdu • Includes guidance on site selection and landslides |
| Structural Concrete Insulated Panel Construction (SCIP) (NESPAK, undated-c) | <ul style="list-style-type: none"> • Alternative to reinforced concrete wall panels • Compatible with code-based design • Stated scope: "homes and other buildings" | <ul style="list-style-type: none"> • Information sheet only • No design guidance |

Table 3. Post-2005 guidelines for vernacular or traditional construction

| Title and reference | Scope and intent | Content notes |
|--|---|---|
| Bhatar Construction (Timber Reinforced Masonry): An illustrated guide for craftsmen (SDC, 2007b) | <ul style="list-style-type: none"> • Stone masonry with horizontal timber bands; concrete plinth band preferred for durability • No occupancy limits stated • Rectangular plan up to 3:1 • Room dimension up to 12 ft • 1-story w/ pitched or flat roof | <ul style="list-style-type: none"> • 12-page illustrated guide • Includes section on site selection • Organized as practical reference; quasi step-by-step procedure |
| Compliance Catalogue: Guidelines for the construction of compliant rural houses (ERRA, 2007b) | <ul style="list-style-type: none"> • Timber frame (dhaji) construction • Timber reinforced masonry (bhatar) • Stated intent: housing • Rectangular plan up to 3:1 • Room dimension up to 15 ft • 1-story w/ pitched timber roof • Stated intent: For use by engineers, trainers, advisors, planners • Not for use by masons or owner-builders | <ul style="list-style-type: none"> • 120-page summary of poster reference guides; includes 1-page versions of posters • Bhatar material from SDC, 2007b • Organized as dos and don'ts • Includes section on site selection • Includes section on site improvements (retaining, etc.) • Includes section on material quality control • Includes section on retrofitting and correcting common defects, with details and procedures • Includes sections on prescriptive engineered construction (see above) |

| Title and reference | Scope and intent | Content notes |
|--|---|--|
| Leepa: Guidelines for the compliant construction of Leepa-type timber post and beam houses (UN-HABITAT, undated) | <ul style="list-style-type: none"> • Timber post and beam (leepa) construction • Stated intent: housing • Square plan recommended • “Double storey” anticipated; 3-story buildings (G+2) w/ hipped roofs shown • No intended audience stated • Usable for new and retrofit construction | <ul style="list-style-type: none"> • 12-page illustrated guide • Organized as dos and don’ts, with “should” language |
| Recommendations for ERRA approved Dhaji Timber Frame House Construction (ERRA, undated-c) | <ul style="list-style-type: none"> • Timber frame (dhaji) construction • Stated intent: housing • Square plan, 15 ft by 15 ft room • 1-story w/ pitched light metal roof | <ul style="list-style-type: none"> • 1-sheet (front and back) poster or illustrated handout • Organized as step-by-step instructions for single room |
| Recommendations for Timber Frame Houses with Lightweight Roof (ERRA, undated-d) | <ul style="list-style-type: none"> • Timber frame construction, either sheathed and insulated or stone-filled (dhaji) • Stated intent: housing • 1-story w/ pitched light metal roof | <ul style="list-style-type: none"> • 1-page poster or illustrated handout • Organized as practical reference in logical sequence |

Table 2 shows how government agencies, notably ERRA, and NGOs working in Pakistan came to embrace the concept of confined masonry in the years after the earthquake. The important distinction between confined masonry and infilled concrete frames has to do with the role of the masonry. In an infilled frame, the concrete does the work, and the masonry often does little more than interfere; in confined masonry, the bricks or blocks are expected to carry significant structural loads. But proper performance requires the right detailing between the masonry and the confining concrete members, and the right sequence of construction. That idea is clear, if only briefly stated, in 2007 BCP Section 9.9.4.7, but the guidelines produced just after the earthquake were not as explicit about it as they would be later. In any case, a growing consensus about the value of confined masonry (which is also less expensive and less detailing-sensitive than an infilled concrete frame) could make this construction type standard in Pakistan for simple houses over the next few years.

Tables 2 and 3 also illustrate the variety of documents currently available to anyone with access to an Internet search engine. This promotes important and useful information, even if local bylaws require no earthquake design for typical houses. But it might also lead to confusion, since the documents vary, and some are obsolete. A useful project would be to compile lessons and best practices from the programs that have used each of these guidelines, to produce a consensus standard for new confined masonry construction in Pakistan, and then to promulgate the new document and reference it in an updated BCP.

ERRA, the army-affiliated Earthquake Reconstruction and Rehabilitation Authority created days after the 2005 earthquake to manage the rebuilding effort, would seem to be the natural organization to lead such a project. Interestingly, Table 2 also illustrates how ERRA’s approach to its post-earthquake mission evolved. ERRA’s “Interim Guidelines” look and read like a building code: comprehensive, technical, rigidly formatted, and likely not usable by anyone but an engineer. Its 2006 Guidelines were still heavy on narrative and background material but had begun to introduce graphics and to focus on “non-engineered” construction. By 2007, the ERRA Compliance Catalogue was based on a set of well-illustrated and concisely-written posters with practical tips and step-by-step usefulness.

Seven years after the earthquake, ERRA remains a powerful and ambitious agency with plans reaching well beyond its initial urgent mission (ERRA, 2006a; 2007a). Yet it has also been forthcoming and generous, even humble, about lessons learned. A revealing ERRA report spends four pages listing challenges the new organization did not anticipate, as well as its own oversights, missteps, and faulty assumptions (ERRA, undated-b). Among these are several related to the usability of ERRA’s initial guidelines documents and the appropriateness of their initial designs. ERRA’s open-minded response to these challenges resulted in the array of documents listed in Tables 2 and 3, covering a range of structure types and presentation formats.

ERRA's success raises interesting possibilities for earthquake risk reduction going forward. On one hand, ERRA is organization decidedly outside the civilian DRR community, as UNDP observed in its own review of earthquake response:

UNDP's decision to support ERRA ... was relevant in the light of global experience and its own mandate as the leader of the Early Recovery Cluster. However, ... it led to the development of an over-centralized and dependent organization. It did not contribute to the Government's substantive capacity-building on a long term basis. It has also not worked to change the over-centralized nature of ERRA's functional structure which is not consistent with the constitution of Pakistan. If ERRA's centralized approach to recovery and reconstruction continues, it would eventually undermine the provincial and district civilian capacities and would cause delays and further complexities in reconstruction efforts. (Malik et al., undated, p9)

Even so, ERRA is everything that the traditional bylaws-driven process of building regulation and housing development in Pakistan is not: focused on disaster issues, able to withstand political pressure, well-resourced enough to resist petty corruption, open to new thinking (its owner-driven approach, for example), and by most accounts severely competent. It is perhaps noteworthy that the above concern, while reasonable, is entirely about the DRR process, not the product. Given the discussion above about shortcomings in implementation of existing building codes and bylaws, one might ask if ERRA's success could really undermine a system that has already failed.

The idea of creating a new agency instead of mainstreaming DRR through the normal regulatory process is not entirely new or without success. This is precisely what California did when it created two of its leading statewide regulatory agencies, the Office of Statewide Health Planning and Development (OSHPD) and the Division of the State Architect (DSA), to oversee the seismic design and construction of the state's hospitals and public schools, rather than leave those tasks to municipal building departments.

In general, long term DRR and DRM capacity-building should resist the creation of another permanent massive bureaucracy. But if ERRA has the resources, the know-how, and the willingness to spend the next ten years building earthquake- and flood-resistant housing all over Pakistan, the DRR community would no doubt benefit. And when the ERRA building program is done, it will have created a stronger platform for mainstreamed DRR programs. After all, the purpose of mitigation – which replacement housing represents – is to make response and recovery feasible. Using new construction to reduce future response and recovery demands would do just that.

