World Housing Encyclopedia

A Resource on Construction in Earthquake Regions

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HOUSING REPORT

RC Moment Frame Building with URM Infills

Report#	159
Last Updated	
Country	Pakistan
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Important

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General Information

Building Type:	RC Moment Frame Building with URM Infills
Country:	Pakistan
Author(s):	Yasir Irfan Badrashi Qaisar Ali Mohammad Ashraf
Last Updated:	
Regions Where Found:	It is estimated that reinforced concrete buildings constitute 10 to 15% of the total building stock in the major cities of Pakistan and this percentage is on the rise.
Summary:	This report addresses reinforced-concrete buildings in Pakistan. Due to the rapid urbanization in Pakistan in the recent past and consequently the scarcity and inflated cost of land in the major cities, builders have been forced to resort to the construction of reinforced-concrete buildings both for commercial and residential purposes. It is estimated that reinforcedconcrete buildings constitute 10 to 15% of the total building stock in the major cities of Pakistan and this percentage is on the rise. However, construction of reinforced concrete buildings in Pakistan is still in nascent stage with construction procedures lacking compliance with the established construction procedures. This report is based on survey of the building stock of 5 major cities in Pakistan and hence provides a realistic picture of construction of reinforced-concrete buildings in Pakistan. The statistics provided in this report are based on personal observation of the authors as well as opinion of professionals working in the construction industry who were interviewed in the course of this survey.
Length of time practiced:	Less than 25 years
Still Practiced:	Yes
In practice as of:	
Building Occupancy:	Mixed residential/commercialOther
Typical number of stories:	3-8

Terrain-Flat:	Typically
Terrain-Sloped:	4
Comments:	Buildings of this construction type can be found in the urban areas of the major cities being the hub of this kind of constructi

