

# World Housing Encyclopedia

*A Resource on Construction in Earthquake Regions*



an initiative of  
Earthquake Engineering Research Institute (EERI) and  
International Association for Earthquake Engineering (IAEE)

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## HOUSING REPORT

### **Reinforced concrete frame building with masonry infills**

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<b>Report#</b>	64
<b>Last Updated</b>	
<b>Country</b>	Turkey
<b>Author(s)</b>	Polat Gulkan, Mark Aschheim, Robin Spence,
<b>Reviewers</b>	Craig D. Comartin,

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### **Important**

This encyclopedia contains information contributed by various earthquake engineering professionals around the world. All opinions, findings, conclusions & recommendations expressed herein are those of the various participants, and do not necessarily reflect the views of the Earthquake Engineering Research Institute, the International Association for Earthquake Engineering, the Engineering Information Foundation, John

## **General Information**

<b>Building Type:</b>	Reinforced concrete frame building with masonry infills
<b>Country:</b>	Turkey
<b>Author(s):</b>	Polat Gulkan Mark Aschheim Robin Spence
<b>Last Updated:</b>	
<b>Regions Where Found:</b>	<p>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.</p>
<b>Summary:</b>	<p>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</p>

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.

<b>Length of time practiced:</b>	25-60 years
<b>Still Practiced:</b>	Yes
<b>In practice as of:</b>	
<b>Building Occupancy:</b>	Residential, 10-19 units
<b>Typical number of stories:</b>	3-7
<b>Terrain-Flat:</b>	Typically
<b>Terrain-Sloped:</b>	3
<b>Comments:</b>	In many Turkish municipalities, particularly in those where rapid economic growth has been registered within the last twenty years

## Features

<b>Plan Shape</b>	Rectangular, solid
<b>Additional comments on plan shape</b>	Most would be rectangular or nearly so. Where dictated by land parcellation patterns, every conceivable shape may be encountered.
<b>Typical plan length (meters)</b>	12
<b>Typical plan width (meters)</b>	18
<b>Typical story height (meters)</b>	3
<b>Type of Structural System</b>	Structural Concrete: Moment Resisting Frame: Designed with seismic effects, with URM infill walls
	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

### **Additional comments on structural system**

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. 24). 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 degree 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 sample plans shown in Fig. 3 and 4. The beams may frame into the columns eccentrically (Fig. 24 and 25). 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. Nearly all reinforcement in local construction is smooth. Reinforcement is routinely bent into a "U" shape (Fig. 7). (4) Roofs usually consist of wood rafters and wood sheathing over a horizontal RC slab. Foundations typically consist of either interconnected RC grade beams or a heavy mat slab (Fig. 6). (5) 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. 9). In recent years, lightweight autoclaved, aerated concrete block has been used in place of hollow clay tiles.

**Gravity load-bearing & lateral load-resisting systems**

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).

**Typical wall densities in direction 1**

4-5%

**Typical wall densities in direction 2**

4-5%

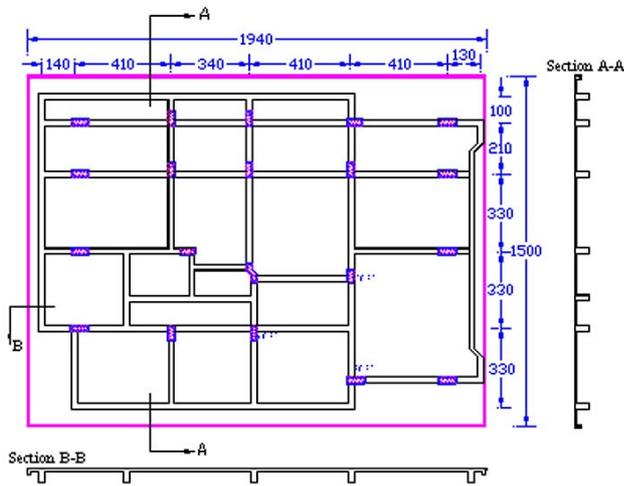
**Additional comments on typical wall densities**