Thus, two top objectives for risk reduction through new construction of the small buildings largely ignored by local bylaws are alignment of the various post-2005 guidelines into a consensus standard for adoption within the BCP, and identification of a DRR-coordinated role for ERRA. In addition, risk reduction in this sector might be achieved by (**See recommended activity 5**):

- Integration of consensus confined masonry standards into planning documents for housing schemes implemented by development authorities or the private sector. Not surprisingly, ERRA has already taken the lead here (ERRA, 2006a; 2007a).
- Promotion of consensus confined masonry standards for new construction and voluntary retrofit of individual houses outside of new planned communities.
- Adaptation and promotion of consensus confined masonry standards for non-residential buildings. The guideline developed by the Swiss Agency for Development and Cooperation has taken the lead here, proposing a simple application for “the shop window problem,” where open first story storefronts would violate the typical rules for minimum wall length and configuration (SDC, 2007a). While useful for shops, offices, and light manufacturing, even high-quality confined masonry might not be appropriate for essential post-earthquake facilities where quick reoccupancy is important, such as hospitals or any public building expected to serve as a shelter or recovery operations center.
- Development of similar prescriptive standards for reinforced concrete houses and non-essential commercial buildings, to fill the gap between the small buildings covered by the masonry guidelines and the code-designed

buildings covered by local bylaws. The idea of a catalog of earthquake-resistant designs covering a range of sizes harkens back to the eight types prescribed in the 1937 Quetta building code (Quetta, 1937, Section 44).

- Development of similar prescriptive standards for multi-family housing. This will be a bigger challenge, but it would seem to fill a growing need. Of course there is already a great deal of multi-family housing in Pakistan's cities, but its seismic capacity is likely inadequate (see the discussion of retrofit below). Multi-unit buildings should already be covered by local bylaw requirements for engineered design, but implementation problems might interfere. The thought here is that the systematic approach, the focused resources, and the lessons learned by ERRA on reconstruction of single-family homes and communities might be effectively applied to this class of buildings. To be clear, however, multi-family housing probably would not be feasible with the owner-driven approach ERRA has successfully endorsed for smaller houses. **(See recommended activity 2)**

Inventory and risk assessment

The first step in planning earthquake mitigation, especially at a city or regional scale, is to inventory the existing stock of buildings and infrastructure. The simplest inventory is a count of buildings that separates types known or suspected to have different performance characteristics. Such a count is enhanced when each building type is characterized by a fragility curve that estimates its damage state, given a level of earthquake shaking. A risk assessment combines the inventory of physical assets – the exposure – with representations of the known earthquake sources – the hazard.

There is a tendency sometimes to over-inventory – that is, to make distinctions between building types that are far finer than our understanding of either the earthquake hazard or the implications of damage – but some quantitative inventory is certainly important. For resilience-based planning, it is equally important to inventory the occupancy or function housed by each building, since recovery of services is as much a metric as damage or human toll. Inventories can be further enhanced by location data, especially when the hazards and implications involve location-specific effects such as landslide, liquefaction, a known fault trace, access roads, etc.

From this perspective, the inventory and risk assessment in much of Pakistan appears quite advanced, with much work accomplished since the 2005 earthquake.

On the hazard side, the Pakistan Meteorological Department, generally working with consultants, has produced seismic hazard data and maps for Islamabad and Rawalpindi (NORSAR, 2006), Quetta (NORSAR, 2012), and the entire country, including Azad Jammu and Kashmir (PMD, 2007).

Building inventories have also been done in a thoughtful way, making important distinctions to account for known deficiencies in common building types:

- Maqsood and Schwarz (2008; 2011) created inventories at the tehsil level based on 1998 census data, field surveys, and damage surveys after the 2005 earthquake and the 2008 Baluchistan earthquake. As their purpose was to assign common structure types to vulnerability categories using the European Macroseismic Scale (EMS), they did not consider occupancy. They have also studied Muzaffarabad at a finer level, considering individual buildings. With a vulnerability model, they simulated the 2005 earthquake and found that their initial model slightly over-predicted damage to the typical building but far under-predicted the rate and incidences of collapse (Maqsood and Schwarz, 2008, Figures 7-8). The authors attribute the discrepancies to simplistic assumptions in their preliminary models.
- NDMA has produced scenario studies involving inventories and loss estimation for Mansehra and Muzaffarabad, two cities that experienced heavy damage in the 2005 earthquake (NDMA, 2009a and 2009b). This was followed by a similar study of the resort town of Murree (NDMA, undated). For each city, a multi-month effort by engineering students and university staff produced inventories for each city at a building level. A loss estimate followed the EMS procedure involving assignment of each building type to a vulnerability class with an assumed damage grade for a given earthquake intensity. The studies also included city infrastructure. (See below for consideration of these inventories as scenario-based planning studies)
- The Quetta hazard assessment (NORSAR, 2012) included an inventory and risk assessment on a neighborhood level (119 “geounits” comprising 13 zones based on socio-economic data). Instead of a direct count, the

inventory assigned about 280,000 buildings to zones, with the number of each of six structure types assigned by group expert opinion. Fragility data was derived from default curves produced with the HAZUS software for a U.S. building stock; to suit the Quetta buildings, the researchers selected what they believed was the most appropriate default relationship, typically one representing pre-code American buildings. Thus, both the inventory and the fragility data include high degrees of approximation and judgment, which the researchers acknowledge. (Field surveys were inhibited by security concerns.) The analysis considered three scenario events, but because the inventory did not consider occupancy data, the direct results predict damage by structure type only.

- Lodi’s team has produced the most ambitious inventory, attempting to cover all of Pakistan (Lodi, 2013). Inventory data was compiled by extrapolating from 1998 census records, supplemented by field surveys and expert consultation. This inventory is both more cognizant of actual conditions and history, acknowledging how little is known and how little should be assumed about a building apart from its wall material, and more complete, recognizing that roof construction is likely as important to response as wall construction. For the risk assessment, Lodi’s study used the EMS terminology and concepts together with damage records from the 2005 earthquake to derive intensity-based fragility curves for each structure type, effectively combining the approaches of the NDMA and Quetta studies. Like Maqsood and Schwarz, Lodi found significant discrepancies between observed damage from 2005 and simulated damage using his inventory and fragility curves, which he attributed primarily to uncertainty in ground motion attenuation relationships.

Table 4 summarizes the assumptions and methods applied in the various inventory studies.

Table 4. Inventory and fragility data used in various studies

| Data category | Maqsood and Schwarz (2008, 2011) | NDMA city earthquake scenarios (NDMA, undated; 2009a; 2009b) | Quetta risk assessment (NORSAR, 2012) | Lodi (2013) |
|---|--|--|---|--|
| Concrete lateral systems | RC frame w/ infill | RC frame w/ infill, 1-3 stories RC frame w/ infill, 4+ stories | RC frame w/ infill, 1-3 stories RC frame w/ infill, 4+ stories | RC frame w/ infill |
| Prescriptive masonry lateral systems | Block, unconfined Block, confined Brick, unconfined Brick, confined | Block Brick (cement mortar) Confined masonry | Brick | Block, heavy roof Block, light roof Brick, heavy roof Brick, light roof |
| Traditional or vernacular lateral systems | Adobe Stone masonry Wood frame w/ masonry infill | Brick (mud mortar) Stone (cement mortar) Stone (mud mortar) | Adobe Stone masonry Wood | Adobe, light roof Stone masonry Wood/bamboo w/ masonry infill Others |
| Occupancies and uses | Not considered | Health Educational Government Public Residential Commercial Industrial | Not considered, except in general way to allocate building types to zones | Not considered |

| Data category | Maqsood and Schwarz (2008, 2011) | NDMA city earthquake scenarios (NDMA, undated; 2009a; 2009b) | Quetta risk assessment (NORSAR, 2012) | Lodi (2013) |
|--------------------------------|---|---|--|---|
| Fragility performance measures | EMS-98 Damage Grades: Slight, Moderate, Substantial, Heavy, Destruction | EMS-98 Damage Grades: Slight, Moderate, Substantial, Heavy, Destruction | HAZUS damage states: Slight, Moderate, Extensive, Complete | EMS-98 Damage Grades: None, Slight, Moderate, Substantial, Heavy, Destruction |
| Fragility hazard measures | Not considered, except for calibration to 2005 earthquake | EMS-98 intensity, similar to MMI | Spectral displacement | EMS-98 intensity, similar to MMI |

The studies summarized in Table 4, as expected, reveal gaps in the knowledge base:

