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HOUSING REPORT
Reinforced concrete buildings in Pakistan

Report #	159
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Country	PAKISTAN
Housing Type	RC Moment Frame Building
Housing Sub-Type	RC Moment Frame Building : Designed for seismic effects, with URM infills
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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 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. 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.

1. General Information

Buildings of this construction type can be found in the urban areas of the major cities being the hub of this kind of construction. Construction of reinforced-concrete buildings is on the rise in the cities of Peshawar, Islamabad, Lahore, Faisalabad and Karachi. This is mainly due to the better economic conditions in these cities, higher population as well as high land costs. In the sub-urban cities, reinforced concrete buildings are constructed, however, their primary function is to accommodate commercial facilities and they are not usually taller than 3 to 4 stories. Percentage of reinforced-concrete buildings in the sub-urban areas is low (1 to 2% of the total building stock). This type of housing construction is commonly found in urban areas.

Reinforced concrete buildings are most commonly constructed in the urban regions of Pakistan. However, it is not uncommon to see reinforced-concrete structures in the sub-urban cities too, though in the majority of the cases, their use is confined to commercial purposes (hotels, shopping centers etc). Major cities of Pakistan have seen rise in the construction of reinforced concrete frame structures in the past two decades. This rise in construction of reinforced-concrete structures can be attributed to the improvement in the economic conditions of the people as well as awareness of the fact that these are a better alternative as compared to traditional unreinforced brick masonry load bearing structures in many aspects, particularly in performance during earthquakes. Since there has been a population burst in Pakistan in the past couple of decades, the land prices have risen appreciably. This has forced builders to adapt to reinforced concrete structures as residential units in addition to their previous role of accommodating commercial facilities. In the other major cities, like Islamabad and Lahore etc., about 10% to 15% buildings are being constructed as reinforced concrete, though commercial and public buildings like plazas, hotels, hospitals, educational institutions etc. constitute the major portion of this percentage. Reinforced concrete structures in these cities are usually low-to-mid rise (3 to 8 stories) however in exceptional cases, reinforced-concrete buildings as tall as 10 to 15 stories are being constructed nowadays. In the relatively less developed cities like Peshawar, Quetta, Faisalabad etc. the ratio of reinforced-concrete buildings of the overall building stock may be lesser, a careful estimate being approximately 5% and they are primarily used for housing commercial and public facilities. Reinforced-concrete buildings in these cities are also low-to-mid rise (3 to 8 stories) with a story height of 3 to 3.35 meters. In Karachi, the percentage of reinforced-concrete structures amongst the total building stock is higher (15 to 20% of the total building stock). Usually reinforced-concrete buildings in Karachi are from 15 to 20 stories tall with a story height of 3 to 3.35 meters. This higher percentage of reinforced-concrete buildings in Karachi may be attributed to the high population and the fact that Karachi is the business hub for economic activities.

This construction type has been in practice for less than 25 years.

Currently, this type of construction is being built. Reinforced-concrete buildings have been constructed in Pakistan for more than 25 years but their percentage has been very low during that time. In the recent past, construction of reinforced concrete buildings has been on the rise, especially in the national capital and the provincial capitals.

2. Architectural Aspects

2.1 Siting

These buildings are typically found in flat terrain. They do not share common walls with adjacent buildings. 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 When separated from adjacent buildings, the typical distance from a neighboring building is 3 to 10 meters.

2.2 Building Configuration

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. The infills used in reinforced-concrete frames are usually constructed in brick and block masonry. 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.

2.3 Functional Planning

The main function of this building typology is mixed use (both commercial and residential use). Other use is for public buildings like hospitals or schools etc. Reinforced-concrete structures are primarily used to accommodate commercial and public facilities such as hotels, shopping malls, hospitals, schools etc. In the recent past, reinforced-concrete buildings have started to be used to accommodate residential apartments, too, while in some cases one building may be used for both commercial and residential purposes. The number of apartments in a building would primarily depend on the overall area of a particular building. Each of these apartments usually accommodates a single family (on average consisting of four persons). In a typical building of this type, there are 1-2 elevators and no fire-protected exit staircases. Access to the upper floors in reinforced-concrete buildings is provided through stairs or in some cases lifts. The number of stairways primarily depends on the area of the building. In the majority of reinforced-concrete buildings, there usually is no concept of provision of emergency escape routes so in case of any emergency these stairs are the only means of escape from these buildings. Stairs have a width of 1.2 to 1.5 meters, however in some cases, smaller widths as low as 1 meter have been observed.