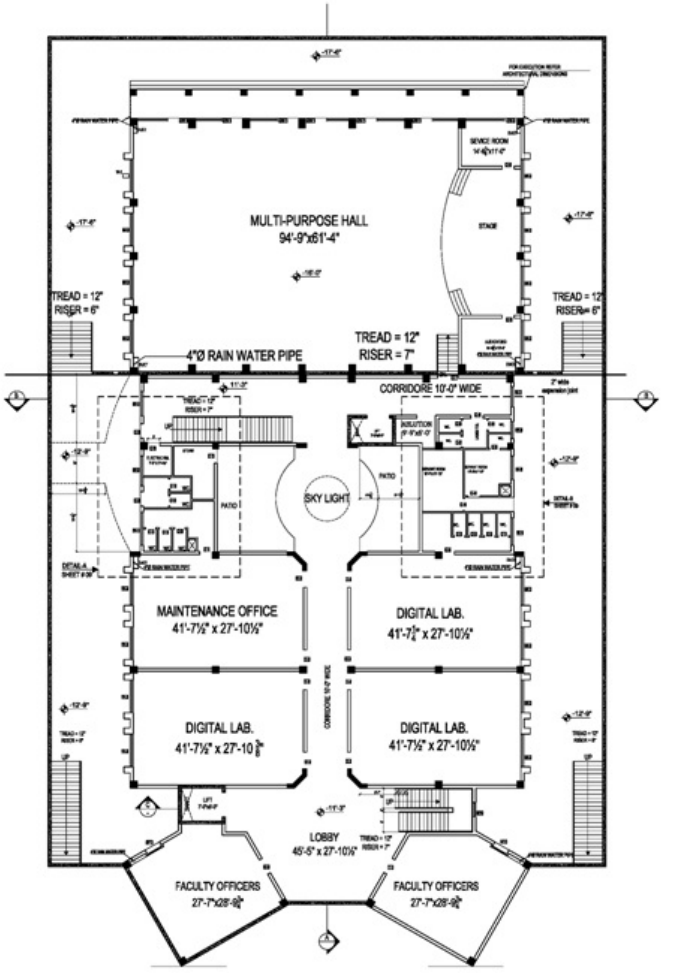
Features

Plan Shape	Rectangular, solid
Additional comments on plan shape	Reinforced-concrete structures are usually rectangular in plan. However, in certain cases other planar profiles such as L, T, U or even curved profiles can also be found in larger buildings like plazas and hotels, aesthetics being the main motivation in adopting irregular shapes. In elevation, these buildings usually have a regular configuration; however, in some cases the difference in stiffness in different stories may cause soft story effect. In privately owned buildings, the trend has been to allocate the ground and first floors to commercial facilities like shops while the upper stories are used as residential dwellings in form of apartments. In order to increase the floor area, these apartments are projected outwards thus causing disproportion between the inter story stiffness. A typical building plan, elevation and picture of construction are given in Figure 1, 2 and 3, respectively.
Typical plan length (meters)	10-40
Typical plan width (meters)	10-20
Typical story height (meters)	3
Type of Structural System	Structural Concrete: Moment Resisting Frame: Designed with seismic effects, with URM infill walls
Additional comments on structural system	The vertical load-resisting system is reinforced concrete moment resisting frame. Gravity loads are resisted purely by the reinforced-concrete frame. The typical load transfer path is from the slabs to beams to columns and finally to the footings of the building. The lateral load-resisting system is reinforced concrete moment resisting frame. Different lateral load resisting systems are provided by structural designers in the reinforced-concrete

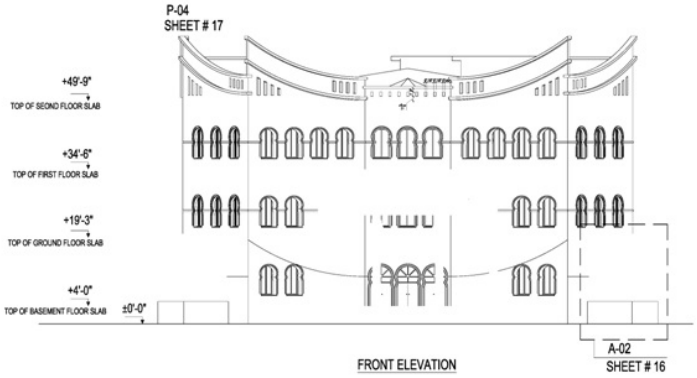
	buildings in Pakistan. Reinforced-concrete frames usually are either OMRF or IMRF. Very important buildings have SMRF configuration as well as in some cases dual systems are encountered, too. Reinforced-concrete frames usually have brick or block masonry infill walls which help contribute to the lateral load-resisting system.
Gravity load-bearing & lateral load-resisting systems	Reinforced-concrete buildings prior to the Kashmir 2005 earthquake were mostly designed for gravity loading only. However, after the Kashmir 2005 earthquake, a reasonable importance is being given to consideration of earthquake induced loading in the design of these buildings. Reinforced-concrete buildings in Pakistan at present are generally designed as moment-resisting frames, however, a particular building-resisting system would depend largely on the budget allocated to the project and to some extent on the importance of the building. Low- to mid-rise buildings are generally OMRF, while taller buildings with a higher importance level, are designed as SMRF or dual systems (moment-resisting frame with shear walls).
Typical wall densities in direction 1	0-1%
Typical wall densities in direction 2	0-1%
Additional comments on typical wall densities	The typical structural wall density is unknown.
Wall Openings	In residential facilities each room is normally provided with one or two doors and one or two windows. Doors are usually located near the corners of the rooms with sizes in the range of 3.0 square meters and are usually wooden, but in some instances aluminum doors are constructed nowadays owing to their durability as compared to wooden doors. Windows are provided in the walls with sizes of 2.0 to 2.25 square meters. Reinforced-concrete lintels are provided above the openings in the brick masonry infills. These lintels are connected to the columns by dowel bars in case of good quality construction but in ordinary construction, this feature is missing. When reinforced-concrete buildings are used to house commercial facilities, openings may be lesser and differently located as compared to the ones in residential units though the sizes of the openings are almost the same. Infills in concrete frames may be of different material for commercial buildings, usually glass infills for decorative purposes which