- Little work has been done on the provincial capitals and other major cities, and the inventory of Quetta appears to be the only one not to have applied on-the-ground surveys. Even so, the work on mid-size cities is useful in developing expertise and lessons to be applied to the big targets later.
- The number and distribution of reinforced concrete buildings remains uncertain, or at least worth some confirmation studies. Consider the NDMA studies of Mansehra and Muzaffarabad. The inventories found that the two cities have about the same total number of buildings (11,000 and 14,000 respectively), and in each city about 85 percent are residential. Yet in Mansehra, 77 percent of the buildings are brick masonry and only 9 percent are infilled concrete frames, while in Muzaffarabad only 3 percent are brick masonry and over half, about 55 percent, are infilled concrete frames. Why would two such similar cities have such different building stocks? Generally, concrete correlates with newer buildings and a more affluent population; possibly the history and demographics explain the difference. But Maqsood and Schwarz (2008, Figure 7) also studied Muzaffarabad in detail and seemed to find a much smaller cohort of concrete than NDMA.
- Both Maqsood and Schwarz and Lodi attempted to calibrate their fragility models by simulating the 2005 earthquake, and both found significant, if completely expected, discrepancies. Both studies were optimistic that more refined analysis might show a better fit, but perhaps the best conclusion is that loss estimation is going to be accurate only within an order of magnitude, which might be good enough for scenario-based planning. Indeed, to suggest that modeling can be more accurate risks giving the wrong impression to DRM experts, policy makers, and the public. If they expect too much, disappointment is inevitable and could lead to rejection of this otherwise promising science.
- While inventory data seems relatively easy to collect, thanks to the availability and effort of many students, fragility data is still being cobbled together from European and American assumptions. As Lodi suggests near the end of his study, more research attention should perhaps be given to the non-conforming and non-engineered masonry structures that make up the great bulk of the country’s building stock. More work on actual observed damage, coupled with lab testing and modeling, should be able to produce fragility data specific to Pakistan’s own buildings.
- Except for the NDMA scenario studies, the inventory work has not considered how the structure types overlay with essential or resilience-critical occupancies. This overlay can always be added later, but the best time to collect and confirm it is while structure type inventories are being compiled. Occupancy data is necessary to translate damage data into citywide implications.

Though the studies to date vary in their approaches and completeness, as a group they show that considerable progress has been made since 2005. The next step might be to convene a working group of researchers to develop a consensus methodology or set of best practices that might be applied next to the provincial capitals and other major cities. **(See recommended activities 2 and 6)**

Resilience planning

Structural inventories and risk assessments allow for loss estimation, and loss estimation provides a basis for risk reduction planning. Losses are traditionally of three types: human casualties, economic losses, and functional losses.

The recent NDMA scenario studies for Mansehra, Muzaffarabad, and Murree project the damage estimates into estimates of casualties and infrastructure outages (NDMA, 2009a; 2009b; undated). (These reports do not project losses in direct or indirect economic terms, perhaps because economic loss is mostly of interest to lenders and insurers, who might not play a large role in municipal DRR planning in Pakistan). For large, but reasonable scenario events, the studies project fatality rates between 2 and 5 percent for each of the three cities. These rates are an order of magnitude less than the staggering rates Mansehra and Muzaffarabad saw in 2005. Still, the estimate of 4,200 deaths in a single foreseeable earthquake in Mansehra alone is already more lives lost than in all past U.S. earthquakes combined.

Having a traceable loss estimate is important, but the goal is to do something about it. The Murree report is the only one of the three to include what it calls an Action Plan (p37), but the nature of the plan is unclear. Its stated purpose is to guide local authorities “in developing a coherent risk reduction approach,” suggesting a plan to be implemented *before* the earthquake to reduce losses and ensure coordinated response and recovery. Yet parts of it read like a response plan to be activated only *after* the earthquake, with such tasks as “declaration of emergency” and “establishment of relief camps.”

More important, the Action Plan makes no reference to the risk assessment or loss estimate. The projected losses – casualties, damaged buildings, etc. – should form the basis for coordinated mitigation and recovery planning. If the loss is not recoverable, the risk needs to be reduced through mitigation; if mitigating the loss is too expensive, a recovery plan is vital. The Murree Action Plan lists activities such as stocking supplies, purchasing ambulances, and opening emergency shelters, but it says nothing about how many, how much it will cost, or how long it will take. The plan should be extended to answer these logistical questions. The answers will help prioritize mitigation and solidify the plan.

Further, the Action Plan says nothing about how much loss in a major earthquake should be acceptable. Of course, a 3 percent fatality rate is the primary loss and is unacceptable on its face. What mitigation should be prioritized now that Murree’s leaders know to expect such a result?

The functional losses, if less compelling, are also important. For example, the study estimates significant damage to 14 percent of Murree’s local roads (p23). Will that make it impossible to transport the injured, deliver supplies, or reopen Murree’s tourist facilities for business? Or might a 14 percent loss be acceptable for the time it takes to complete repairs?

Functional losses are measured partly in time: how long will it take to restore the pre-loss condition? For buildings, the answer will depend on the nature of the damage and the structure type, but the implications of that downtime depend also on the function of the building. This is why it is important to inventory occupancy data along with the structural data. The three NDMA studies have this information, and it allows planners to ask (and hopefully answer) more nuanced questions. Consider, for example, the Muzaffarabad damage data tabbed by occupancy (Table 4.4). Overall, for this large earthquake, 40 percent of the city’s buildings are projected to see collapse or heavy damage. But considering just the commercial buildings, the number is 51 percent, while for institutional buildings it is only 26 percent. To be sure, a 26 percent loss is not small, but this assessment with occupancy data is revealing that the commercial sector is in much greater danger of not recovering than the institutional sector. Certainly more details are needed before deciding on a mitigation scheme – some parts of each sector are more crucial to the city’s overall recovery than others – but one can see from this breakdown how occupancy can (and should) color an otherwise undifferentiated loss estimate.

Actionable plans should be thinking about the implications of projected losses in these ways. **(See recommended activity 6)**

Retrofit

Where a city's building stock is relatively stable, earthquake risk reduction plans tend to move quickly toward structural and nonstructural retrofit. Retrofit is not always feasible or cost effective for severe deficiencies or very high performance objectives, but it is generally less disruptive than demolition and replacement, and innovative techniques continue to develop. An introductory manual of conceptual repair and retrofit techniques has even been developed with Pakistan's building stock in mind (Ali, 2009a).

From a public policy perspective, retrofit is an option for public buildings, but the bigger question is how retrofit programs should target private buildings. In particular, retrofit (which is a direct form of risk reduction or mitigation) is indicated if the expected losses are both unacceptable and unrecoverable. The logic is as follows:

- For a given sector of the building stock (residential, healthcare, etc.), is the structure type such that expected damage and losses are unacceptable?
 - If so, is efficient, planned recovery (involving repair, relocation, backup facilities, etc.) the most cost-effective option, compared with pre-earthquake retrofit or replacement? Some losses are recoverable; deaths, of course, are not.
 - If not, is retrofit more cost effective than building replacement?

If so, a retrofit program is indicated. The question then becomes: How best to accomplish the retrofit of dozens, hundreds, or even thousands of buildings? If retrofit is strongly indicated, a mandate is often the only timely and effective approach. Otherwise, retrofit might be achieved through incentives for voluntary work, or through triggers in the building code or building control bylaws.

Again, however, retrofit is an appropriate risk reduction strategy when the building stock is already relatively stable. In Pakistan's cities, however, academics, engineers, and development authority staff agree this is not the case (Gilani, 2013; Lodi et al., 2013; Basit, 2013). Buildings are already being replaced at such a fast pace, due to obsolescence or opportunity costs, that retrofitting to extend their short lives is hardly worthwhile. And urban growth is adding so many new buildings that targeting the older ones might actually be less effective at reducing risk than ensuring the new ones (as well as replacements for earthquake- and flood-damaged buildings) are designed and constructed properly.

Further, a typical U.S.-style retrofit program, whether mandated, incentivized, or triggered, would likely be hampered by the same implementation and corruption problems that affect new construction. Records and reliable drawings of existing buildings might not be available. Thorough technical guidance, such as the U.S. standard ASCE 41, has not been tailored to Pakistan's building stock (the exception proves the rule: see GHI-NED, undated), and Pakistan engineers and regulators are not familiar with advanced retrofit techniques (Rafeeqi and Tucker, 2011). While NDMA and UNDP produced a short manual of retrofit techniques (Ali, 2009a), it is generic and suitable for buildings where small but effective improvements might be made at the same time as repairs; it does not address the evaluation and retrofit design of whole buildings. Some of the guidelines for new design of prescriptive and traditional structure types also offer limited retrofit guidance of this sort (see Tables 2 and 3).