2.4 Modification to Building

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.

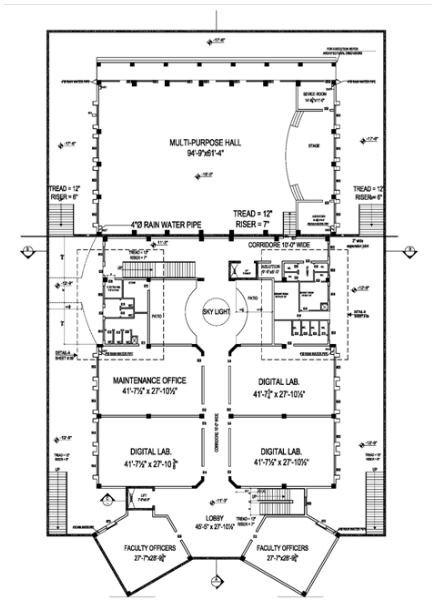

Figure 1: Plan of a typical reinforced-concrete building in Pakistan.

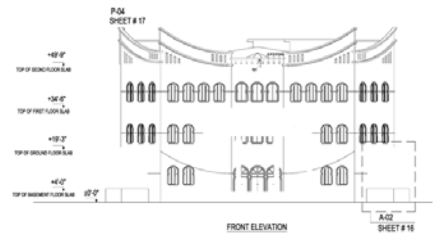

Figure 2: Elevation of a typical reinforced-concrete building in Pakistan.


Figure 3: Construction of building in progress.

3. Structural Details

3.1 Structural System

Material	Type of Load-Bearing Structure	#	Subtypes	Most appropriate type
Masonry	Stone Masonry Walls	1	Rubble stone (field stone) in mud/lime mortar or without mortar (usually with timber roof)	☐
		2	Dressed stone masonry (in lime/cement mortar)	☐
	Adobe/ Earthen Walls	3	Mud walls	☐
		4	Mud walls with horizontal wood elements	☐
		5	Adobe block walls	☐
		6	Rammed earth/Pise construction	☐
	Unreinforced masonry walls	7	Brick masonry in mud/lime mortar	☐
		8	Brick masonry in mud/lime mortar with vertical posts	☐
		9	Brick masonry in lime/cement mortar	☐
		10	Concrete block masonry in cement mortar	☐
	Confined masonry	11	Clay brick/tile masonry, with wooden posts and beams	☐
		12	Clay brick masonry, with concrete posts/tie columns and beams	☐
		13	Concrete blocks, tie columns and beams	☐
	Reinforced masonry	14	Stone masonry in cement mortar	☐
		15	Clay brick masonry in cement mortar	☐
		16	Concrete block masonry in cement mortar	☐
		17	Flat slab structure	☐

Structural concrete	Moment resisting frame	18	Designed for gravity loads only, with URM infill walls	☐
		19	Designed for seismic effects, with URM infill walls	☑
		20	Designed for seismic effects, with structural infill walls	☐
		21	Dual system – Frame with shear wall	☐
	Structural wall	22	Moment frame with in-situ shear walls	☐
		23	Moment frame with precast shear walls	☐
	Precast concrete	24	Moment frame	☐
		25	Prestressed moment frame with shear walls	☐
		26	Large panel precast walls	☐
		27	Shear wall structure with walls cast-in-situ	☐
		28	Shear wall structure with precast wall panel structure	☐
Steel	Moment-resisting frame	29	With brick masonry partitions	☐
		30	With cast in-situ concrete walls	☐
		31	With lightweight partitions	☐
	Braced frame	32	Concentric connections in all panels	☐
		33	Eccentric connections in a few panels	☐
	Structural wall	34	Bolted plate	☐
		35	Welded plate	☐
Timber	Load-bearing timber frame	36	Thatch	☐
		37	Walls with bamboo/reed mesh and post (Wattle and Daub)	☐
		38	Masonry with horizontal beams/planks at intermediate levels	☐
		39	Post and beam frame (no special connections)	☐
		40	Wood frame (with special connections)	☐
		41	Stud-wall frame with plywood/gypsum board sheathing	☐
		42	Wooden panel walls	☐
Other	Seismic protection systems	43	Building protected with base-isolation systems	☐
		44	Building protected with seismic dampers	☐
	Hybrid systems	45	other (described below)	☐

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).

