World Housing Encyclopedia

an Encyclopedia of Housing Construction in
Seismically Active Areas of the World

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HOUSING REPORT
Reinforced concrete frame building with masonry infills

Report #	64
Report Date	05-06-2002
Country	TURKEY
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

Approximately 80 percent of Turkey's urban households live in mid-rise apartment blocks constructed of cast-in-situ, reinforced concrete with masonry infill. The vertical structure consists of columns 200-300 mm in thickness, longer in one direction than in the other, and

designed to fit within the walls. Floor and roof slabs are of "filler slab" construction, with hollow clay or concrete tiles used to form the voids, and are usually supported by reinforced concrete beams. In some cases the framing is flat-slab construction. The reinforced concrete frame is infilled with hollow-tile or masonry-block walls which are rarely connected structurally to the frame. These buildings have not performed well in recent earthquakes because poor design and construction have resulted in insufficient lateral resistance in the framing system. In many cases, this has been coupled with an inappropriate building form. Notwithstanding the existence of earthquake-resistant design codes for more than 30 years, many buildings have not been designed for an earthquake of a magnitude that could occur within the building's lifetime.

1. General Information

Buildings of this construction type can be found in entire Turkey. The majority of Turkey's urban population lives in multi-story apartment blocks constructed of reinforced concrete. Statistics on urban housing compiled from State Institute of Statistics sources indicate that in the three largest cities (Istanbul, Izmir, and Ankara) over 50 percent of the buildings in existence today are of reinforced concrete frame construction, and over 75 percent of these are of more than three stories. Some 80 percent of urban households therefore live in these mid-rise apartment blocks. The annual increment over recent years is even more heavily dominated by mid-rise reinforced concrete frame construction-perhaps over 90 percent of new housing units have been built this way. This type of housing construction is commonly found in urban areas.

There are many of these buildings in suburban areas. Areas previously considered rural exhibit poorly crafted imitations of this type in recent times.

This construction type has been in practice for less than 50 years.

Currently, this type of construction is being built. The building type discussed here is a product of about the last 40-50 years.

Figure 1: Typical Building

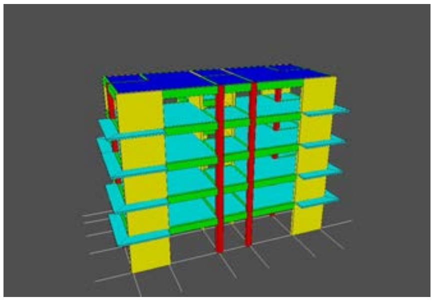

Figure 2: Key Load-Bearing Elements

2. Architectural Aspects

2.1 Siting

These buildings are typically found in flat terrain. They do not share common walls with adjacent buildings. When separated from adjacent buildings, the typical distance from a neighboring building is 6 meters.

2.2 Building Configuration

Most would be rectangular or nearly so. Where dictated by land parcellation patterns, every conceivable shape may be encountered. See Item 1.4. Depending on climate, much window area may be provided in these houses that are typically not well insulated. In many urban areas these sit in adjacent plots with only a separation joint between them, but more common pattern is alone-standing buildings with some 6 m separation.

2.3 Functional Planning

The main function of this building typology is multi-family housing. In many Turkish municipalities, particularly in those where rapid economic growth has been registered within the last twenty years or so, the zoning ordinances and master plans prepared by the town planning departments have been overtaken by the dynamics of urban growth. Changing circumstances occur faster than planning responses can be put into action. This in effect has resulted in a planning environment that follows, rather than dictates, patterns of urban development. Zones defined in master plans cannot be maintained as their intended categories, with many zones being transformed into ill-defined mixed-use areas. Even further removed from the formal planning process are the informal settlements where almost no building quality measures can be enacted. In many metropolitan areas the most dangerous sites, steep and unstable hills, stream gullies, riverbeds and environmentally hazardous areas have been covered with runaway settlements. The human and material losses of a severe hazard affecting these areas are likely to be very high. In a typical building of this type, there are no elevators and 1-2 fire-protected exit staircases. The common type of access/exit for a one- or multistory building is through a single door. Except for isolated recent construction no additional exit stair besides the main stairs exists.

2.4 Modification to Building

Objectionable forms of arbitrarily executed structural modifications are encountered. The most common type among these is the building of additional stories above the existing framing, usually either in response to municipal ordinance amendments relaxing building height limitations, or by accumulation of funds by owners to build on top of what already exists. Removal of columns or bearing walls to connect adjoining flats, connecting new stairs, or elimination of vertical continuity by punching openings in walls are examples of this.