On the nonstructural side, very little guidance exists within Pakistan. An NDMA training course on school earthquake safety, for example, illustrates typical hazards and includes tips for treating injuries, but has practically nothing to say about simple techniques for bracing tall furniture, falling hazards, or potential fire sources (UNDP Pakistan, undated). Ironically, perhaps, day-to-day life in Pakistan has made the country more resilient with respect to likely nonstructural earthquake damage (with the exception of life-threatening falling hazards, of course). Power is unreliable and scheduled outages are routine, so many facilities (including many houses) already have diesel-fueled emergency generators. Much of the population already drinks mostly bottled water. Even major utilities report that damage due to vandalism is so common that their repair procedures are well-rehearsed and efficient (Abid, 2012). For much of the population, a building still represents little more than protection from the elements. Disrupted mobile phone service is likely to cause more dissatisfaction than building-related nonstructural damage.

This is not to suggest that conditions are acceptable everywhere or should not be improved. In particular, buildings with fire suppression systems should have those systems braced, essential facilities might need an uninterruptible power source (something more sophisticated than a diesel generator), and emergency operation centers need to be located in earthquake resistant buildings with protected nonstructural components.

Thus, the intuition of the technical community that retrofit programs might not be the best use of available DRR resources is consistent with advice from an economic perspective:

Given the high cost of complying with regulations regarding retrofit and earthquake proofing, their comparatively low benefit, and the significant negative side-effects of such regulation in environments prone to corruption, the optimal solution may be to focus, simplify and limit such regulation In particular it might be best to focus limited regulation and oversight capacity in areas where potential returns are highest. (Kenny, 2009, p22)

Kenny suggests that “large public buildings” might meet his criteria for prioritization. A more consistent recommendation would be to follow the findings of careful risk assessments and loss estimates. Applying the logic suggested above, one might expect retrofit (or outright replacement) to be the best approach for deficient hospitals, deficient emergency facilities, and, perhaps surprisingly, collapse-prone multi-family housing.

Sharif et al. (2011) found that a hospital completed in mid-2005 saw minor but unacceptable damage in the 2005 earthquake and could be improved by retrofit. Older hospitals performed much worse. The donor-funded program to reconstruct health facilities in the earthquake-affected areas can be expected to develop best practices for mitigation that might be applied pre-earthquake in other parts of the country (AJKHIP, 2013). Indeed, every province has already identified hospitals, schools (expected to serve as shelters or community centers), and emergency operation centers as potential retrofit or replacement projects (NDMA, 2012a).

One class of buildings that has not received much attention, however, is the class of multi-unit housing blocks that line the streets and boulevards of every major city in Pakistan. These mixed-use buildings, using concrete frames with brick or block masonry infill, typically have three to five stories of apartments over a first story of shops. The shop fronts are open – not infilled – creating vertical and torsional irregularities that make the building prone to collapse under earthquake shaking (Khan and Rodgers, undated-a; b; c). Karachi alone has perhaps thousands of these buildings.

These buildings are not “essential” from a traditional code perspective, as they contain only housing and commercial uses. But any rational understanding of earthquake recovery will recognize that a deficiency repeated thousands of times throughout a vast city represents a disproportionate potential loss of life and property. Add the disproportionate functional loss of housing, and from the perspective of citywide recovery, the whole is far greater than the sum of its parts (SPUR, 2009). More work is needed to quantify the risk, but it seems likely that this class of buildings should be prioritized for mitigation programs much as hospitals and schools already are. Indeed, one way to make the existing schools and emergency facilities feasible is to reduce the potentially overwhelming demands that will be placed on them when large portions of the housing stock fail. **(See recommended activity 2)**

Part 3. Recommended Risk Reduction Activities

Based on the preceding analysis of building codes, bylaws, and earthquake risk reduction efforts, the following activities are recommended as potential activities in earthquake risk reduction:

Activity 1. Build capacity for building code implementation.

Activity 2. Develop fragility data and retrofit schemes for resilience-critical urban building types.

Activity 3. Mainstream DRR policy through the code update process.

Activity 4. Support professional development of the engineering community.

Activity 5. Promulgate existing guidelines for earthquake-resistant non-engineered construction.

Activity 6. Produce an urban scenario study to help define performance expectations and objectives.

Activity 7. Develop consensus protocols for post-earthquake safety assessment to aid early recovery.

Each recommended activity fills a gap or extends an effort identified through research and interviews with officials, NGOs, donors, academics, and practicing engineers. They are presented here in order of recommended importance.

Activity 1. Build capacity for building code implementation

Pakistan has good structural engineers and university-level engineering education, as well as a new building code with earthquake design provisions that will improve over time (see recommended activity 3). Yet it is the strong consensus that structures of marginal or questionable quality continue to be built, largely because there is no reliable means for construction quality assurance: Contractors ignore the approved design documents in favor of traditional or cheaper methods; developers stray from the approved design in order to increase building height and area or reduce allowed setbacks; structural materials are not vetted when they arrive on site; and, perhaps most significant, building inspectors (on both public and private sector projects) work within a culture of corruption in which payments of “speed money” are commonplace, even expected.

Activities. Project activities are geared to improving the current situation in two main ways: Increasing the number of qualified building inspectors and increasing their professional integrity and esteem (see also recommended activity 4).

- Produce a quantitative analysis of the number of building inspectors employed relative to the square footage of new development, by key development authorities (DAs) and public agencies.
- Perform a review of building inspector SOPs. Develop new SOPs as needed.
- Study the feasibility and impact of splitting development authority operations into separate agencies for development of public projects and regulation of private projects.
- Develop checklists and other tools to facilitate reviews of code compliance, as opposed to reviews of owner and designer self-certification.
- Develop training courses covering the building code and its provisions for material testing and inspection, periodic structural inspection, and special inspection. Explore opportunities to link promotion and advancement to training and adequate staffing.
- Explore opportunities to reform civil service structures to ensure opportunities for promotion and advancement by diploma holders and government engineers.
- Explore opportunities for linking project funding to documented code compliance.
- Work with NGOs and existing anti-corruption initiatives to focus on construction permitting and inspection.
- Develop engineering curricula that link theoretical design concepts to the importance of construction quality assurance.

Partnerships. Partners and stakeholders in these activities might include:

- Pakistan Engineering Council, which registers engineers and oversees building code development.
- Key DAs and public works agencies, which employ building inspectors.
- NDMA, whose DRM priorities include outreach and development of “strategies to promote implementation of building codes, particularly in major urban centres” (NDMA, 2007, p33).
- NESPAK, which has produced some preliminary checklists for use with the new seismic provisions in the 2007 Building Code of Pakistan.
- Professional associations of engineers, architects, builders, owners, and lenders, which represent civil society.

- Organizations with active programs on civil service reform and governance, such as DFID's anti-corruption strategy and the UN Convention against Corruption.
- Engineering colleges and universities where structural design and construction management are taught.

Coverage. The main public works agencies are concentrated in Islamabad. The largest DA is in Karachi. In addition to those organizations and cities, if resources allow, we recommend working with the Quetta DA, because Quetta has a unique history of earthquake-resistant design and construction from which lessons might be learned, and a Tehsil Municipal Administration in a high seismic area such as KPK or AJK, to represent the situation outside the major cities.

Activity 2. Develop fragility data and retrofit schemes for resilience-critical urban building types

The best way to reduce earthquake risk is to reduce earthquake risk. That is, mitigation by structural retrofit or replacement of resilience-critical structures is more directly effective than awareness programs, preparedness, professional training, or code development. But retrofit is uncommon in Pakistan, likely to be prohibitively expensive and disruptive, and in many cases not cost-beneficial given the rate of building obsolescence. So we are not proposing any specific retrofit or mitigation programs at this time. Having said that, retrofit and mitigation is certainly part of a serious future program, which can be prioritized.

Mitigation begins with inventory and analysis of critical building types. Among these are the ubiquitous 4- to 6-story concrete frame buildings with (or without) concrete block infill, with open first stories along at least one side. Initial case studies by NED Karachi and GeoHazards International indicate that these buildings, which exist by the thousands throughout Karachi and the other major cities, represent significant collapse risks likely to severely inhibit response and recovery.

Activities. Project activities will establish the technical bases for future mitigation policy development.