	are provided generally in the front walls. Such type of individual commercial units usually have one door and no openings.
Is it typical for buildings of this type to have common walls with adjacent buildings?	No
Modifications of buildings	When modified, reinforced-concrete buildings are modified at times without permission of the governing authority that is responsible for the construction in a particular area and in some instances the builder may get away with it, too. The most common modifications performed on the building are relocation of the masonry infill walls to suit the needs of the residents. In some cases, brick masonry infill walls are replaced with wooden boards as partition walls. Other modifications include the construction of additional stories as well as the confinement of the terraces to increase living space. The addition of stories that are not considered in the design of the building can lead to catastrophes.
Type of Foundation	Shallow Foundation: Reinforced concrete isolated footingShallow Foundation: Reinforced concrete strip footingShallow Foundation: Mat foundationDeep Foundation: Reinforced concrete skin friction piles
Additional comments on foundation	It consists of reinforced concrete skin-friction piles. Foundations for low- to mid-rise reinforced-concrete buildings are usually isolated column footings with size in the range of 1.5 square meters with thickness of about 0.15 meters. A layer of lean concrete is usually provided beneath the footing to act as a cushion against the soil effects. At times combined footings are also provided when loads are higher for low- to mid-rise buildings. In larger structures and heavy loadings, raft foundations are preferred in recent construction practice. In high-rise buildings, taller than 20 stories, deep foundations are also provided consisting of usually skin-friction piles.
Type of Floor System	Other floor system
Additional comments on floor system	Solid Slabs (Cast-in-Place) Flat Slabs (Cast-in-Place) Other: Floors/roofs are generally constructed in reinforced concrete and are monolithic with the load-resisting system (beams). Usually the thickness of roof slabs is 0.13 to 0.15 meters. Slabs are supported on their edges by beams which are cast

	monolithical with reinforced-concrete slabs.
Type of Roof System	Roof system, other
Additional comments on roof system	Floors/roofs are generally constructed in reinforced concrete and are monolithic with the load-resisting system (beams). Usually the thickness of roof slabs is 0.13 to 0.15 meters. Slabs are supported on their edges by beams which are cast monolithical with reinforced-concrete slabs.
Additional comments section 2	Since the major cities of Pakistan are located on flat terrain, it can be safely said that reinforced-concrete frame structures are most commonly found in flat areas. However, after the October 2005 earthquake and the reconstruction following in its wake, reinforced-concrete buildings are constructed in the hilly areas of Abbottabad and Mansehra, too, but their proportion in the total building stock is much less (not more than 1 to 2% of the total building stock) as compared to the major cities. Small residential buildings located in densely populated areas of cities do not have an appreciable distance between them but larger buildings do have a distance from 3 to 10 meters between them.



Plan of a typical reinforced-concrete building in Pakistan.



Elevation of a typical reinforced-concrete building in Pakistan.

Construction of building in progress.

Building Materials and Construction Process

Description of Building Materials

Structural Element	Building Material (s)	Comment (s)

Wall/Frame	Wall: Usually unreinforced brick masonry w alls are used in reinforced-concrete buildings, how ever, in some cities, like Karachi, scarcity of bricks has forced builders to use block masonry infill w alls. Masonry infill w alls are laid usually in cement-sand mortar.	Characteristic Strength: Brick masonry compression strength varies from 2 to 5 MPa. Mix Proportions/Dim.: 1:8 cement sand or 1:4: 4 cement, sand and stone dust. Brick size: 230 mm x 115 mm x 65 mm. w alls are usually 230 mm thick how ever in some instances half brick w alls having thickness of 115 mm are also provided as masonry infills.
Foundations	Concrete and steel.	Characteristic Strength: Concrete has a compressive strength of 17 to 21 MPa. Steel reinforcement has a yield strength of 275 to 415 MPa and a tensile strength of 480 to 625 MPa. Mix Proportions/Dim.: Concrete mix proportions of 1:2:4 (Cement, Sand, Coarse aggregate) are used for construction of foundations. Foundations are usually isolated column footings having an average w idth of 1.5 square meters w ith a thickness of 0.15 meters.
Floors	Floors and Roofs are usually constructed as reinforced concrete slabs w ith different configurations. Materials used for construction are concrete and reinforcing steel.	Characteristic Strength: Concrete has a compressive strength of 17 to 21 MPa. Yield strength of steel is in the range of 275 to 415 MPa and a tensile strength from 480 to 625 MPa. Mix Proportions/Dim.: Concrete has a compressive strength of 17 to 21 Mpa. Yield strength of steel is in the range of 275 to 415 MPa and a tensile strength from 480 to 625 MPa. Floors and roofs are