3.2 Gravity Load-Resisting 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.

3.3 Lateral Load-Resisting System

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.

3.4 Building Dimensions

The typical plan dimensions of these buildings are: lengths between 10 and 40 meters, and widths between 10 and 20 meters. The building has 3 to 8 storey(s). The typical span of the roofing/flooring system is 3 to 6 meters. The typical plan dimensions may be different than the mentioned spans depending on the nature of the building. In some commercial buildings, spans as small as 3 meters have been observed. Construction joints are provided usually after 30 meters in one direction if the building size is larger. Number of stories varies from city to city and building to building. In the less developed cities of Peshawar, Faisalabad and Quetta etc., reinforced-concrete buildings are low- to mid-rise (3 to 8 stories with a story height of about 3 meters). In the well-developed cities like Lahore and Islamabad, reinforced-concrete buildings are mid-to-high rise, usually 8 to 15 stories on average. Reinforced-concrete buildings in Karachi are usually high rise, an average number of stories being 15 and in many cases even taller (25 to 30 stories). The typical storey height in such buildings is 3 meters. The typical structural wall density is none. .

3.5 Floor and Roof System

Material	Description of floor/roof system	Most appropriate floor	Most appropriate roof
Masonry	Vaulted	☐	☐
	Composite system of concrete joists and masonry panels	☐	☐
Structural concrete	Solid slabs (cast-in-place)	☑	☑
	Waffle slabs (cast-in-place)	☐	☐
	Flat slabs (cast-in-place)	☑	☑
	Precast joist system	☐	☐
	Hollow core slab (precast)	☐	☐
	Solid slabs (precast)	☐	☐
	Beams and planks (precast) with concrete topping (cast-in-situ)	☐	☐
	Slabs (post-tensioned)	☐	☐
Steel	Composite steel deck with concrete slab (cast-in-situ)	☐	☐
Timber	Rammed earth with ballast and concrete or plaster finishing	☐	☐
	Wood planks or beams with ballast and concrete or plaster finishing	☐	☐
	Thatched roof supported on wood purlins	☐	☐
	Wood shingle roof	☐	☐
	Wood planks or beams that support clay tiles	☐	☐
	Wood planks or beams supporting natural stones slates	☐	☐
	Wood planks or beams that support slate, metal, asbestos-cement or plastic corrugated sheets or tiles	☐	☐
	Wood plank, plywood or manufactured wood panels on joists supported by beams or walls	☐	☐
Other	Described below	☑	☑

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.

3.6 Foundation

Type	Description	Most appropriate type
Shallow foundation	Wall or column embedded in soil, without footing	☐
	Rubble stone, fieldstone isolated footing	☐
	Rubble stone, fieldstone strip footing	☐
	Reinforced-concrete isolated footing	☑
	Reinforced-concrete strip footing	☑
	Mat foundation	☑
	No foundation	☐
Deep foundation	Reinforced-concrete bearing piles	☐
	Reinforced-concrete skin friction piles	☑
	Steel bearing piles	☐
	Steel skin friction piles	☐
	Wood piles	☐
	Cast-in-place concrete piers	☐
	Caissons	☐
Other	Described below	☐

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.

4. Socio-Economic Aspects

4.1 Number of Housing Units and Inhabitants

Each building typically has 21-50 housing unit(s). The number of housing units in a reinforced-concrete building primarily depends on the size of the building and the function of the building (residential, commercial or public building). The usual number of housing units in an average sized reinforced-concrete building used for residential purposes is from 20 to 50. Reinforced-concrete buildings housing commercial facilities may have more commercial units since they require relatively less space for their establishment. Generally, an average sized reinforced-concrete building may house 60 to 80 commercial facilities. On the other hand, public buildings in the form of reinforced-concrete buildings may have 40 to 50 offices located in them for an average sized building. The number of inhabitants in a building during the day or business hours is more than 20. Depending on the nature of the building, the number of residents is highly variable. The total number of occupants during the day time tend to be lower as compared to the occupants at night time. The number of inhabitants during the evening and night is more than 20. 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.

4.2 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.

4.3 Economic Level of Inhabitants

Income class	Most appropriate type
a) very low-income class (very poor)	☐
b) low-income class (poor)	☐
c) middle-income class	☑
d) high-income class (rich)	☑

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.