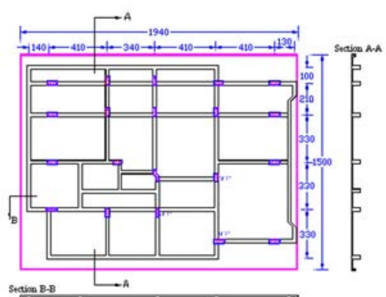

Figure 3A: Plan of a Typical Building - Example of a Five-story Building, Containing Two Residential Units Per Floor (EERI 2000)

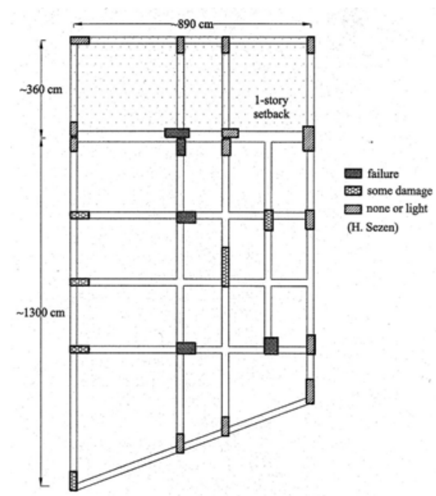

Figure 3B: Typical Plan Illustrating Damaged Columns in Lowest Floor of a Five-Story Building in Adapazari (EERI 2000)

3. Structural Details

3.1 Structural System

Material	Type of Load-Bearing Structure	#	Subtypes	Most appropriate type
	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)	☐
		3	Mud walls	☐

Masonry	Adobe/ Earthen 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	☐
Structural concrete	Moment resisting frame	17	Flat slab structure	☐
		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	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	☐

	frame		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)	☐

The most common structural system for this housing type is #16: "Frame with unreinforced masonry infill walls". However, some buildings of this type could be characterized with other structural types summarized in the table above. In some cases, the structural system is "Flat slab structure" (type #17), or (rarely) " frame with concrete shear walls - dual system" (type #19). Tunnel form reinforced concrete building have also become more common during the last 20 years. As this construction practice has been followed in Turkey in the last 50 years, older buildings of this type were designed for gravity loads only (type #14) i.e. without seismic considerations, whereas the more recent construction was (or has been expected to be) designed with seismic features (type #15).

3.2 Gravity Load-Resisting System

The vertical load-resisting system is others (described below). Features of the gravity load bearing system are described under Section 4.1.

3.3 Lateral Load-Resisting System

The lateral load-resisting system is others (described below). A typical construction consists of RC slabs cast monolithically with RC beam and column framing. Masonry infill is mortared in place to form partition walls. Buildings are typically 3 to 7 stories, and are frequently built incrementally mostly without elevators. Although not explicitly part of the design, the infill often contributes to the building's strength. The use of the lowest floor for commercial purposes creates soft stories. First and upper floors are commonly cantilevered out from the ground floor, resulting in undesirable framing arrangements. Large window openings and cantilevered balconies are common. Foundations are usually comparatively shallow, consisting of spread footings under individual columns or of strips joining lines of columns. Design shortcomings contribute to the increase in seismic demand and poor lateral resistance. The cantilevered upper stories place the outer skin of stiff and brittle infill walls out of the plane of the structural frame. This, together with the common practice of omitting walls at the ground floor, triggers a large eccentric dynamic loading on the bare frame at the ground-floor level, causing weak- story collapses. Also, the quality of the concrete and the poor detailing of the reinforcement detract from the ductility required by the frame to resist repeated cycles. Much of the damage observed in the 1999 Kocaeli and Duzce earthquakes was triggered by the failure of the frame connections of the ground-floor columns. Typical Dimensions, Details, Construction Methods, and Material Properties (1) Plan dimensions vary considerably. Story heights are typically between 2.7 to 3 m, except for the lowest story which may be 3.5 or 4.5 m. (2) Reinforced-concrete floor slabs are typically 10 to 12 cm thick. The slabs are supported on beams that often are 50 to 60 cm deep (including the slab) and 20 to 25 cm wide. Irregular beam spans range between 3 to 6 m, owing to irregular column spacing. In poorly constructed buildings, beam reinforcement usually consists of 3 to 4 longitudinal bars ranging from 12 to 16 mm in diameter. Typically, the middle bars are bent diagonally near the gravity-load inflection points to serve as bottom bars near midspan and as top bars near the supports (Fig. 6n). Transverse stirrups usually are 6 to 10 mm in diameter and are spaced uniformly at 20 to 25 cm along the beam; the ends of each stirrup usually terminate with 90° hooks. (3) Architectural and gravity-load considerations lead to irregular column arrangements. Most columns have rectangular cross sections contained within flat wall surfaces, as illustrated in Fig. 4a and in the sample plans shown in Fig. 3 and 3a. The beams may frame into the columns eccentrically (Fig. 6n and 6p). The irregular orientations can create substantial disparities in the lateral resistance provided in orthogonal horizontal directions. Where beams frame into the narrow side of the column, the outermost longitudinal beam bars pass outside the column cage in some cases, leaving them anchored only in the joint cover concrete (Fig. 6p). Nearly all reinforcement in local construction is smooth. Reinforcement is routinely bent into a "U" shape (Fig. 4d). (4) Roofs usually consist of wood rafters and wood sheathing over a horizontal RC slab (Fig. 6). Foundations typically consist of either interconnected RC grade beams or a heavy mat slab (Fig. 4a). (5) Typical wood forms and shoring are shown in Fig. 4e. Concrete for the beams, slab, and column below is usually placed all at once so that forms can be advanced one story at a time. Concrete quality is quite variable. Segregation and honeycombing are common in older construction, and the largest aggregates often are no larger than about 1 cm in size. (6) The most common masonry infill material is red hollow clay tile. A typical tile block is 19 cm long and has a 13.5 by 19 cm cross section (Fig. 4d). In recent years, lightweight autoclaved, aerated concrete block has been used in place of hollow day tiles.