Masonry wall density (walls constructed of hollow clay units) ranges: 0.02-0.06

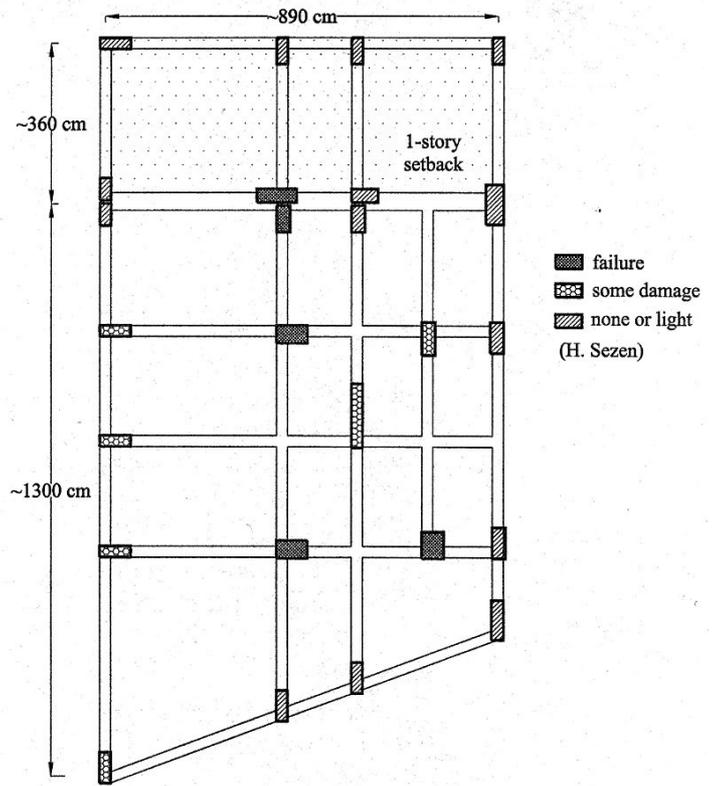
**Wall Openings**

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.

<p><b>Is it typical for buildings of this type to have common walls with adjacent buildings?</b></p>	<p>No</p>
<p><b>Modifications of buildings</b></p>	<p>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.</p>
<p><b>Type of Foundation</b></p>	<p>Shallow Foundation: Reinforced concrete isolated footing Shallow Foundation: Reinforced concrete strip footing Shallow Foundation: Mat foundation</p>
<p><b>Additional comments on foundation</b></p>	<p>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.</p>
<p><b>Type of Floor System</b></p>	<p>Other floor system</p>
<p><b>Additional comments on floor system</b></p>	<p>Other- Structural Concrete: cast in place solid slabs, cast in place flat slabs Structural analysis is usually done with the assumption that floor systems form rigid diaphragms.</p>
<p><b>Type of Roof System</b></p>	<p>Roof system, other</p>
<p><b>Additional comments on roof system</b></p>	<p>Other- Structural Concrete: cast in place solid slabs, cast in place flat slabs</p>
<p><b>Additional comments section 2</b></p>	<p>When separated from adjacent buildings, the typical distance from a neighboring building is 6 meters.</p>



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



**Typical Plan Illustrating Damaged Columns in Lowest Floor of a Five-Story Building in Adapazari (EERI 2000)**

## **Building Materials and Construction Process**

### **Description of Building Materials**

<b>Structural Element</b>	<b>Building Material (s)</b>	<b>Comment (s)</b>
Wall/Frame	Concrete	Characteristic Strength-10-20Comp.Mix Proportion/Dimensions-1:2:3(Cement:sand:gravel)Cored samplescan sometimesexhibit poorerstrength.
Foundations	Concrete	Characteristic Strength-10-20Comp.Mix Proportion/Dimensions-1:2:3(Cement:sand:gravel)Cored samplescan sometimesexhibit poorerstrength.
Floors	Concrete	Characteristic Strength-10-20Comp.Mix Proportion/Dimensions-1:2:3(Cement:sand:gravel)Cored

		samples can sometimes exhibit poorer strength.
Roof	Concrete	Characteristic Strength-10-20 Comp. Mix Proportion/Dimensions-1:2:3 (Cement:sand:gravel) Cored samples can sometimes exhibit poorer strength.
Other		

## Design Process

<b>Who is involved with the design process?</b>	Engineer/Architect
<b>Roles of those involved in the design process</b>	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.
<b>Expertise of those involved in the design process</b>	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.

## Construction Process

<b>Who typically builds this construction type?</b>	Contractor
<b>Roles of those involved in the building process</b>	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.
<b>Expertise of those involved in building</b>	

<b>process</b>	
<b>Construction process and phasing</b>	The construction of this type of housing takes place incrementally over time. Typically, the building is originally designed for its final constructed size.
<b>Construction issues</b>	

## Building Codes and Standards

<b>Is this construction type address by codes/standards?</b>	Yes
	<p>"Specifications for Buildings to Be Built in Disaster Areas. "; 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</p>

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 current 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.