- Document the actual construction, including materials and detailing, of characteristic buildings.
- Analyze characteristic models for a suite of ground motions; derive fragility relationships.
- Prepare scenario loss estimates on city and neighborhood scales, and project the impacts of direct losses in terms of response and recovery demands.
- Develop schematic retrofit designs representing a range of costs and performance objectives; link expected retrofit performance to evolving codes and retrofit standards.
- Estimate the benefit-cost ratio and net benefit of a voluntary retrofit.
- Document and publicize the findings for a variety of audiences: owners, tenants, DRR and DRM agencies, community leaders, public officials, engineers, and architects.

Partnerships. Partners and stakeholders in these activities might include:

- NED Karachi and GeoHazards International, who have already produced inventories of Pakistan building types, as well as initial studies of this building type.
- Other universities (JET Peshawar, for example) with active programs in analysis and testing of existing building types and retrofit technologies.
- Geological Survey of Pakistan, together with university researchers working to refine the seismic risk in Karachi and southern Pakistan.
- Professional associations of engineers, architects, builders, owners, and lenders, which represent civil society.
- DRR and DRM agencies and NGOs at the Karachi municipal and Sindh provincial levels.
- Karachi municipal and Sindh provincial government departments, including the development authority of Karachi and housing authorities.

Coverage. While this general building type is found in Islamabad, Lahore, and other cities, we propose that the project should focus, at least initially, on conditions found in Karachi.

Activity 3. Mainstream DRR policy through the code update process

The Building Code of Pakistan (BCP) was revised in 2007 with the adoption of new seismic provisions based on an American model code and some of its reference standards. National bylaws call for the BCP to be updated "every five

years or earlier.” While many expect the update process to begin in 2013, it is clearly already overdue. With the update will come an opportunity to revise the BCP in ways that will improve earthquake design and mainstream aspects of DRR policy into normal design and construction practice.

Activities. Project activities involve support for the code development process and advocacy within that process for certain code revisions.

- Engage with the Pakistan Engineering Council (PEC), which maintains the BCP and is expected to name the members of a code development committee.
- Support analytical and benefit-cost studies needed to support DRR-related code change proposals.
- Advocate for DRR-related code change proposals. Ideas for DRR-related code updates are discussed above.
- As needed, work with provinces to develop model bylaws for implementation of the BCP and for local revisions where appropriate (see recommended activity 5).

Partnerships. Partners and stakeholders in these activities might include:

- PEC, as well as individuals and organizations represented on its code development committee.
- The Earthquake Reconstruction and Rehabilitation Authority (ERRA), which developed its own design criteria after the 2005 earthquake and is expected to advocate for certain positions in the next BCP update cycle.
- NESPAK, which was charged with developing the 2007 BCP seismic provisions and is expected to play an important role in the coming update cycle.
- Major development authorities. The DAs should be familiar with the BCP provisions and can be expected to advocate for certain positions in the coming update cycle.

Coverage. The BCP is a national document. While most of the work will therefore be at the national level, if local bylaws will seek revisions based on local conditions, the work can be done at the provincial and city level as well.

Activity 4. Support professional development of the engineering community

Every DRR initiative does better with support from civil society. Pakistan has good structural engineers, some of whom are able and willing to lend their expertise, but the engineering community as a whole does not appear to be active in earthquake risk reduction activities or within the DRR policy community. The Pakistan Engineering Council organizes some technical training, but the PEC is primarily a regulatory body and not independent of the government. NESPAK, the engineering firm that compiled the 2007 BCP seismic provisions, is also closely allied with the government as a major client. The PEC-organized committee that advised NESPAK in its code work is *ad hoc* only. Two professional organizations, the Institution of Engineers, Pakistan, and the Association of Consulting Engineers, Pakistan, are independent professional associations, but neither appears to be active in DRR with respect to either flood- or earthquake-resistant design, and neither was mentioned by any of the experts interviewed for this report. Meanwhile, several subjects noted that public sector engineers responsible for implementing earthquake regulations do not have adequate opportunities for advancement or professional development and are thus not incentivized to produce better-performing buildings. A standing committee to represent the voice of the engineering community – both its private and public sector members – would facilitate implementation of current regulations (see recommended activity 1) and development of updates and improvements (see recommended activity 3).

Activities. Project activities would support two related objectives: To develop a consistent leadership voice for practicing engineers, and to recognize the important role played by public sector engineers.

- Collaborate with IEP and ACEP to organize standing committees to develop consensus positions on codes and bylaws related to earthquake- and flood-resistant structural design. One possibility is to establish a DRR committee with three subcommittees:
 - A Construction Quality Assurance subcommittee to document best practices for testing and inspection during construction of code-designed buildings.
 - A New Buildings subcommittee to review questions about current earthquake design provisions in the BCP and bylaws, to propose changes, and to take positions on changes proposed by others.
 - An Existing Buildings subcommittee to review questions about the evaluation and retrofit of pre-code engineered and non-engineered buildings, identifying how provisions for new buildings might or might not apply.

- Work with public sector agencies to review current protocols for engineer and inspector hiring, training, promotion, compensation, and professional advancement. Develop new protocols as needed to promote and ensure high quality in engineered construction.

Partnerships. Partners and stakeholders in these activities might include:

- IEP and ACEP, two existing professional associations.
- PEC, which regulates engineering practice and sponsors professional development.
- Organizations active in civil service reform.

Coverage. Karachi has by far the largest number of practicing private sector engineers, and most public sector engineers are probably with agencies based in Islamabad, so initial work could focus on those two cities. However, this might miss the point of bringing public and private sector engineers together under one professional association. IEP, ACEP, and the PEC are all active nationally.

Activity 5. Promulgate existing guidelines for earthquake-resistant non-engineered construction

After the 2005 earthquake, a number of design guidelines for vernacular housing were produced. Documents were printed and distributed, masons and owners were trained, and a number of pilot projects were constructed. Seven years later, however, the energy behind these efforts has waned, perhaps in part due to the understandable shift of DRR focus to flooding. But the need to continue this work remains, not least in areas that were *not* affected as extensively in 2005.

Activities. Project activities would be based on materials already developed by various organizations.

- Review the available documents on earthquake-resistant prescriptive construction to identify both best practices and necessary corrections.
- Review the pilot projects associated with the available documents to gauge effectiveness and sustainability.
- Organize representatives of the agencies who developed the existing guidelines, as well as related documents from outside Pakistan, to resolve differences between the documents and explore the feasibility of a new consensus guideline or standard.
- Work with partners to identify new venues for document distribution and training.
- Advocate for building code revisions and local bylaws that set minimum seismic safety standards for new housing and, where appropriate, reference the consensus guideline (or one or more of the existing documents) as deemed-to-comply alternatives.

Partnerships. Partners and stakeholders in these activities might include:

- ERRA, which already has the interest and capacity to reach new markets.
- GHI, BuildChange, and other NGOs working on prescriptive guidelines for design and retrofit.
- UET Peshawar, whose faculty developed one of the current guidelines with NDMA and UNDP.

Coverage. The focus should be on rural or semi-rural areas with substantial seismic risk that were *not* heavily affected by the 2005 earthquake. Each province has some areas that meet these criteria. For examples, parts of Balochistan outside of Quetta or along the fault zone that runs from Nushki to Bela, parts of Sindh south of Badin along the Indian border, or parts of Punjab west of the Indus.

Activity 6. Produce an urban scenario study to help define performance expectations and objectives

Many jurisdictions and DRR organizations have done some work on earthquake response or loss estimation, but practically none have addressed the questions that should drive mitigation and recovery planning: How much loss is acceptable? How should we set a mitigation objective? And especially in urban areas, how might direct losses cascade into a disproportionate citywide catastrophe? Perhaps the most effective way to start addressing these questions is with a scenario study that projects specific losses from a specific hypothetical event, then studies the effects of those losses and the options for recovery. NDMA has produced three such studies with loss estimates for Mansehra, Muzaffarabad, and Murree. The Murree report includes an Action Plan, but its only recommendations involve generic planning and development principles not linked to the risk assessment. These scenario studies should be extended to establish

objectives for coordinated recovery and mitigation planning. A similar approach can then be applied to a larger, more complex jurisdiction.