3.4 Building Dimensions

The typical plan dimensions of these buildings are: lengths between 12 and 12 meters, and widths between 18 and 18 meters. The building has 3 to 7 storey(s). The typical span of the roofing/flooring system is 6.5 meters. Typical Plan Dimensions: They feature a great deal of variability. Typical Story Height: Usually typical story height is from 2.7 to 3 meters. Typcial Span: Typical span varies from 4.5 to 6.5 meters. The typical storey height in such buildings is 3 meters. The typical structural wall density is up to 5 %. Masonry wall density (walls constructed of hollow day units) ranges: 0.02-0.06.

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	☑	☑

Structural analysis is usually done with the assumption that floor systems form rigid diaphragms.

3.6 Foundation

Type	Description	Most appropriate type
	Wall or column embedded in soil, without footing	☐
	Rubble stone, fieldstone isolated footing	☐
	Rubble stone, fieldstone strip footing	☐

Shallow foundation	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	☐

Foundations are usually comparatively shallow, consisting of spread footings under individual columns or strips joining lines of columns. Piling is rarely used for buildings of this height.


Figure 4A: Critical Structural Details - Irregular Column Orientations and Layout (EERI 2000)


Figure 4B: Critical Structural Details - Heavy Mat Slab Foundation (EERI 2000)


Figure 4C: Critical Structural Details - Smooth Reinforcing Steel Delivered to a Construction Site Bent into a "U" Shape (no material certification provided) (EERI 2000)

Figure 4D: Critical Structural Details - Wooden Roofs Over Reinforced Concrete Beam-Column Framing (EERI 2000)

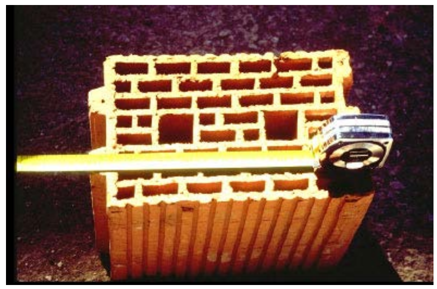

Figure 4E: Critical Structural Details - Typical Hollow Clay Tile Infill Block (EERI 2000)

Figure 5: Key Seismic Deficiencies - A Weak-Story Mechanism Developed at the First Floor (the case of the lowest floor used for commerical purposes and lacking the stiffness provided by the infill at the upper floors (EERI 2000)

4. Socio-Economic Aspects

4.1 Number of Housing Units and Inhabitants

Each building typically has 10-20 housing unit(s). 12 units in each building. This is the same as Item 3.1 The number of inhabitants in a building during the day or business hours is 5-10. The number of inhabitants during the evening and night is 11-20.

4.2 Patterns of Occupancy

Typically, the number of families occupying a typical residential building ranges from 6 to 12. In some cases this may be as many as 20 or more.

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)	☑

Economic Level: For Middle Class the Housing Price Unit is 25000 and the Annual Income is 8000.

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)	☐

As a general rule banks do not provide for housing mortgage, at least for the social segment considered here. A residence may be purchased with cash up front, or acquired as a deal where land is exchanged with a developer for residence/business units. In each housing unit, there are no bathroom(s) without toilet(s), 1 toilet(s) only and 1 bathroom(s) including toilet(s).

A typical unit will contain one bathroom with toilet facility. Many contain an additional toilet, and some an additional shower. .

4.4 Ownership

The type of ownership or occupancy is renting, outright 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)	☐

In general, investment in residential property for rental purposes in Turkey is not an attractive prospect because rents are low, and regulated in favor of tenants by courts. When the return on investment is low, owners are not interested in maintaining their property, or convert residential units to commercial use. It is not uncommon to see mixed patterns of commercial/residential occupation in multi-unit buildings.

5. Seismic Vulnerability

5.1 Structural and Architectural Features

Structural/ Architectural Feature	Statement	Most appropriate type		
		Yes	No	N/A
	The structure contains a complete load path for seismic force effects from any horizontal direction that serves			

Lateral load path	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	In areas of poor soils, expect excessive foundation movement.			