		usually 150 mm thick on average.
Roof	Floors and Roofs are usually constructed as reinforced concrete slabs w ith different configurations. Materials used for construction are concrete and reinforcing steel.	Characteristic Strength: Concrete has a compressive strength of 17 to 21 MPa. Yield strength of steel is in the range of 275 to 415 MPa and a tensile strength from 480 to 625 MPa. Mix Proportions/Dim.: Concrete has a compressive strength of 17 to 21 Mpa. Yield strength of steel is in the range of 275 to 415 MPa and a tensile strength from 480 to 625 MPa. Floors and roofs are usually 150 mm thick on average.
Other	Concrete and reinforcing steel are used for the construction of frame elements.	Characteristic Strength: Concrete has a compressive strength of 17 to 21 MPa. Yield strength of steel is in the range of 275 to 415 MPa and a tensile strength from 480 to 625 MPa. Mix Proportions/Dim.: A mix ratio generally used for concrete for the construction of frame elements is from 1:1.5:3 to 1:2:4, in w hich the former mix proportion at times is used for construction of columns w hile the later is most commonly used for construction of beams. Size of the members w ould primarily depend on the structural configuration and the loading that the system is subjected to. How ever, the average size of beams is from 305 mm and 460 mm (w idth and depth) to 380 mm and 760 mm. Columns are usually square w ith dimensions

		ranging from 305 mm x 305 mm to 460 mm x 460 mm.

Design Process

Who is involved with the design process?	EngineerArchitect
Roles of those involved in the design process	Since a lot of capital is involved in the construction of reinforced-concrete buildings, the owners hire the services of architects and structural engineers to carry out the architectural and structural design of the buildings. The role of engineers and architects for designing and construction of a reinforced-concrete building in Pakistan vary from project to project and from city to city. For projects of importance, it has been a usual practice to hire services of an architect for carrying out the architectural design while a structural designer would further design the agreed architecture of the building.
Expertise of those involved in the design process	The expertise of these professionals varies from city to city in Pakistan. If a project is of high importance, architects and structural engineers from other developed cities may also be employed for carrying out the designs.

Construction Process

Who typically builds this construction type?	MasonOther
Roles of those involved in the building process	Regarding execution of the construction activities, in good projects, the contractor may hire services of a site engineer or a group of engineers for supervising the construction activities, their number dependent on the spectrum of the project. In construction, there may be or may not be site engineers hired for supervising the construction.
Expertise of those involved in building process	Masons, steel fixers and other skilled workers rely solely on their experience gained over the years and are seldom trained professionally.
	Construction process of reinforced concrete buildings may be different for public and privately owned buildings. In case of public buildings, owned by government of Pakistan, the concerned line department both designs and supervise the construction itself or it may hire services of a private consulting agency to carry out the design

Construction process and phasing	and supervise the execution of construction activities. In case of privately owned reinforced concrete buildings, several possibilities have been observed. The owners may hire the services of an architect for carrying out the architectural design of the building. Architects would further hire services of a structural engineer to carry out the structural design. Usually execution of construction is carried out through a contractor who may either charge the owner through a BOQ (Bill of Quantities) or carry out the construction by providing with skilled workmen while the materials are supplied either by a third party or arranged by the owners themselves. The former procedure amongst the two is more common. The construction sequence involves the leveling of the work site, excavation of the foundation pits, pouring of lean concrete (1:4:8 or 1:8:16), placement of the formwork and tying of the reinforcing bars and finally pouring of concrete. This is further followed up by the construction of the stub columns and plinth beams (in some cases) and the construction of the columns. Beams are cast in place after the construction of the columns making sure that there is enough embedment of the column reinforcement into the beams. RCC slab follows the construction of the beams. Brick masonry infill walls are constructed after laying of the roof slab and finally plastering and other finishing works are carried out. The construction of this type of housing takes place in a single phase. Typically, the building is originally designed for its final constructed size. In well-planned construction, it is usually ensured that the actual construction would comply to the designed plans and structural configurations as provided by the design office. However, in some cases, the builders/owners may change the configuration of the building themselves. The usual changes incorporated in this way are covering up open spaces to increase living area, relocation of infill walls etc.
Construction issues	