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## **Applicable codes or standards**

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### **Process for building code enforcement**

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.

## Building Permits and Development Control Rules

<b>Are building permits required?</b>	Yes
<b>Is this typically informal construction?</b>	No
<b>Is this construction typically authorized as per development control rules?</b>	Yes
<b>Additional comments on building permits and development control rules</b>	

## Building Maintenance and Condition

<b>Typical problems associated with this type of construction</b>	
<b>Who typically maintains buildings of this type?</b>	Owner(s) No one
<b>Additional comments on maintenance and building condition</b>	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.

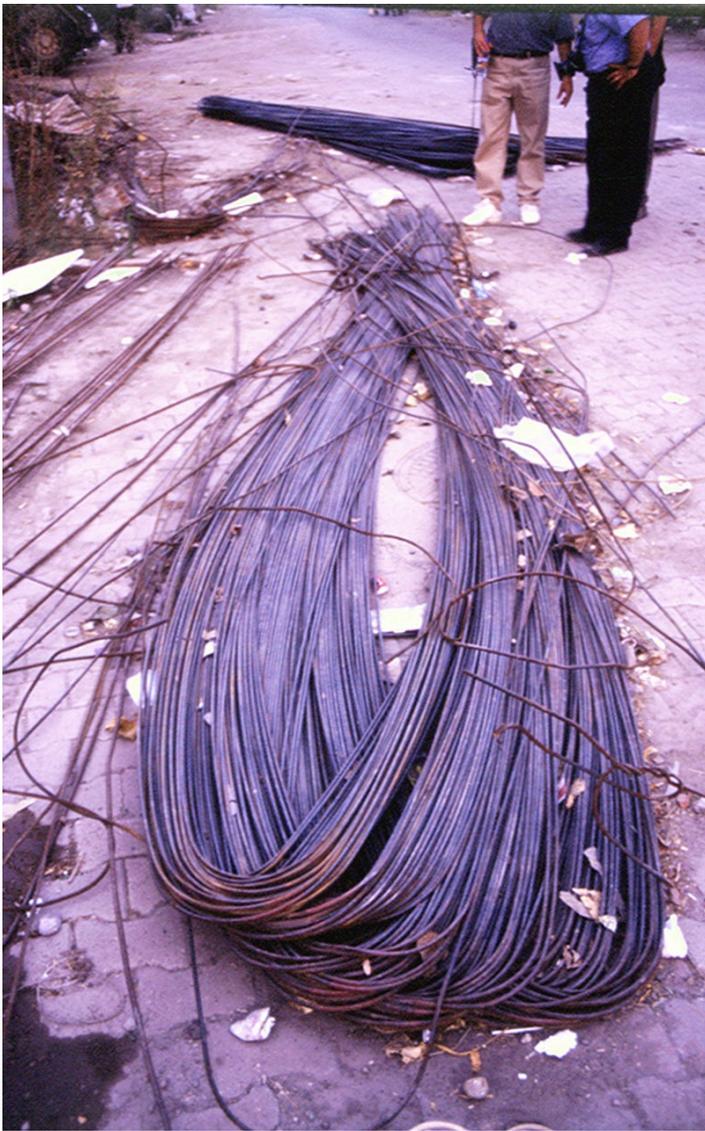
## Construction Economics

<b>Unit construction cost</b>	The unit cost to the owner of a typical sample would be of the order of 400,000,000 TL/m <sup>2</sup> , or 250-300 US\$/m <sup>2</sup> .
<b>Labor requirements</b>	It may take up to two years for the construction of a building to be completed.
<b>Additional comments section 3</b>	

□ ***Critical Structural Details - Irregular Column Orientations and Layout (EERI 2000)***



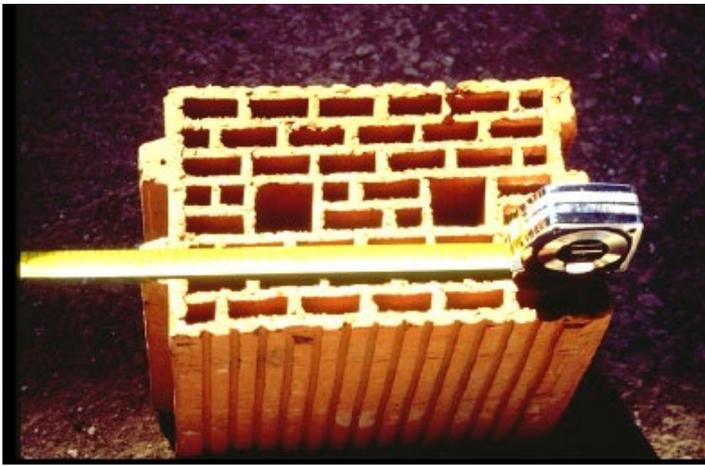
***Critical Structural Details - Heavy MatSlab Foundation (EERI 2000)***