5.2 Seismic Features

Structural Element	Seismic Deficiency	Earthquake Resilient Features	Earthquake Damage Patterns
Wall	Masonry walls are partition panels, with highly variable structural contribution. In typical multistory residential frames structural walls are not utilized.	Many observations have confirmed that masonry walls sometimes modify structural response	Major diagonal cracking can develop even in moderate

		substantially	shaking.
Frame (columns, beams)	Columns are rectangular, with high aspect ratios. Many frames exhibit highly irregular geometry in plan and elevation, with questionable force paths. Detailing and workmanship in these members contravene codes and traditions of good practice.	Conformance to the end confinement requirements improves resilience.	Hinging at ends, or shear cracking are observed in many cases.
Roof and floors	Slab panels are bounded by girders. In cinder block panel slabs (asmolen) the girders are arranged with the longer side horizontal so that the ceiling becomes flat.	Joist type flat slabs have been shown to be contributors to increased story drifts and enhanced second order effects.	

Some of the key seismic design deficiencies related to this construction practice, which contribute to the increased seismic demand and the poor lateral resistance of even the most recently built buildings, are: (1) The cantilevered upper stories place the outer skin of stiff and brittle infill walls out of the plane of the structural frame. This together with the common practice of omitting any walls at ground floor triggers a large eccentric dynamic loading on the bare frame at ground floor causing so-called "weak story" collapses. (2) The concrete frames are rarely designed to take the large lateral and torsional loads caused by ground shaking. (3) The poor quality of the concrete, the poor detailing of the reinforcement all detract from the ductility required by the frame to resist the repeated cycles.

5.3 Overall Seismic Vulnerability Rating

The overall rating of the seismic vulnerability of the housing type is B: MEDIUM-HIGH VULNERABILITY (i.e., poor seismic performance), the lower bound (i.e., the worst possible) is A: HIGH VULNERABILITY (i.e., very poor seismic performance), and the upper bound (i.e., the best possible) is C: MEDIUM VULNERABILITY (i.e., moderate 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
1999	Golcuk, Turkey	7.4	X

The principal reason for the poor performance of these buildings in the 1999 earthquakes was due to the lack of lateral resistance of the framing system, resulting from poor design and construction, coupled in many cases with inappropriate form. Observers have suggested that, notwithstanding the existence of earthquake-resistant design codes for more than 30 years, many buildings have been designed with little appreciation of the need to design for lateral forces at the level of the expected lifetime earthquake. In the recent (1999) Kocaeli and (the later) Duzce earthquakes, it was also observed that, in the slightly damaged buildings, the poor connection between the brittle infills and the concrete frame led to severe damage of large number of the panels. In the severely damaged and collapsed buildings, it was apparent that much of the damage was triggered by the failure of the frame connections of the ground floor columns. Recent earthquakes have also demonstrated that this type of reinforced concrete construction is much more vulnerable to damage or collapse in an earthquake than the low-rise construction in which most other people live. The comparative performance of mid-rise and low-rise buildings in recent damage surveys has proven that buildings of 4 stories and above were much more prone to serious damage and collapse than low-rise buildings. See Figures 6A-6N for illustrations of typical patterns of damage.

Figure 6A: Typical Earthquake Damage - Multiple-Story Collapse in a Six-story building at Golcuk (EERI 2000)

Figure 6B: Typical Earthquake Damage - Hollow Clay Tile Wall "popped" out fjrom a Six-Story Building in Golcuk (EERI 2000)

Figure 6C: Typical Earthquake Damage

Figure 6D: Typical Earthquake Damage - Pullout of Column Reinforcement in a Low-Rise Building in Adapazari (EERI 2000)

Figure 6E: Typical Earthquake Damage - Close Up of Uppermost Corner Column Joint in the Building Shown on the Previous Figure (EERI 2000)

Figure 6F: Typical Earthquake Damage: Weak-story Mechanism Developed in the Building at the left (note columns oriented to increase the glazing area). The columns at the front of the building at the right are oriented perpendicular to those of the building.

Figure 6G: Typical Earthquake Damage: Weak-Story Mechanism Developed in te Bottom Story

Figure 6H: Typical Earthquake Damage - Column Failure

Figure 6I: Typical Earthquake Damage - Pier Failure

Figure 6J : Typical Earthquake Damage - Diagonal Cracking of Infill Often Preceeded the Out-of-Plane Failure (EERI 2000)

Figure 6K: Typical Earthquake Damage to Beam-Column Joints of an Iregular building in Adapazari Maintaining Gravity Load Support (EERI 2000)

Figure 6L: Typical Earthquake Damage - Pounding Between a Six-Story Building and a Two-Story Building in Golcuk, Causing Damage to the Column of th Six-Story Building (EERI 2000)