Activities. Project activities would include:

- Review and extend the Mansehra, Muzaffarabad, and Murree scenarios:
 - Establish an expected recovery timeline for various sectors of city services (housing, schools, utilities, etc.).
 - Posit a target recovery timeline based on community expectations and resources.
 - Conceptualize a combined mitigation and recovery plan to transition from the current timeline to the target timeline.
- Apply a similar scenario development and analysis to a larger city.

Partnerships. Partners and stakeholders in these activities might include:

- NDMA and Punjab PDMA, who participated in the existing scenarios.
- The PDMA, DDMA, and city agencies of the city selected for the new scenario.
- Researchers who have data on local seismicity, building stock, and infrastructure of the city selected for the new scenario.

Coverage. After the three existing scenarios, the focus should be on an urban area, ideally one with a representative building stock and population (as opposed to a planned city like Islamabad or a rebuilt city like Quetta), subject to significant seismicity (as opposed to Lahore, for example), and relatively stable with respect to development (as opposed to, say, Karachi or Peshawar). Possibly Mardan, in KP, or Sialkot, in Punjab, would be good candidates.

Activity 7. Develop consensus protocols for post-earthquake safety assessment to aid early recovery

Reliable post-earthquake safety assessments are key to early recovery. Their objective is to keep people out of dangerous buildings but to expedite re-occupancy elsewhere. After the 2005 earthquake, a number of informal assessment procedures developed out of necessity. As one might have expected, they produced inconsistent results, some of which led to improper demands for relief services, inefficient delivery of those services, and other recovery delays. Now, before the next damaging event, is the time to draw lessons from 2005 and establish a uniform procedure for rapid post-earthquake safety assessments geared to Pakistan's building stock.

Activities. Project activities would include:

- Review the technical bases of the various post-earthquake assessment protocols developed or applied after the 2005 earthquake, and statistically review their results.
- Study assessment schemes developed for other countries, many of which are based on the American protocol known as ATC 20.
- Build consensus among stakeholder agencies regarding conceptual attributes for a uniform post-earthquake safety assessment protocol.
- Develop the proposed protocol.

Partnerships. Partners and stakeholders in these activities might include:

- ERRA, which developed one of the protocols used after the 2005 earthquake, and which is likely to play a lead role in post-earthquake early recovery.
- NDMA, the key coordinating agency for DRR activities.
- PEC, IEP, ACEP, and other organizations from which volunteer trainees will likely be drawn.

Coverage. The project has national application. Indeed, since an earthquake in one province will draw volunteers from other undamaged provinces, one of this project's objectives should be to avoid significant local or regional variations.

References

- Abid, Z., 2012. "Aftermath: What if a killer earthquake were to strike Karachi." *The Express Tribune*, July 29.
- ADPC (Asian Disaster Preparedness Center), 2012. *Risk Assessment and Formulation of Disaster Risk Reduction Strategies for Flood Affected Areas in Punjab and Sindh Provinces*. Concern Worldwide on behalf of Alliance2015. July.
- AJKHIP, 2013. "AJK Health Infrastructure Program." <http://www.ajkhip.net/>.
- Ali, S. M., 2013. Personal interview by David Bonowitz, S.E. at UET Peshawar, February 21.
- Ali, Q., 2009a. *Seismic Retrofitting and repair Manual for Buildings*. National Disaster Management Authority (NDMA) Pakistan, December.
- Ali, Q., 2009b. *Easily Understandable Guidelines on Earthquake Safer Construction (Confined Masonry)*. National Disaster Management Authority (NDMA) Pakistan, December.
- Ambraseys, N. and Bilham, R., 2011. "Corruption kills." *Nature* n469, p153-155, January 13.
- APP (Associated Press of Pakistan), 2007. "New building code for seismic resistance in place with immediate effect." August 26.
- Aziz, S., 2013. Personal interview by David Bonowitz, S.E. at UNDP Pakistan, Islamabad, February 28.
- Badrashi, Y.I., Ali, Q., and Ashraf, M., 2010. "Housing Report: Reinforced concrete buildings in Pakistan" Report No. 159 in *World Housing Encyclopedia*, www.world-housing.net. July 7.
- Balochistan, Government of, 2013. "Quetta Development Authority." http://www.balochistan.gov.pk/index.php?option=com_content&view=category&id=47&Itemid=552
- Basit, A., 2013. Personal interview by David Bonowitz, S.E. at NESPAK, Lahore, February 26.
- Bendimerad, F., Buika, J., Fernandez, J., Mattingly, S., Reyes, M., and Van Boskirk, E., 2007. *Manual of Sound Practices* [EMI Topical Report TR-07-02]. Earthquakes and Megacities Initiative (EMI), Quezon City.
- Berlinski, C., 2011. "1 Million Dead in 30 Seconds." *City Journal*, v21, n3, Summer.
- Bilham, R., Lodi, S., Hough, S., Bukhary, S., Khan, A. M., and Rafeeqi, S.F.A., 2007. "Seismic Hazard in Karachi, Pakistan: Uncertain Past, Uncertain Future," in *Seismological Research Letters* v.78 n.6, November/December.
- BIS, 1993. *Improving Earthquake Resistance of Low Strength Masonry Buildings – Guidelines* [Indian Standard 13828:1993]. Bureau of Indian Standards, New Delhi. August.
- BIS, 2005. *National Building Code of India 2005*. Bureau of Indian Standards, New Delhi. <https://law.resource.org/pub/in/bis/is.nbc.2005.svg.html>
- Bonowitz, D., 2012. "Engineering for Resilient Communities." Proceedings of Fourth Iran-U.S. Joint Seismic Workshop: Urban Earthquake Engineering, Sharif University of Technology, Tehran, December 18-21.
- Bothara, J. and Brzev, S., 2011. *A Tutorial: Improving the Seismic Performance of Stone Masonry Buildings* [WHE-2011-01]. Earthquake Engineering Research Institute, Oakland. July.
- Brzev, S., 2007. *Earthquake-Resistant Confined Masonry Construction*. National Information Center of Earthquake Engineering, Indian Institute of Technology, Kanpur. December.

- Build Change, 2012. *Building Back Housing in Post-Disaster Situations – Basic Engineering Principles for Development Professionals: A Primer*. United States Agency for International Development (USAID). January.
- CDA, 1993. "Islamabad Residential Sectors Zoning (Building Control) Regulation." Capital Development Authority (CDA).
- Dawn, 2005. "Earthquake: How safe are your cities?" *Dawn*, November 10.
- DHA, 2011. "Building Control & Town Planning Regulations 2011." Pakistan Defence Officers Housing Authority (DHA). <http://www.dhakarachi.org/regulations2011.asp>
- Dowall, D. and Ellis, P., 2007. "Urban Land and Housing Markets in the Punjab, Pakistan" [Working Paper 2007-04]. Berkeley Institute of Urban and Regional Development, November.
- EEC, 2007. *Field Practicing Manual*. Government of NWFP, Pakistan. August. *August 2007 English version of February 2006 First Edition prepared by the Earthquake Engineering Center (EEC), Department of Civil Engineering, NWFP UET Peshawar.*
- ERRA, undated-a. "Interim Guidelines for Design and Construction of Buildings in Earthquake Affected Areas." Earthquake Reconstruction & Rehabilitation Authority (ERRA).
- ERRA, undated-b. "Principles, Themes and Lessons Learnt: Design and implementation of ERRA's rural housing programme." Earthquake Reconstruction & Rehabilitation Authority (ERRA).
- ERRA, undated-c. "Recommendations for ERRA approved Dhaji Timber Frame House Construction." Earthquake Reconstruction & Rehabilitation Authority (ERRA).
- ERRA, undated-d. "Recommendations for Timber Frame Houses with Lightweight Roof." Earthquake Reconstruction & Rehabilitation Authority (ERRA).
- ERRA, 2006a. "Rural housing reconstruction strategy of earthquake hit districts in NWFP and AJK." Earthquake Reconstruction & Rehabilitation Authority (ERRA). March (electronic version dated April 20).
- ERRA, 2006b. "Guidelines for Earthquake Resistant Construction of Non-Engineered Rural and Suburban Masonry Houses in Cement Sand Mortar in Earthquake Affected Areas (DRAFT)." Earthquake Reconstruction & Rehabilitation Authority (ERRA). May.
- ERRA, 2006c. "Few Recommendations for Single Storey Masonry Houses in Cement Sand Mortar (Version 02)." Earthquake Reconstruction & Rehabilitation Authority (ERRA), August.
- ERRA, 2007a. "Urban Development: A strategy for reconstruction, rehabilitation, and development of earthquake-affected urban areas." Earthquake Reconstruction & Rehabilitation Authority (ERRA). August.
- ERRA, 2007b. *Compliance Catalogue: Guidelines for the Construction of Compliant Rural Houses*. UN-HABITAT, Islamabad. September 18.
- ERRA, 2009. "Reconstruction and Rehabilitation Strategy for Governance Sector." Earthquake Reconstruction & Rehabilitation Authority (ERRA). July 2006 to June 2009.
- ERRA, 2010. *Build Back Better: Lessons learned from the experience of ERRA*. Earthquake Reconstruction & Rehabilitation Authority (ERRA), Islamabad. April.
- GHI-NED, undated. "Draft FEMA 310 Screening Phase (Tier 1) Checklist Modified for Pakistan Conditions." Unpublished draft provided by GeoHazards International.
- Gilani, 2013. Personal interview by David Bonowitz, S.E. at UET Peshawar, February 21.