Building Codes and Standards

Is this construction type address by codes/standards?	Yes
	This construction type is addressed by the codes/standards of the country. Building Code of Pakistan governs the design and construction of reinforced-concrete buildings in Pakistan. The year

Applicable codes or standards	the first code/standard addressing this type of construction issued was 2007. Building code of Pakistan 2007 (BCP 2007) is the code that is followed for design of reinforced-concrete buildings. However, since BCP 2007 is essentially UBC 97 except for seismic zonation that has been carried out indigenously, in true essence these buildings are designed in accordance with design specifications of UBC 97. The specifications usually referred to regarding materials are ASTM specifications which govern the quality assurance of steel, concrete, bricks etc. The most recent code/standard addressing this construction type issued was 2007. Building Code of Pakistan is typically used to design and construct these buildings.
Process for building code enforcement	Ideally the design and construction of reinforced concrete buildings should be governed by the building code of Pakistan. Every city has a building control authority that authorizes the construction after evaluating it. However this evaluation in most cases is limited to verification of the proposed design in light of the local building by-laws. In buildings of high importance, there has been a growing trend in the major cities of Karachi and Lahore to vet the structural designs too, though this practice is not common in the other cities. In government owned buildings, construction is either supervised by the nominated consultants or by the government organization itself which somehow ensures construction according to approved designs and specifications. On the other side, construction of reinforced concrete buildings owned privately, there usually is no supervision of construction quality by a building code enforcing agency. Summarizing it, it may be stated that designs are usually compliant to the building code of Pakistan while quality of construction vary and may not conform to the standard specifications.

Building Permits and Development Control Rules

Are building permits required?	Yes
Is this typically informal construction?	No
Is this construction typically authorized as per development control rules?	Yes

Additional comments on building permits and development control rules	Since reinforced-concrete buildings are mostly constructed in the urban areas of Pakistan which usually has a building control authority that governs the construction of buildings in that particular city. Therefore building permits are required to execute construction of these buildings.

Building Maintenance and Condition

Typical problems associated with this type of construction	
Who typically maintains buildings of this type?	Owner(s)Renter(s)
Additional comments on maintenance and building condition	Typically, the building of this housing type is maintained by Owner(s) and Tenant(s). Since these buildings are either sold to individual owners or rented out to tenants, maintenance of these buildings is carried out by either of these.

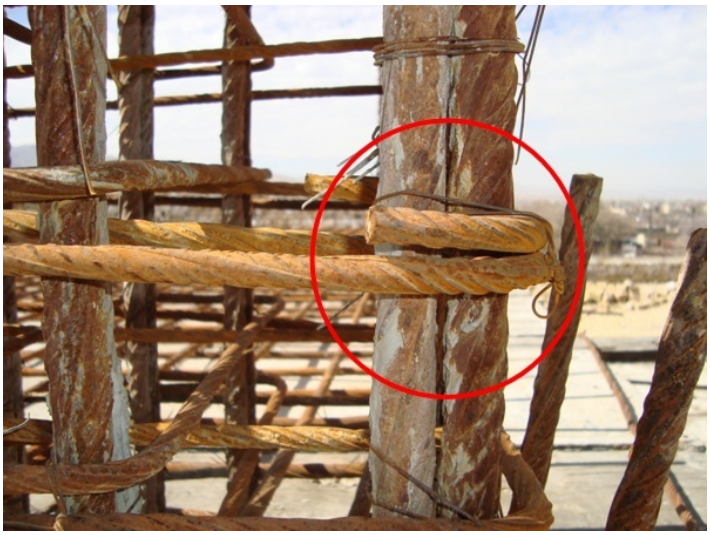
Construction Economics

Unit construction cost	Unit construction cost of reinforced concrete buildings in Pakistan is highly variable. The cost varies according to the location of the building to the amount of facilities provided in the building.
Labor requirements	10-15 persons working 8 hours a day can complete an approximately 280 square meter building in four months.
Additional comments section 3	

Manual batching of concrete may result in mix proportions different than the specified proportions.

Use of sub-standard formw orks result in concrete dimensions different than the designed dimensions.