Figure 6M: Typical Earthquake Damage Due to Pounding Effect (detail of a six-story building shown on the previous figure) (EERI 2000)

Figure 6N: Typical Earthquake Damage - Building Under Construction, Revealing Location of Central Bent-Up Longitudinal Beam Bar, Infrequent Stirrups, and Beams Framing Eccentrically Into Columns (EERI 2000)

Figure 6O: Typical Earthquake Damage to a Building Under Construction, Revealing Eccentric Beam-Column Framing, Beam Longitudinal Bars Located Outside the Column Cage, and Infrequent Transverse Hoops (EERI 2000)

6. Construction

6.1 Building Materials

Structural element	Building material	Characteristic strength	Mix proportions/dimensions	Comments
Walls	Concrete	10-20 MPa Comp.	1:2:3 (Cement:sand:gravel)	Cored samples can sometimes exhibit poorer strength.
Foundation	Concrete	10-20 MPa Comp.	1:2:3 (Cement:sand:gravel)	Cored samples can sometimes exhibit poorer strength.
Frames (beams & columns)	Concrete	10-20 MPa Comp.	1:2:3 (Cement:sand:gravel)	Cored samples can sometimes exhibit poorer strength.
Roof and floor(s)	Concrete	10-20 MPa	1:2:3 (Cement:sand:gravel)	Cored samples can sometimes exhibit poorer strength.

6.2 Builder

The person who builds these apartment buildings is usually an independent small contractor. A variety of schemes is possible for financing them, but the most common procedure is that the contractor will sell units from his share of the property as construction progresses. Some live in what they have built, but most do not.

6.3 Construction Process, Problems and Phasing

The construction process is summarized in Figure 7.3a (at the end of this section) . Its annotation is given partially under Item 7.10. The construction of this type of housing takes place incrementally over time. Typically, the building is originally designed for its final constructed size. This issue has been addressed under Items 1.4 and 4.1.

6.4 Design and Construction Expertise

Currently, there exist little additional requirements for the practice of engineering or architecture in Turkey other than a valid diploma. Contracting services fall under the purview of commercial activity, and any entrepreneur can undertake a business that provides building services. Recent legal changes have been introduced enabling design and construction supervision by qualified firms. A building is designed by an architect, and the contractor usually has a structural engineer to whom he commissions the structural design. In a typical situation, both are underpaid in a sharply competitive environment, so ingenuity and creativity are not the prime issue. As a result buildings are poorly conceived and designed (and built). Many urban areas contain these mediocre samples that have been cloned from a master design.