- GSHAP, 1999. "Global Seismic Hazard Map." Global Seismic Hazard Assessment Program, <http://www.seismo.ethz.ch/static/gshap/>.
- Habib, Y., 2011. "Building Control Authority to regulate building issues." *Pakistan Today*, January 27.
- Hanif, I., 2007. "CDGs given deadline to adopt building bylaws." *Dawn*, July 27.
- Hanif, I., 2012. "Building control body Punjab govt jumps the 'warning signals'." *Dawn*, December 21.
- Haseeb, M., Malik, R., et al., 2011. "Construction of Earthquake Resistant Buildings and Infrastructure Implementing Seismic Design and Building Code in Northern Pakistan 2005 Earthquake Affected Area," in *International Journal of Business and Social Science*, v.2 n.4, March.
- High Court Balochistan, 1997. "Begum Saida Qazi Isa v. Quetta Municipal Corporation," in *The All Pakistan Legal Decisions* [PLD 1997 Quetta], v.XLIX, pp 1-17.
- IAEE, 1986. *Guidelines for Earthquake Resistant Non-Engineered Construction*. International Association for Earthquake Engineering, Tokyo. Reprinted with permission in 2004 by the National Information Center of Earthquake Engineering, Kanpur, India.
- ICBO, 1997. *1997 Uniform Building Code*. International Conference of Building Officials, Whittier, California. April.
- Inskeep, S., 2011. *Instant City: Life and Death in Karachi*. Penguin Books, New Delhi.
- Kayani, K., 2013. Personal correspondence with David Bonowitz, S.E., April 25.
- Kayhar, Z., 2010. "Integration of Disaster Risk Reduction into Development Process." Circular No. 5(7)Misc./PP&H/PD/10, November 23.
- Kenny, C., 2009. "Why Do People Die in Earthquakes: The costs, benefits and institutions of disaster risk reduction in developing countries" [Policy Research Working Paper 4823]. The World Bank Sustainable Development Network, Finance Economics & Urban Department. January.
- Khan, A., 2010. "Margalla Towers collapse: The accused rise as probe report gathers dust." *The Express Tribune*, December 20.
- Khan, R. and Rodgers, J, undated-a. "Five Storey Mixed Use Building in Karachi: A Case Study of Seismic Assessment and Retrofit Design." NED University of Engineering and Technology.
- Khan, R. and Rodgers, J, undated-b. "6-Storey Mixed Use Building in Karachi: A Case Study of Seismic Assessment and Retrofit Design." NED University of Engineering and Technology.
- Khan, R. and Rodgers, J, undated-c. "6-Storey Mixed Use Building in Karachi: A Pilot Case Study of Seismic Assessment and Retrofit Design." NED University of Engineering and Technology.
- Lodi, S., Farooqui, R. U., and Ahmed, S. M., 2009. "Development of a Strategic Model for Improvement of Construction Project Management Education, Research, and Practice in Pakistan." The National Academies, Washington, D.C. November 11.
- Lodi, S., 2012. "Seismic Vulnerability and Seismic Codes of Pakistan." Unpublished presentation slides presented at 45th IEP Convention, December 21, 2012. December.
- Lodi, S., 2013. "Seismic Vulnerability Assessment of Existing Buildings in Pakistan." February 11. *Draft submittal of Work Package 4 to Earthquake Model for Middle East Region, provided by Dr. Lodi but without named authors.*

- Lodi, S., undated. "Status of Built Environment in Pakistan – A Review." Unpublished presentation slides.
- Lodi, S. et al., 2013. Group interview by David Bonowitz, S.E. of engineering researchers, building officials, and practicing engineers organized by Dr. Sarosh Lodi, Dean, Civil Engineering and Architecture. NED University of Engineering and Technology, Karachi, February 25.
- Malik, J. A., Omar, S., and Vatsa, K., undated. *Evaluation of UNDP's Earthquake Response Programme in Pakistan*. United Nations Development Programme Pakistan.
- Mahmood, K., 2007. "Factors Affecting Reinforced Concrete Construction Quality in Pakistan," in *Electronic Proceedings of the International Workshop – Cement Based Materials and Civil Infrastructure*, Karachi, December 10-11. http://enpub.fulton.asu.edu/cement/CBM_CI/home.htm.
- Maqsood, S.T. and Schwarz, J., 2008. "Seismic Vulnerability of Existing Building Stock in Pakistan," in *Proceedings of the 14th World Conference on Earthquake Engineering, October 12-17, Beijing, China*. October.
- Maqsood, S.T. and Schwarz, J., 2011. "Development of a Building Inventory and Vulnerability Database for Pakistan," in *Proceedings of the Australian Earthquake Engineering Society Conference, Nov 18-20, Barossa Valley, South Australia*. November.
- Meli, R., Brzev, S., et al., 2011. *Seismic Design Guide for Low-Rise Confined Masonry Buildings*. Earthquake Engineering Research Institute, Oakland. August.
- Memon, S., 2010. "Whose jurisdiction is it, anyway?" *The Express Tribune*, September 28.
- MOHW, 1986. *Building Code of Pakistan*. Government of Pakistan, Ministry of Housing & Works.
- MOHW, 2007. *Building Code of Pakistan, Seismic Provisions – 2007*. Government of Pakistan, Ministry of Housing & Works.
- Murtaza, N., Alam, K., and Bhatti, S., 2012. *Disaster Risk Reduction in Pakistan: The Contributino of DEC Member Agencies, 2010-2012*. Disasters Emergency Committee (DEC). July 27.
- NAS, 2005. "Responding to the Pakistan Earthquake of October 8, 2005: The U.S. National Academies Reconstruction Assistance Team Trip Report, December 9-17, 2005." The National Academies. December.
- NAS, 2006. "Responding to the Pakistan Earthquake of October 8, 2005: The U.S. National Academies Reconstruction Assistance Team Trip Report, June 12-17, 2006." The National Academies. June.
- Naseer, A., Khan, A. N., and Hussain, Z., 2010. "Observed Seismic Behavior of Buildings in Northern Pakistan During the 2005 Kashmir Earthquake," in *Spectra*, v.26 n.2, May.
- Nation, The, 2011. "Building code being violated in Quetta quake red zone." April 9.
- NDMA, undated. *Earthquake Risk Scenario and Action Plan: Murree City*. National Disaster Management Authority.
- NDMA, 2007. *National Disaster Risk Management Framework Pakistan*. National Disaster Management Authority. March.
- NDMA, 2009a. *Mansehra City's Earthquake Scenario*. National Disaster Management Authority, December.
- NDMA, 2009b. *Muzaffarabad City's Earthquake Scenario*. National Disaster Management Authority, December.
- NDMA, 2010. "Earthquake Mitigation Course at NIDM for the District Officials and NGOs." National Disaster Management Authority, March 16, <http://www.ndma.gov.pk/nidm.php>.