Ratio of housing unit price to annual income	Most appropriate type
5:1 or worse	☑
4:1	☐
3:1	☐
1:1 or better	☐

What is a typical source of financing for buildings of this type?	Most appropriate type
Owner financed	☑
Personal savings	☑
Informal network: friends and relatives	☐
Small lending institutions / micro-finance institutions	☐
Commercial banks/mortgages	☐
Employers	☐
Investment pools	☐
Government-owned housing	☑
Combination (explain below)	☐
other (explain below)	☐

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 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. .

4.4 Ownership

The type of ownership or occupancy is renting, outright ownership , individual ownership and ownership by a group or pool of persons.

Type of ownership or occupancy?	Most appropriate type
Renting	☑
outright ownership	☑
Ownership with debt (mortgage or other)	☐
Individual ownership	☑
Ownership by a group or pool of persons	☑
Long-term lease	☐
other (explain below)	☐

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.

5. Seismic Vulnerability

5.1 Structural and Architectural Features

Structural/ Architectural Feature	Statement	Most appropriate type		
		Yes	No	N/A
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.	☑	☐	☐
Building Configuration	The building is regular with regards to both the plan and the elevation.	☐	☑	☐
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.	☑	☐	☐
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.	☑	☐	☐

Foundation performance	There is no evidence of excessive foundation 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.	☑	☐	☐
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);	☑	☐	☐
Foundation-wall connection	Vertical load-bearing elements (columns, walls) are attached to the foundations; concrete columns and walls are doweled into the foundation.	☑	☐	☐
Wall-roof connections	Exterior walls are anchored for out-of-plane seismic effects at each diaphragm level with metal anchors or straps	☐	☑	☐
Wall openings	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.	☐	☐	☑
Quality of building materials	Quality of building materials is considered to be adequate per the requirements of national codes and standards (an estimate).	☐	☑	☐
Quality of workmanship	Quality of workmanship (based on visual inspection of few typical buildings) is considered to be good (per local construction standards).	☐	☑	☐
Maintenance	Buildings of this type are generally well maintained and there are no visible signs of deterioration of building elements (concrete, steel, timber)	☐	☑	☐
Additional Comments				

5.2 Seismic Features

Structural Element	Seismic Deficiency	Earthquake Resilient Features	Earthquake Damage Patterns
Frame (columns, beams)	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.	Due to high redundancy, multiple load paths are available for efficient resistance of seismic forces, masonry infill walls contribute to the lateral resisting system.	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.
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.	As such, 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.
Foundations	Seismic design of the isolated column footing is not usually considered. Though rarely any foundation failure were observed in the October	In some cases, plinth beams are provided to connect the individual spread footings. This practice results	As such no damage of the foundations was observed in reinforced concrete structures during the past earthquakes in Pakistan.

	2005 Muzaffarabad earthquake.	in a more efficient seismic performance of the RC frames.	

During the past earthquakes, especially the Kashmir 2005 earthquake, almost all types of construction were heavily damaged. Mostly damaged was the load-bearing brick masonry structures and stone masonry residential buildings. Reinforced-concrete buildings failed too in many places, especially the worst hit areas of Abbottabad and Mansehra and even in the national capital, Islamabad. Deficiency in the construction materials (concrete, improper placement of the reinforcement etc.) and strong beam-weak column phenomena were the main reasons for the failure of the RC frame structures. These local failures caused global instability in the structural system. Typical damage patterns of reinforced concrete are given in Figures 4, 5 and 6.

5.3 Overall Seismic Vulnerability Rating

The overall rating of the seismic vulnerability of the housing type is C: MEDIUM VULNERABILITY (i.e., moderate seismic performance), the lower bound (i.e., the worst possible) is B: MEDIUM-HIGH VULNERABILITY (i.e., poor seismic performance), and the upper bound (i.e., the best possible) is D: MEDIUM-LOW VULNERABILITY (i.e., good seismic performance).

Vulnerability	high	medium-high	medium	medium-low	low	very low
	very poor	poor	moderate	good	very good	excellent
Vulnerability Class	A	B	C	D	E	F
	☐	☑	☐	☑	☐	☐

5.4 History of Past Earthquakes

Date	Epicenter, region	Magnitude	Max. Intensity
1994	Hindu Kush	6.5	V
2002	Hindu Kush	6.3	V
2005	Kashmir	7.6	VI-VIII

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.

Figure 4: Typical damage pattern of strong beam-weak column in 2005 Kashmir earthquake.