6.5 Building Codes and Standards

This construction type is addressed by the codes/standards of the country. Specifications for Buildings to Be Built in Disaster Areas. The year the first code/standard addressing this type of construction issued was See below. See below. The most recent code/standard addressing this construction type issued was The reinforced concrete code, TS500, was revised in 2000. The earthquake code went into effect in 1998.The first set of explicit legal provisions for earthquake resistance in Turkey appeared in 1944 within the articles of Law No. 4623. The title of the law was ambitious: "Measures to Be Put into Effect Prior and Subsequent to Occurrence of Ground Tremors." It empowered the Ministry of Public Works to regulate all building construction in what were termed "disaster areas," and for this purpose a regulation of construction requirements and a map defining the seismic regions were ratified. The map was really a list of the provinces and the subprovincial centers in them that fell in one of two zones. Any center of settlement that was omitted from the list was considered to be located in a "safe" zone.Two further updates of the regulation were made in 1949 and 1953. In reality these were little more than editorial changes to reflect the amendments in the seismic zones map of the country.Turkey's history of earthquakes and other forms of natural disasters led in 1958 to the establishment of a Ministry of Reconstruction and Resettlement. The Ministry was made responsible for updating and promulgating both the seismic building code and the earthquake-zoning map. The first seismic building code to be issued after the creation of the Ministry of Reconstruction and Resettlement is dated from 1961. When building heights exceeded six stories, then the structural designs needed to be permitted by the Ministry itself.When the number of earthquake zones was increased to 3 in 1963, a discrepancy appeared between the code requirements and the map. This was addressed in 1968 when a revised code was issued. The reinforced concrete building regulation issued by the Turkish Association for Bridge and Structural Engineering was mentioned. In addition to the customary detailing and construction requirements this code did contain significant improvements over its predecessor: the base shear coefficient C was made a function of the calculated fundamental period of the building, and the inverted triangular distribution of the story level lateral forces was formulated. The seismic zones map issued in 1972 defined 4 different areas, again falling in contradiction with the code. The 1975 issue of the code addressed not only this apparent conflict, but imposed many additional requirements in the design and detailing of reinforced concrete buildings. This code was influenced partly by the "Blue Book," the California design requirements of the time. Although the basic design reference for reinforced concrete, the Turkish Standard TS500 did not at that time contain any strength design requirements, these were introduced in an indirect way into the body of the text. The other important revision was the increasing of the basic base shear coefficient for Zone 1 from 0.06 to 0.10, a 67 percent increase. The remaining zones were also proportionately increased. The latest revision of the code became effective as of 1998, and the map, shown in Figure 1, in 1996. This map is substantially different from its 1972 predecessor in the way the boundaries of the various zones have been defined. Whereas the earlier map defined zones on the basis of maximum observed intensity, the curent one is based on the calculated maximum effective ground acceleration caused by a ground motion with a return period of 475 years. The 1998 Regulation is similar in structure and concept to the 1997 version of the requirements of Chapter 16, Division IV of the Uniform Building Code. Title of the code or standard: Specifications for Buildings to Be Built in Disaster Areas Year the first code/standard addressing this type of construction issued: See below. National building code, material codes and seismic codes/standards: See below. When was the most recent code/standard addressing this construction type issued? The reinforced concrete code, TS500, was revised in 2000. The earthquake code went into effect in 1998. The first set of explicit legal provisions for earthquake resistance in Turkey appeared in 1944 within the articles of Law No. 4623. The title of the law was ambitious: #Measures to Be Put into Effect Prior and Subsequent to Occurrence of Ground Tremors.# It empowered the Ministry of Public Works to regulate all building construction in what were termed #disaster areas,# and for this purpose a regulation of construction requirements and a map defining the seismic regions were ratified. The map was really a list of the provinces and the subprovincial centers in them that fell in one of two zones. Any center of settlement that was omitted from the list was considered to be located in a #safe# zone. Two further updates of the regulation were made in 1949 and 1953. In reality these were little more than editorial changes to reflect the amendments in the seismic zones map of the country. Turkey's history of earthquakes and other forms of natural disasters led in 1958 to the establishment of a Ministry of Reconstruction and Resettlement. 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The account below is a brief description of the way building code enforcement functioned until early 2000 when a Building Construction Supervision law was passed by parliament. In the new system private firms acting on behalf of both owner and the municipal government provide oversight in design and construction inspection. This narrative is provided because it is the version that matches the rest of the answers on this form. The principal instrument governing how buildings are created is the Development Law. This document has a few articles in Part 4 that regulate the supervision of building construction. The law holds municipalities (or governorates for buildings outside of urban areas) responsible for project supervision. Construction supervision is entrusted to the so-called engineers of record. Holders of deeds or parcel assignment certificates submit petitions to either the relevant municipality or the governorate to acquire building permits. In addition to the certificate of land ownership the applicant must submit architectural, structural, and mechanical designs as well as a schematic drawing of the buildings location. Some municipalities have transferred this duty to the local branches of the Chambers of Civil Engineers or Architects through informal agreements. The customary procedure is that the engineering offices of municipalities function as rubber stamps in their approval work. The Development Law does not specify what measures are to apply if erroneous designs are approved. Legal precedent appears to hold the design engineer responsible in this regard. The Development Law No. 3194 requires the engineer of record to report to the municipality or governorate any contraventions by the contractor of the design he supervises. When such a violation occurs it is incumbent upon the local government to seal the construction site, and to order the owner to take corrective action. If within one month this action is taken, the order for work stoppage is rescinded. If the owner does not comply with the order, then his permit is revoked, and the building demolished at his expense. This process is largely illusory. There exist a number of penalties for the contractor or the engineer if certain provisions of the law are not fulfilled. In general, the penalty clauses of the law are weakly enforced, and violations are tolerated. A glaring omission is that no guidelines are given in the text of the law as to how the engineer is to supervise the construction for which he is responsible. He seems to have freedom in his actions, but reporting violations is all he does. A more serious situation is that, even though the engineer of record is charged with the protection of the rights of the property owner, in the case of private build-sell agreements between landowner and contractor, he usually receives his salary from the latter.

6.6 Building Permits and Development Control Rules

This type of construction is an engineered, and authorized as per development control rules.   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 No one.   Rents are typically very low, and courts usually side with renters so that owners have little incentive for financing costly maintenance or upgrade jobs. Sometimes dangerous interventions are made for converting property to other (usually commercial) uses.

6.8 Construction Economics

The unit cost to the owner of a typical sample would be of the order of 400,000,000 TL/m², or 250-300 US$/m².   It may take up to two years for the construction of a building to be completed.