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



***Critical Structural Details -  
Wooden Roofs Over Reinforced  
Concrete Beam-Column Framing  
(EERI 2000)***



**Critical Structural Details - Typical Hollow Clay Tile Infill Block (EERI 2000)**



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

## Socio-Economic Issues

<b>Patterns of occupancy</b>	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.
<b>Number of inhabitants in a typical building of this construction type during the day</b>	5-10
<b>Number of inhabitants in a typical building of this construction type during</b>	10-20

<b>the evening/night</b>	
<b>Additional comments on number of inhabitants</b>	
<b>Economic level of inhabitants</b>	Low-income class (poor)Middle-income classHigh-income class (rich)
<b>Additional comments on economic level of inhabitants</b>	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: 3:1
<b>Typical Source of Financing</b>	Owner financedPersonal savingsInformal network: friends or relativesInvestment pools
<b>Additional comments on financing</b>	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.
<b>Type of Ownership</b>	RentOwn outrightOwned by group or pool
<b>Additional comments on ownership</b>	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.
<b>Is earthquake insurance for this construction type typically available?</b>	Yes
<b>What does earthquake insurance typically cover/cost</b>	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.
<b>Are premium discounts or higher coverages available for seismically strengthened buildings or new buildings built to incorporate seismically resistant features?</b>	No

## Additional comments on premium discounts

### Additional comments section 4

## Earthquakes

### Past Earthquakes in the country which affected buildings of this type

Year	Earthquake Epicenter
1999	Golcuk, Turkey

## Past Earthquakes

### Damage patterns observed in past earthquakes for this construction type

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 11-25 for illustrations of typical patterns of damage.

**Additional comments on earthquake damage patterns**

Overall damage patterns observed in past earthquakes for this type of construction included: Major diagonal cracking can develop even in moderate shaking. (walls) Hinging at ends, or shear cracking are observed in many cases. (frame)

**Structural and Architectural Features for Seismic Resistance**

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

The total width of door and window openings in a wall is: For brick masonry construction in cement mortar : less than 1/2 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.

<b>Structural/Architectural Feature</b>	<b>Statement</b>	<b>Seismic Resistance</b>
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.	FALSE
Building Configuration-Vertical	The building is regular with regards to the elevation. (Specify in 5.4.1)	FALSE
Building Configuration-Horizontal	The building is regular with regards to the plan. (Specify in 5.4.2)	FALSE
Roof Construction	The roof diaphragm is considered to be rigid and it is expected that the roof structure will maintain its integrity, i.e. shape and form, during an earthquake of intensity expected in this area.	TRUE
Floor Construction	The floor diaphragm(s)	TRUE

	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.	TRUE
Wall and Frame Structures-Redundancy	The number of lines of walls or frames in each principal direction is greater than or equal to 2.	TRUE
Wall Proportions	Height-to-thickness ratio of the shear walls at each floor level is: Less than 25 (concrete walls); Less than 30 (reinforced masonry walls); Less than 13 (unreinforced masonry walls);	TRUE
Foundation-Wall Connection	Vertical load-bearing elements (columns, walls) are attached to the foundations; concrete columns and walls are doveled into the foundation.	TRUE
Wall-Roof Connections	Exterior walls are anchored for out-of-plane seismic effects at each diaphragm level with metal anchors or straps.	FALSE
Wall Openings		FALSE
Quality of Building Materials	Quality of building materials is considered to be adequate per the requirements of national codes and standards (an estimate).	FALSE

Quality of Workmanship	Quality of workmanship (based on visual inspection of a few typical buildings) is considered to be good (per local construction standards).	FALSE
Maintenance	Buildings of this type are generally well maintained and there are no visible signs of deterioration of building elements (concrete, steel, timber).	FALSE

## Building Irregularities

<b>Additional comments on structural and architectural features for seismic resistance</b>	In areas of poor soils, expect excessive foundation movement.	
<b>Vertical irregularities typically found in this construction type</b>	Torsion eccentricity	
<b>Horizontal irregularities typically found in this construction type</b>	Soft/weak story Change in vertical structure	
<b>Seismic deficiency in walls</b>	Masonry walls are partition panels, with highly variable structural contribution. In typical multistory residential frames structural walls are not utilized.	
<b>Earthquake-resilient features in walls</b>	Many observations have confirmed that masonry walls sometimes modify structural response substantially.	
<b>Seismic deficiency in frames</b>	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.	
<b>Earthquake-resilient features in frame</b>	Conformance to the end confinement requirements improves resilience.	
<b>Seismic deficiency in roof and floors</b>	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.	