Stomping of laborers over the reinforcement change its configuration thus hampering its intended function.



Lack of provision of seismic hooks despite follow ing the SMRF configuration may result in performance much low er than designed one.

Socio-Economic Issues

Patterns of occupancy	As these types of structures are used for residential, commercial and public services, the number of residents in these buildings may alter by quite an appreciable margin depending on the time of the day. The number of occupants residing in a residential multi-story reinforced-concrete building would depend on the size of the residential unit and the number of residential units in that building. Usually 4 to 6 residents reside in one building unit and depending on the size, the number of occupants in one building may reach in terms of hundreds. In reinforced-concrete buildings accommodating commercial and public facilities, there can be a higher variation in the number of people present in the building at a given time due to the nature of the use. The inhabitants in these buildings may reach into hundreds during the day while the number of occupants may trickle down to 5 to 10 residents during the night time. The lateral load-resisting system is reinforced concrete moment resisting frame. Different lateral load resisting systems are provided by structural

	designers in the reinforced-concrete buildings in Pakistan. Reinforced-concrete frames usually are either OMRF or IMRF. Very important buildings have SMRF configuration as well as in some cases dual systems are encountered, too. Reinforced-concrete frames usually have brick or block masonry infill walls which help contribute to the lateral load-resisting system.
Number of inhabitants in a typical building of this construction type during the day	>20
Number of inhabitants in a typical building of this construction type during the evening/night	>20
Additional comments on number of inhabitants	
Economic level of inhabitants	Middle-income classHigh-income class (rich)
Additional comments on economic level of inhabitants	Reinforced-concrete frame structures, if used as residential buildings, are normally constructed in areas which give the best access to the city center, hence the price of the single residential units are higher. However, due to the population burst in the recent past, buildings are being constructed in the suburbs of the main cities, too. However, since these buildings are developed by well-established builders with a better quality of construction, the price tag of these units is high. Therefore, the cost of a single residential unit is highly variable, depending upon the location of the building, the quality of construction, the size of the housing unit and the story it is located (lower stories tend to be expensive). Commercial buildings are usually constructed in the city center or close to it, where the cost of land is highly inflated. For this reason the cost of building units in reinforced-concrete buildings in these areas is very high.
Typical Source of Financing	Owner financedPersonal savingsGovernment-owned housing
	The most common source of financing for reinforced-concrete buildings is by the owner of the building which maybe private or government owned. In case of privately owned buildings, there may be multiple owners of the building if the cost of construction is too high. Reinforced-concrete buildings housing residential units are usually

Additional comments on financing	constructed by developers who subsequently either rent them out, or sell the individual housing units. In some cases, the builders would sell the individual units before they are constructed and use this capital to help construct the building. Buildings housing commercial facilities have a similar pattern of financing. Public buildings (owned by government of Pakistan) are owned and constructed by a government organization. In each housing unit, there are no bathroom(s) without toilet(s), no toilet(s) only and 2 bathroom(s) including toilet(s). It is normal in the architectural features of a building in Pakistan to provide a separate toilet with bathing facilities for each bedroom in a residential unit. Since each unit of a residential building houses 1 to 3 bedrooms, the number of bathrooms maybe 2 to 3. In reinforced-concrete buildings housing commercial facilities, there may be a collective toilet allocated to a particular number of commercial units or there may be toilets provided at each floor level for inhabitants of that floor. .
Type of Ownership	RentOwn outrightOwned by group or pool
Additional comments on ownership	The typical ownership is that either the owner of the building sells the ownership rights to the interested people or he puts out the individual housing units on rent. So these buildings are either owned by a single person or in many instances by multiple individuals who reside in these building units. The same pattern of ownership applies to buildings housing commercial facilities. In case of public buildings, they are used primarily for government offices and in some instances maybe rented out to commercial facilities.
Is earthquake insurance for this construction type typically available?	No
What does earthquake insurance typically cover/cost	Earthquake insurance is not available in Pakistan. In some instances, it may be available but building owners do not avail this facility.
Are premium discounts or higher coverages available for seismically strengthened buildings or new buildings built to incorporate seismically resistant features?	No
	For seismically strengthened existing buildings or new buildings incorporating seismically resilient

