World Housing Encyclopedia

A Resource on Construction in Earthquake Regions

an initiative of
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International Association for Earthquake Engineering (IAEE)

HOUSING REPORT

Semi-rigid steel frame with "Khorjinee" connections

Report#	26
Last Updated	
Country	Islamic Republic of Iran
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Important

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General Information

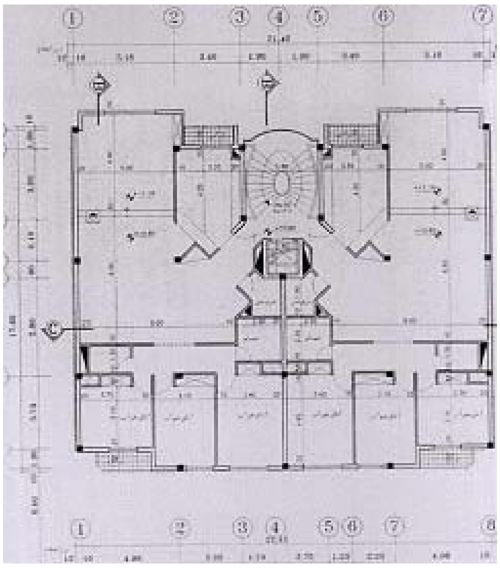
Building Type:	Semi-rigid steel frame with "Khorjinee" connections
Country:	Islamic Republic of Iran
Author(s):	Behrokh Hosseini Hashemi Mohsen Ghafory Ashtiany
Last Updated:	
Regions Where Found:	Buildings of this construction type can be found in urban and in some rural areas of Iran, especially in less humid regions. The percentage of this housing type in those regions is almost 70% of steel buildings. This type of housing construction is commonly found in both rural and urban areas.
Summary:	This housing type is commonly used for low-rise building construction in Iran, mainly for family apartment buildings. This structure is characterized with a special type of semi-rigid beam-to- column connection called #Khorjinee connection#. This connection consists of a pair of continuous beams spanning over several columns and connected to the column sides by means of angle sections. Beam and column are welded to the angle section. One of the major problems with the khorjinee connections is that it is very difficult to improve the rigidity of the connection in the weak direction (the direction perpendicular to the connection) since the crossed beams are connected to the web of khorjinee beams. Thus in the weak direction of the frames the connections are considered as pinned (hinges) and the bracing is used to resist seismic loads. However, in the khorjinee direction, since the possibility of using the bracing is very limited, the frame is considered as a rigid structure. Also, out-of-plane partial beam-to-column transfer of bending moment and early onset of failure in the angles are the most likely cause of failure for a building subjected to lateral earthquake loads. These buildings are vulnerable in earthquakes (e.g. 1990 Manjil earthquake).
Length of time practiced:	25-60 years
Still Practiced:	Yes
In practice as of:	
Building Occupancy:	Residential, 5-9 units
Typical number of stories:	4-6

Terrain-Flat:	Typically
Terrain-Sloped:	Typically
Comments:	This type of construction is followed in the last 30 years.

Features

Plan Shape	Rectangular, solid
Additional comments on plan shape	
Typical plan length (meters)	12-20
Typical plan width (meters)	9-15
Typical story height (meters)	2.7
Type of Structural System	Steel: Braced Frame: Concentric connections in all panels
Additional comments on structural system	In both directions of the building the lateral load-resisting system should be provided by steel bracing (according to seismic code of Iran). However in most of these buildings, the steel bracing system is only used in one direction (the direction which is perpendicular to the street). The other direction (which is usually parallel to street), due to the existence of large opening in the wall of this direction, does not have any lateral resisting system. Gravity loads are sustained by steel frames.
Gravity load-bearing & lateral load-resisting systems	
Typical wall densities in direction 1	0-1%
Typical wall densities in direction 2	0-1%
Additional comments on typical wall densities	The typical structural wall density is 0.1.
Wall Openings	To view outside the building, typically a large window opening is in the transverse direction of the building. This window almost takes 70% of the external wall area. The other wall has one or two doors or windows opening. The door sizes are typically 90 X 210 (cm) and the other window sizes are 160 X 90 (cm). The overall window and door areas are about 35% of the overall wall surface area.
Is it typical for buildings of this type to have common walls with adjacent buildings?	No
Modifications of buildings	Adding stories on the top of the building, removing the