BUILDING TYPE / BUREAUCRATIC STEP	PRIVATE PROPERTY			INSTITUTIONAL BUILDING
	Single Detached Building (Business or Rental Facility)	Collective Housing through Cooperatives	Land-in-Exchange for Share of Property (Build-Sell)	
1. Establish land ownership	The Deeds Bureau or Assignment/Lease Bureau: Acquisition of the deed or assignment paper			Deed and/or expropriation
2. Financial arrangements	Individual	Collect money from members	Private agreement between parcel owner/ contractor	Budget and funds
3. Conformance with development plan	Municipality or Provincial Office of Ministry of Public Works and Settlements			
	Deed holder applies	Deed holder (or Coop. Board) applies	Deed holder applies	End user applies w/ deed + petition
	For lands with no plans, new plans must be attached			
4. Design: architectural, structural, installations	Design Offices (Engineer-Architects)			Subcontracted, with in-house check or design in-house
5. Building permit	Municipality or Provincial Office of Ministry of Public Works and Settlements: An engineer of record must be designated			
6. Preparation for construction/ contracting	Private award to contractor, invite for tender, or turnkey arrangement		Private agreement	Follow Contracts Law procedures
7. Construction	Contractor + (subcontractor) + engineer of record (Municipality checks only foundation, subbasement and story elevations)			Contractor + sub-Contractor + site engineer
8. Supervision, progress payment, quantity surveys, workplan, conformance check	Private Supervisors		As per Agreement between parties	Agency units, supervisory units, engineer of record
9. Engineering responsibility	Engineer of record: The engineer of record designated during the taking out of the permit is on paper only. Law holds contractor responsible, even for design errors. He often is able to pass it on to the site engineer.			True responsibility does not exist: civil employees cannot be held liable
10. Occupation permit: delivery of works to owner	Check with Social Security Agency for workers' compensations; check for completion of project (municipality, public health, fire bureau, architectural and engineers chambers, utility connections)			Supervisory unit within agency grants certificate of completion

Figure 8: The Construction Process

7. Insurance

Earthquake insurance for this construction type is typically available.   For seismically strengthened existing buildings or new buildings incorporating seismically resilient features, an insurance premium discount or more complete coverage is unavailable.   DASK, a recently established entity similar to California Earthquake Authority, provides mandatory country-wide insurance for all property up to a ceiling of $28,000. For amounts in excess of this owners must purchase voluntary insurance.   Insurance provided by DASK covers structure only. In high-hazard areas a dwelling of the type described under this section will have a premium of some $50.

8. Strengthening

8.1 Description of Seismic Strengthening Provisions

Strengthening of Existing Construction :

Seismic Deficiency	Description of Seismic Strengthening provisions used
Lateral force resisting system understrength	The most prevalent form of seismic strenghtening is the insertion of structural walls by removing filler walls. The basic principle is to provide a minimum wall area, and to distribute the elements in symmetrical fashion in plan.
Column rehabilitation through jacketing	Damaged columns are encased in reinforced shells.
Column, girder or wall epoxy injection	Usually done after lateral strength is ensured through walls.
Other	Untried or unworkable schemes have been cited.

The building type for which retrofitting is most likely to be needed is the mid-rise reinforced concrete frame apartment building. In Turkey this is now the standard type of dwelling for the urban population. These buildings are commonly 4 to 7 stories in height (often with no elevator), containing up to four or more apartments on each floor. The principal reason for the poor performance of these buildings in recent earthquakes is lack of lateral resistance of the framing system, resulting from poor design and construction, coupled in many cases with inappropriate form. Observers have suggested that, notwithstanding the existence of earthquake-resistant design codes for more than 30 years, many buildings have been designed with little appreciation of the need to design for lateral forces at the level of the expected lifetime earthquake. Options for retrofitting The principal options for improving the lateral load-carrying ability existing reinforced concrete structures include: 1) Addition of concrete shear walls 2) Buttressing 3) Jacketing 4) Addition of cross-bracing or added external frames Only the first option has been practiced to any degree in Turkey and will be explained in more detail. 1) Addition of Concrete Shear Walls The most common method of strengthening of reinforced concrete frame structures is the addition of shear walls. These are normally of reinforced concrete, or may exceptionally be of reinforced masonry. In either case, they are reinforced in such a way as to act together with the existing structure, and careful detailing and materials selection is required to ensure that bonding between new and existing structure is effective. The addition of shear walls substantially alters the force distribution in the structure under lateral load, and thus normally requires strengthening of the foundations. In most of the large scale retrofit programs undertaken in Turkey, this method has been chosen for implementation. There now exist contracting companies experienced in carrying out this form of intervention.

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?
In Turkey, at the present level of retrofit, there is (not surprisingly) no skills shortage. Retrofit experience has been gained by designers and to a certain extent by contractors. Short training courses and seminars on retrofit design issues have been organized by engineering associations and universities. But the skills needed to make a correct structural assessment for a building, and then to suggest ways of addressing any deficiencies are not widely available.