Additional comments on premium discounts	features, an insurance premium discount or more complete coverage is unavailable. Earthquake insurance is not available in Pakistan. In some instances, it may be available but building owners do not avail this facility.
Additional comments section 4	

Earthquakes

Past Earthquakes in the country which affected buildings of this type

Year	Earthquake Epicenter
1994	Hindu Kush
2002	Hindu Kush
2005	Kashmir

Past Earthquakes

Damage patterns observed in past earthquakes for this construction type	A low to moderate seismic activity has been active in many parts of Pakistan, especially in the Northwestern province, though the other parts of Pakistan had also experienced mild to severe intensity earthquakes in the past. In 1936, the earthquake with a magnitude of 8.1 on the Richter scale, that hit the capital of the Balochistan province, Quetta, resulted in a very high death toll (around 30,000 killed). But the usual seismic activity occurs in the northwestern part of Pakistan with the epicenter in range of 250 kilometers from the provincial metropolis, Peshawar. According to MSK, Peshawar may be placed in intensity zone VI or at most in VII, Islamabad in VI, and Lahore in V. In October 2005, a strong earthquake hit the upper northern parts of the NWFP province causing severe damage to buildings and resulted in loss of lives in the tune of 70,000.
Additional comments on earthquake damage patterns	

Structural and Architectural Features for Seismic Resistance

The main reference publication used in developing the statements used in this table is FEMA 310 “Handbook for the Seismic Evaluation of Buildings-A Pre-standard”, Federal Emergency Management Agency, Washington, D.C., 1998.

The total width of door and window openings in a wall is: For brick masonry construction in cement mortar : less than ½ of the distance between the adjacent cross walls; For adobe masonry, stone masonry and brick masonry in mud mortar: less than 1/3 of the distance between the adjacent cross walls; For precast concrete wall structures: less than 3/4 of the length of a perimeter wall.

Structural/Architectural Feature	Statement	Seismic Resistance
Lateral load path	The structure contains a complete load path for seismic force effects from any horizontal direction that serves to transfer inertial forces from the building to the foundation.	TRUE
Building Configuration-Vertical	The building is regular with regards to the elevation. (Specify in 5.4.1)	FALSE
Building Configuration-Horizontal	The building is regular with regards to the plan. (Specify in 5.4.2)	FALSE
Roof Construction	The roof diaphragm is considered to be rigid and it is expected that the roof structure will maintain its integrity, i.e. shape and form, during an earthquake of intensity expected in this area.	TRUE
Floor Construction	The floor diaphragm(s) are considered to be rigid and it is expected that the floor structure(s) will maintain its integrity during an earthquake of intensity expected in this area.	TRUE
Foundation Performance	There is no evidence of excessive foundation	TRUE

	movement (e.g. settlement) that would affect the integrity or performance of the structure in an earthquake.	
Wall and Frame Structures-Redundancy	The number of lines of walls or frames in each principal direction is greater than or equal to 2.	TRUE
Wall Proportions	Height-to-thickness ratio of the shear walls at each floor level is: Less than 25 (concrete walls); Less than 30 (reinforced masonry walls); Less than 13 (unreinforced masonry walls);	TRUE
Foundation-Wall Connection	Vertical load-bearing elements (columns, walls) are attached to the foundations; concrete columns and walls are doweled into the foundation.	TRUE
Wall-Roof Connections	Exterior walls are anchored for out-of-plane seismic effects at each diaphragm level with metal anchors or straps.	FALSE
Wall Openings		N/A
Quality of Building Materials	Quality of building materials is considered to be adequate per the requirements of national codes and standards (an estimate).	FALSE
Quality of Workmanship	Quality of workmanship (based on visual inspection of a few typical buildings) is considered to be good (per local construction standards).	FALSE
Maintenance	Buildings of this type are	FALSE

	generally well maintained and there are no visible signs of deterioration of building elements (concrete, steel, timber).