- NDMA, 2012a. *Disaster Risk Management Needs Report 2012*. Government of Pakistan, National Disaster Management Authority. June.
- NDMA, 2012b. *National Disaster Management Plan: Executive Summary*. Government of Pakistan, Ministry of Climate Change, National Disaster Management Authority. August.
- NESPAK, undated-a. "Reconstruction & Fast Track Technology." National Engineering Services Pakistan (NESPAK), Disaster Management & Reconstruction Division.
- NESPAK, undated-b. "Pre-engineered Light Gauge Cold Formed Galvanized Steel Structure." National Engineering Services Pakistan (NESPAK), Earthquake Reconstruction Division.
- NESPAK, undated-c. "Structural Concrete Insulated Panel Construction (SCIP)." National Engineering Services Pakistan (NESPAK).
- NESPAK, undated-d. "General Location of Faults." National Engineering Services Pakistan (NESPAK), Earthquake Reconstruction Division.
- NESPAK, undated-e. "Earthquake Reconstruction and Rehabilitation Project Check List for Design Evaluation." " National Engineering Services Pakistan (NESPAK).
- NHA, undated. "Key Aspects of *Building Code of Pakistan, Seismic Provisions – 2007*." National Housing Authority, <http://www.nhagov.pk/bldgcodes.html>.
- NORSAR, 2006. "Seismic Hazard Analysis for the cities of Islamabad and Rawalpindi." Pakistan Meteorological Department. February.
- NORSAR, 2012. "Earthquake Risk Assessment of Quetta." Pakistan Meteorological Department. September.
- OPP, undated. "Earthquake Data Manual." Orangi Pilot Project, Research and Training Institute.
- Pakistan Observer, 2012. "All set to establish DBCA." November 12.
- Pakistan Today, 2011. "Building Control Authority to regulate building issues." January 27.
- PEC, 1986. "Conduct and Practice of Consulting Engineers, Bye-Laws, 1986," in *The Gazette of Pakistan*. August 24. *Later amended by PEC, 2008a*.
- PEC, 2008a. "Notification," in *The Gazette of Pakistan*, September 10.
- PEC, 2008b. "Professional Development of Engineers, Bye-Laws, 2008," in *The Gazette of Pakistan*. December 31.
- PEC, 2010. "Construction and Operation of Engineering Works Bye-laws, 1987 (Amended up to December 27, 2010)," in *The Gazette of Pakistan*.
- PEC, 2011. "PEC Act, 1976 (Amended up to January, 2011)," in *The Gazette of Pakistan*.
- Planning Commission, Government of Pakistan, 2013. "PC Forms." <http://www.pc.gov.pk/forms.html>
- PMD, 2007. "Seismic Hazard Analysis and Zonation for Pakistan, Azad Jammu and Kashmir." Pakistan Meteorological Department (PMD). July.
- PUDB, 1985. "N.-W.F.P. Building Regulations, 1985," in *Government Gazette, North West Frontier Province*. Provincial Urban Development Board (PUDB), Peshawar, May 13.

- Punjab, Government of the, 2007a. *Model Building and Zoning Regulations for Development Authorities in Punjab*. Local Government & Community Development Department, Government of the Punjab. July.
- Punjab, Government of, 2007b. "Assessment of Urban Land Development and Management Practices in Five Large Cities of Punjab (Draft Final Report)." The Urban Unit, Planning and Development Department.
- Punjab Gazette, 2008. "Lahore Development Authority Notification: Lahore Development Authority Building & Zoning Regulations 2007." February 27.
- Qadeer, S., 2013. Personal interview by David Bonowitz, S.E. at NESPAK, Lahore, February 26.
- Qadri, 2013. Personal interview by David Bonowitz, S.E. at Qadri Associates, Islamabad, February 22.
- Quetta, Municipality of, 1937. *Building Code for Quetta Municipality*. Staff College Printing Press, Quetta. With amendments dated August 29, 1940.
- Rafeeqi, S.F.A. and Tucker, B., 2011. "Pakistan-U.S. Science and Technology Cooperation Program: Final Technical Report." Unpublished report by GeoHazards International, Palo Alto. October 31.
- RDA, 2007. "Building and Zoning Regulations, 2007." Rawalpindi Development Authority (RDA).
- Rodgers, J. and Deierlein, G., undated. "An Introduction to Framed Infill." GeoHazards International.
- Rossetto, T. and Peiris, N., 2008. "Kashmir Earthquake of October 8, 2005: Field Observations and Study of Current Seismic Provisions for Buildings in Pakistan," in *Proceedings of the 14th World Conference on Earthquake Engineering, October 12-17, Beijing, China*. October.
- Saleem, M., 2010. "TMA gets green signal to raze illegal plaza." *Dawn*, January 9.
- SBCA, 2013. "Karachi Building and Town Planning Regulations – 2002," including updates through January 2013. Sindh Building Control Authority (SBCA).
- SDC, 2007a. "Confined Masonry: An illustrated guide for masons." Swiss Agency for Development and Cooperation (SDC). March 6.
- SDC, 2007b. "Bhatar Construction (Timber Reinforced Masonry): An illustrated guide for craftsmen." Swiss Agency for Development and Cooperation (SDC). May.
- Shabbir, M. J. and Ilyas, M., 2007. "Development and Adoption of *Building Code of Pakistan*," in Electronic Proceedings of the International Workshop – Cement Based Materials and Civil Infrastructure, Karachi, December 10-11. http://enpub.fulton.asu.edu/cement/CBM_CI/home.htm.
- Shabbir, M. J. and Qadeer, S., 2009. "Earthquake Resistant Design of Buildings in Pakistan: Awareness and Enforcement." Presentation slides from SAARC Workshop on Earthquake Risk Mitigation & Management in South Asia, October 8-9.
- Sharif, M. B., Qazi, A. U., Ilyas, M., and Mohsin, N., 2011. "New Seismic Parameters for Building Code of Pakistan and Their Effect on Existing Reinforced Concrete Buildings: A Case Study," in *Pakistan Journal of Science*, v.63 n.2, June.
- Sharif, M. B., Qazi, U. A., Hameed, A., Khan, N. M., and Jabeen, S., 2011. "Analytical Post Earthquake Damage Assessment of RC Building and Its Retrofitting: A Case Study," in *Pakistan Journal of Science*, v.63 n.04, December.
- SPUR, 2009. "The Resilient City, Part I: Before the Disaster." *Urbanist*, February.
- Stephenson, M., 2008. "Notes from experience in post-earthquake rural housing reconstruction in Pakistan." Presentation notes from Building Back Better workshop, Beijing, July.

- TCDPAP, 2007. "Comprehensive Report: Regional Conference on Engineering and Disaster Management, 20-22 March, 2007, Lahore, Pakistan." Technical Consultancy Development Programme for Asia and the Pacific.
- UNDP Pakistan, undated. "Participants' Manual: EQ Preparedness in School" [in Urdu]. United Nations Development Program Pakistan, http://www.ndma.gov.pk/Documents/DRM_plan/ERP_publications.
- UN-HABITAT, undated. "Leepa: Guidelines for the compliant construction of Leepa-type timber post and beam houses." UN-HABITAT.
- UN-HABITAT, 2008. "B.9: Pakistan – 2005 – Earthquake," in *Shelter Projects 2008*. UN-HABITAT.
- UN-HABITAT, 2010. "Technical Specification for masonry house in flood affected areas (seismic zone 2B and lower) up to two storey height." UN-HABITAT Housing Early Recovery Working Group. December 30. Available at <http://115.186.134.22:43038/Guidelines/Forms/AllItems.aspx>
- USAID, undated. "Property Rights & Resource Governance: Pakistan."
- USGS, 2013. "M7.7 – 83km E of Khash, Iran." United States Geological Survey, April 16, http://earthquake.usgs.gov/earthquakes/eventpage/usb000g7x7#shakemap_pga.
- Zahra, T. and Zehra, Y., 2012. "Effect of Rising Seismic Risk on the Design of High Rise Buildings in Karachi," in *International Journal of Civil & Environmental Engineering (IJCEE-IJENS)*, v.12 n.06, December.

Final Note

In addition to sources listed here and interviews arranged by UNDP (not all of which are listed here), this report is based on pre-mission interviews with representatives of recent Pakistan projects by GeoHazards International and the U.S. National Academies and interviews in Pakistan with staff of Qadri & Qadri, Islamabad; academic faculty at UET Peshawar; academic faculty, professional engineers and DA officials at NED University of Technology, Karachi; and engineers at NESPAK, Lahore. Further input was obtained through post-mission correspondence with various practitioners, public servants, and experts via online survey. Some interview subjects not cited directly in the report are not listed here. Finally, the report is based on personal observations of buildings and construction projects in Pakistan by David Bonowitz, S.E.



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