Was the work done as a mitigation effort on an undamaged building, or as repair following an earthquake?
In Turkey as in other countries, strengthening of existing buildings has in most cases been carried out in the context of repair of earthquake damage. The earliest experience was after the 1967 Mudurnu earthquake, when the recently completed five-story Adapazari Municipal building was slightly damaged, and subsequently strengthened using both jacketing of existing columns and a system of additional concrete shear walls. This retrofitted building is of considerable significance because it was severely shaken in the 1999 Kocaeli earthquake (intensity around EMS=9) and survived with no damage. Following the 1992 Erzincan earthquake, there was a programme of retrofitting for schools, office buildings and private apartment blocks. Several hundred buildings were retrofitted; a mixture of eccentric shear

walls, concentric shear walls and some steel cross-bracing was used. Following the 1995 Dinar and the 1998 Ceyhan earthquakes there have been somewhat smaller retrofit programmes ? about 100 buildings in each event, and these have all used concentric shear walls, there being some doubts about the shear transfer capacity of the connections of eccentric shear walls to existing structure; and about the workmanship aspects of steel cross-bracing. Further retrofitting was done in the area affected by the 1999 Kocaeli and Duzce earthquakes ? certainly large numbers of buildings were be improved in this way; and in a field study conducted for this report nearly all those buildings visited were using concentric shear walls. In Turkey there is extensive experience of drawing up retrofit schemes for existing buildings, in most cases in the context of post-earthquake damage repair. This work is generally overseen by earthquake engineering specialists from one of three leading University Departments, METU, Boğaziçi University and Istanbul Technical University, working in conjunction with local design offices. No special design standards apply, except for the provision in the seismic code that ?any major structural intervention must bring the building to the level where it satisfies the current code,? i.e., itself . The experience of METU is summarized in the following paragraphs. In the few cases where plans and/or original design blueprints of the building are available, these are used as the principal guidelines. A few spot checks are then run to see if they conform. More commonly on-site measurements are used to reconstruct the structure as it exists. Plan dimensions, member sizes, location and thickness of partition walls, reinforcement details, etc. are recovered from this. For damaged buildings that have been vacated by their inhabitants, this can be done relatively easily. For existing and inhabited buildings, resistance is encountered from owners who do not want people measuring up their property, and chipping of cover concrete to see what is inside. For reinforcement, magnetic sensors are used, but this achieves moderate success only. Impact hammer and coring (10 cm diameter) are used for assessing concrete strength. The analytical model is based on measured dimensions and material properties. On a first sweep, linear analyses are usually performed to see if any members exist with appreciable capacity deficits, which is normally the case. Excessive torsional rotation, story drift, or abundance of overstressed members can serve as arbiters of rejection. Each building is handled on a case-by-case basis. METU has developed a general form that has been used in the Is Bank building survey. In the case of reinforced concrete buildings, if column shear stresses are in excess of $0.2\sqrt{f'}$or wall shear stresses more than $0.3\sqrt{f'}$ in many cases, that building is not passed for retrofitting. Linear analyses, with ?reduced? properties for the existing framing are employed for design and assessment, and all projects are designed for full compliance with the Turkish code.

8.3 Construction and Performance of Seismic Strengthening

Was the construction inspected in the same manner as the new construction?

Yes, the construction inspected in the same manner as the new costruction.

Who performed the construction seismic retrofit measures: a contractor, or owner/user? Was an architect or engineer involved?

The construction is done by a contractor in accordance with an engineer's design. See Figures 7A and 7B.

What was the performance of retrofitted buildings of this type in subsequent earthquakes?

This is generally good. The best known example of this is the Sakarya Governor's Office Building rehabilitated in 1970, and performed very well in 1999. The number of such cases is too small to permit generalization.

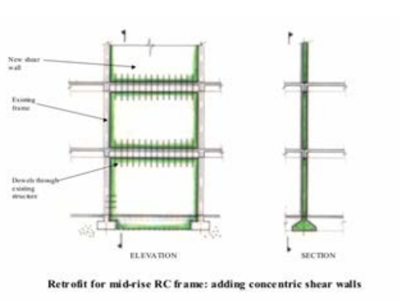

Figure 7A: Seismic Strengthening Techniques

BUILDING TYPE → / BUREAUCRATIC STEP ↓	PRIVATE PROPERTY			INSTITUTIONAL BUILDING
	Single Detached Building ([illegible])	Collective Housing through Cooperative	Land-or-Exchange for Share of Property (Build-Sell)	
1 Establish land ownership	[illegible]			[illegible]
2 Financial arrangements	Individual	[illegible]	[illegible]	Budget and funds
3 Conformance with development plan	Deed holder applies	Deed holder (or Coop. Board) applies	Deed holder applies	[illegible]
4 Design: architectural, structural, installations	Design Office (Engineer-Architects)			[illegible]
5 Building permit	[illegible]			
6 Preparation for construction/ [illegible]	[illegible]		[illegible]	Follow [illegible] Law procedures
7 Construction	[illegible]			[illegible]
8 Supervision, progress payments, [illegible]	Private Supervision		[illegible]	[illegible]
9 Engineering responsibility	Engineer of record [illegible]			[illegible]
10 Occupancy permit: delivery of works to owner	[illegible]			[illegible]

Figure 7B: Seismic Strengthening Techniques

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