Building Irregularities

Additional comments on structural and architectural features for seismic resistance	
Vertical irregularities typically found in this construction type	Other
Horizontal irregularities typically found in this construction type	Other
Seismic deficiency in walls	
Earthquake-resilient features in walls	
Seismic deficiency in frames	Inadequate seismic design, sub-standard concrete quality, disparity between the specified design and actual layout of reinforcement, deficiency in the provision of clear cover in concrete, vertical alignment of columns is sometimes not ensured. Strong beam-weak column failures are the most common. In October 2005 Muzaffarabad earthquake, main failure was due to the formation of the plastic hinges just below the beam-column connection and at the base of the column.
Earthquake-resilient features in frame	Due to high redundancy, multiple load paths are available for efficient resistance of seismic forces, masonry infill w alls contribute to the lateral resisting system.
Seismic deficiency in roof and floors	Failure of the roof slabs and floors were not noticed in the Muzaffarabad 2005 earthquake. The roof slabs that failed were due to the additional demand that was a result of the failure of the adjoining frame elements.
Earthquake resilient features in roof and floors	The usual thickness of the roof slabs is 125 to 150 mm. These slabs have high stiffness and thus efficiently transfer the seismic loads to the concrete frames they are connected to.

Seismic deficiency in foundation	Seismic design of the isolated column footing is not usually considered. Though rarely any foundation failure were observed in the October 2005 Muzaffarabad earthquake. As such no damage of the foundations was observed in reinforced concrete structures during the past earthquakes in Pakistan.
Earthquake-resilient features in foundation	In some cases, plinth beams are provided to connect the individual spread footings. This practice results in a more efficient seismic performance of the RC frames.

Seismic Vulnerability Rating

For information about how seismic vulnerability ratings were selected see the Seismic Vulnerability Guidelines

	High vulnerability		**Medium vulnerability**		**Low vulnerability**	
	A	B	C	D	E	F
Seismic vulnerability class		-|	o	|-		

Typical damage pattern of strong beam-weak column in 2005 Kashmir earthquake.

Total structural collapse of reinforced-concrete building in 2005 Kashmir earthquake.

Global instability of a reinforced-concrete building during Kashmir 2005 earthquake.

Retrofit Information

Description of Seismic Strengthening Provisions

Structural Deficiency	Seismic Strengthening
Strong beam-weak column phenomenon	CFRP jacketing w as carried out on the columns to strengthen them (Figure 11)
Resizing of existing columns	Column sizes w ere increased to incorporate additional capacity into the system (Figure 12)

Additional comments on seismic strengthening provisions	Seismic strengthening is usually carried out in accordance with the Building Code of Pakistan.
Has seismic strengthening described in the above table been performed?	Pakistan has been struck by many earthquakes ranging from mild to high intensities but there have been no records of the damages incurred by the buildings. The practice of retrofitting or strengthening has not been prevalent in Pakistan. People prefer to raze down the buildings and reconstruct them. This can be attributed to lack of research and absence of skilled engineers working in the field of seismic retrofitting and strengthening. However, in recent times, especially in the areas severely affected by the 2005 earthquake, several projects have been carried out to retrofit schools

	and hospital buildings, but on a larger scale usually no retrofitting is carried out.
Was the work done as a mitigation effort on an undamaged building or as a repair following earthquake damages?	This work was carried out as a repair work after the Kashmir 2005 earthquake.
Was the construction inspected in the same manner as new construction?	
Who performed the construction: a contractor or owner/user? Was an architect or engineer involved?	Strengthening was carried out by structural engineers from Earthquake Engineering Centre, University of Engineering & Technology, Peshawar
What has been the performance of retrofitted buildings of this type in subsequent earthquakes?	There has been no earthquake of appreciable damage potential since this work was carried out to assess the performance of the strengthened building.
Additional comments section 6	

CFRP jacketing is used in some buildings to strengthen the existing columns.

Resizing (widening) of the columns are carried out to increase the potential of the structural system.

References

A critical review of the seismic risk zoning and development of design spectra for Peshawar and adjoining areas Qaisar Ali and Akhtar Naeem Khan 13th World Conference on Earthquake Engineering, Vancouver, B.C., Canada 2004

Seismic performance study of brick masonry building systems in Peshawar region Qaisar Ali

Observed Seismic Behavior of Buildings in Northern Pakistan During the 2005 Kashmir Earthquake Amjad Naseer, Akhtar Naeem Khan, Zakir Hussain, and Qaisar Ali Earthquake Spectra 2010 26

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