Figure 5: Total structural collapse of reinforced-concrete building in 2005 Kashmir earthquake.

Figure 6: Global instability of a reinforced-concrete building during Kashmir 2005 earthquake.

6. Construction

6.1 Building Materials

Structural element	Building material	Characteristic strength	Mix proportions/dimensions	Comments
Walls	Usually unreinforced brick masonry walls are used in reinforced-concrete buildings, however, in some cities, like Karachi, scarcity of bricks has forced builders to use block masonry infill walls. Masonry infill walls are laid usually in cement-sand mortar.	Brick masonry compression strength varies from 2 to 5 MPa.	1:8 cement sand or 1:4: 4 cement, sand and stone dust. Brick size: 230 mm x 115 mm x 65 mm. walls are usually 230 mm thick however in some instances half brick walls having thickness of 115 mm are also provided as masonry infills.	
Foundation	Concrete and steel.	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.	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 width of 1.5 square meters with a thickness of 0.15 meters.	
Frames (beams & columns)	Concrete and reinforcing steel are used for the construction of frame elements.	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.	A mix ratio generally used for concrete for the construction of frame elements is from 1:1.5:3 to 1:2:4, in which the former mix proportion at times is used for construction of columns while the later is most commonly used for construction of beams. Size of the members would primarily depend on the structural configuration and the loading that the system is subjected to. However, the average size of beams is from 305 mm and 460 mm (width and depth) to 380 mm and 760 mm. Columns are usually square with dimensions ranging from 305 mm x 305 mm to 460 mm x 460 mm.	
Roof and floor(s)	Floors and Roofs are usually constructed as reinforced concrete slabs with different configurations. Materials used for construction are concrete and reinforcing steel.	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.	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.	

6.2 Builder

Regarding the residents of reinforced-concrete buildings in Pakistan, as stated earlier, these buildings are constructed either by government, a single owner or a consortium. Government buildings are mostly used for housing government offices, however in some cases these buildings may be used for dual purpose of accommodating government offices as well as some commercial facilities like shops or gathering halls etc. If these buildings are constructed privately by a single owner, he would either sell the building units (commercial or residential) to interested parties or may rent these out. Buildings constructed by conglomerates are usually sold to the users.

6.3 Construction Process, Problems and Phasing

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 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.

6.4 Design and Construction Expertise

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 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. 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. Masons, steel fixers and other skilled workers rely solely on their experience gained over the years and are seldom trained professionally. 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. In construction, there may be or may not be site engineers hired for supervising the construction.

6.5 Building Codes and Standards

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 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.

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.

6.6 Building Permits and Development Control Rules

This type of construction is an engineered, and authorized as per 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 permits are required to build this housing type.

6.7 Building Maintenance

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.

6.8 Construction Economics

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. 10-15 persons working 8 hours a day can complete an approximately 280 square meter building in four months.


Figure 7: Manual batching of concrete may result in mix proportions different than the specified proportions.


Figure 8: Use of sub-standard formworks result in concrete dimensions different than the designed dimensions.


Figure 9: Stomping of laborers over the reinforcement change its configuration thus hampering its intended function.


Figure 10: Lack of provision of seismic hooks despite following the SMRF configuration may result in performance much lower than designed one.

7. Insurance

Earthquake insurance for this construction type is typically unavailable. For seismically strengthened existing buildings or new buildings incorporating seismically resilient 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.

8. Strengthening

8.1 Description of Seismic Strengthening Provisions

Strengthening of Existing Construction :

Seismic Deficiency	Description of Seismic Strengthening provisions used
Strong beam-weak column phenomenon	CFRP jacketing was carried out on the columns to strengthen them (Figure 11)
Resizing of existing columns	Column sizes were increased to incorporate additional capacity into the system (Figure 12)

Seismic strengthening is usually carried out in accordance with the Building Code of Pakistan.

8.2 Seismic Strengthening Adopted

Has seismic strengthening described in the above table been performed in design and construction practice, and if so, to what extent?
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 repair following an earthquake?
This work was carried out as a repair work after the Kashmir 2005 earthquake.

8.3 Construction and Performance of Seismic Strengthening

Who performed the construction seismic retrofit measures: 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 was 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.

Figure 11: CFRP jacketing is used in some buildings to strengthen the existing columns.

Figure 12: Resizing (widening) of the columns are carried out to increase the potential of the structural system.

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