**Earthquake resilient features in roof and floors**

Joist type flat slabs have been shown to be contributors to increased story drifts and enhanced second order effects.

**Seismic deficiency in foundation**

**Earthquake-resilient features in foundation**

**Seismic Vulnerability Rating**

For information about how seismic vulnerability ratings were selected see the [Seismic Vulnerability Guidelines](#)

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



**Typical Earthquake Damage - Multiple-Story Collapse in a Six-story building at Golcuk (EERI 2000)**



**Typical Earthquake Damage - Hollow Clay Tile Wall "popped" out from a Six-Story Building in Golcuk (EERI 2000)**



**Typical Earthquake Damage**



**Typical Earthquake Damage - Pullout of Column Reinforcement in a Low-Rise Building in Adapazari (EERI 2000)**



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



**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.**



***Typical Earthquake Damage: Weak-Story Mechanism Developed in the Bottom Story***



***Typical Earthquake Damage - Column Failure***



***Typical Earthquake Damage - Pier Failure***



***Typical Earthquake Damage - Diagonal Cracking of Infill Often Preceded the Out-of-Plane Failure (EERI 2000)***



**Typical Earthquake Damage to Beam-Column Joints of an Irregular building in Adapazarı Maintaining Gravity Load Support (EERI 2000)**



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



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



**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)***



***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)***

### **Retrofit Information**

#### **Description of Seismic Strengthening Provisions**

<b>Structural Deficiency</b>	<b>Seismic Strengthening</b>
Lateral force resisting system understrength	The most prevalent form of seismic strengthening 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

**Additional comments on seismic strengthening provisions**

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.

**Has seismic strengthening described in the above table been performed?**

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.

In Turkey as in other countries, strengthening of

**Was the work done as a mitigation effort on an undamaged building or as a repair following earthquake damages?**

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 project was extensively documented in a paper for the first Turkish earthquake engineering conference in 1972. 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 which included 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 for 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 is currently in progress in the area affected by the 1999 Kocaeli and Duzce earthquakes and certainly large numbers of buildings will be improved in this way; and in a field study conducted for this report nearly all those buildings visited were using concentric shear walls and in spite of the loss in some cases of commercial frontage to urban streets. In one notable project, TuPRAS has undertaken the strengthening of all 7 multi-story apartment blocks in its Izmit housing complex, only two of which suffered significant damage. The only other known programme of proactive retrofit is that of Isbank, which is assessing and where necessary retrofitting all its bank buildings in the major earthquake risk areas; again adoption of concentric shear walls is the normal solution used. 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, Bogazici 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 many major structural intervention must bring the building to the level where it satisfies the current code. 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 do 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  $0.2v_f'$  or wall shear stresses more than  $0.3v_f'$  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.

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

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

**Who performed the construction: 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 27 and 28.

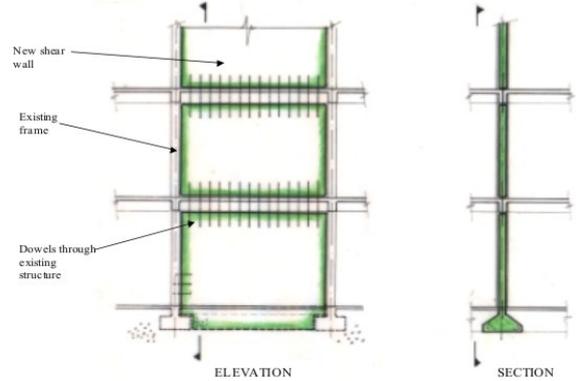
**What has been the performance of retrofitted buildings of**

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

**this type in subsequent earthquakes?**

1999. The number of such cases is too small to permit generalization.

**Additional comments section 6**



**Retrofit for mid-rise RC frame: adding concentric shear walls**

**The Construction Process**

**Seismic Strengthening Techniques**

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

**Seismic Strengthening Techniques**

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