Modifications of buildings	partition walls.
Type of Foundation	Shallow Foundation: Reinforced concrete isolated footingShallow Foundation: Reinforced concrete strip footing
Additional comments on foundation	Seismic problems related to the foundation system are rare. Single footings are connected to each other by strong ties.
Type of Floor System	Other floor system
Additional comments on floor system	Concrete joists with infilled hollow blocks topped with concrete slab. The floor and roof are considered to be rigid diaphragm.
Type of Roof System	Roof system, other
Additional comments on roof system	Concrete joists with infilled hollow blocks topped with concrete slab. The floor and roof are considered to be rigid diaphragm.
Additional comments section 2	When separated from adjacent buildings, the typical distance from a neighboring building is several meters.



Plan of a Typical Building

Building Materials and Construction Process

Description of Building Materials

Structural Element	Building Material (s)	Comment (s)
Wall/Frame	Wall: Clay brick masonry; Concrete Steel bars Frame:	Characteristic Strength: Clay brick masonry :100 kg/cm28

	Steel	kg/cm2 Concrete: 210 kg/cm2 Steel bars: 4200 kg/cm2 Mix Proportion/Dimensions: Clay brick masonry: 1:6 / 55x110x220 (mm) Concrete: 1:2:4
Foundations		
Floors	Concrete	Characteristic Strength: 210 kg/cm2
Roof	Concrete	Characteristic Strength: 210 kg/cm2
Other		

Design Process

Who is involved with the design process?	EngineerBuilder
Roles of those involved in the design process	For design of building, engineers and architectures are both involved. However, in most projects, during the construction process they do not spend any remarkable time to visit the site.
Expertise of those involved in the design process	As far as the member sizes and foundations design concern, engineers are expert enough to design this type of building. In most projects engineers do not address any detail of the connection and they leave this part of job to experienced builders.

Construction Process

Who typically builds this construction type?	Other
Roles of those involved in the building process	It is typically built by developers or for speculation.
Expertise of those involved in building process	
Construction process and phasing	Typically developers build these types of constructions. Process starts with the foundations and fixing base plates on them. Then erection of steel frame and placing of joists and blocks, purring the concrete topping and then working out the infill walls and finally putting the finishing on the hole building. The construction of this type of housing takes place incrementally over time. Typically, the building is originally designed for its final constructed size.
Construction issues	The main problems are associated with the construction process. In most projects, designers do not provide any detail for the connections and this responsibility is left to

Construction issues	experienced builders, who have no knowledge about the better performance of the connections in the case of earthquake happens.

Building Codes and Standards

Is this construction type address by codes/standards?	Yes
Applicable codes or standards	The first official issue about this type of building was in 1999. The Iranian Code of Practice for Seismic Resistant Design of Buildings (Standard 2800) in its 2nd revised edition (1999) addressed this type of construction to be considered as a Type 2 construction (i.e. simple framing in both directions). Iranian Code of Practice for Seismic Resistant Design of Building, 2nd Edition-1999 Iranian National Building Code, Part: 10, Steel Structures, 1994
Process for building code enforcement	The building department of municipalities approves the design and holds the designer responsible for the projects. After finishing the construction the municipal authorities check the finished project and issue occupancy permit stage. However, most of these controls are the subjects of the architectural views.

Building Permits and Development Control Rules

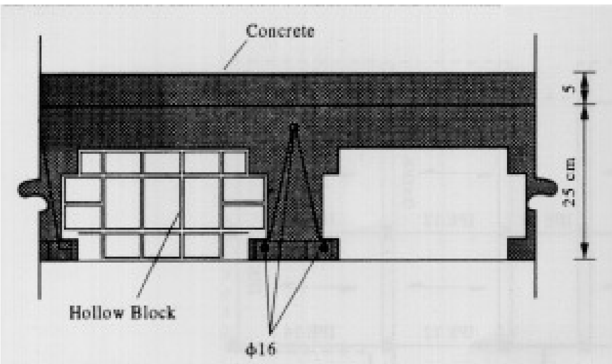
Are building permits required?	Yes
Is this typically informal construction?	No
Is this construction typically authorized as per development control rules?	No
Additional comments on building permits and development control rules	

Building Maintenance and Condition

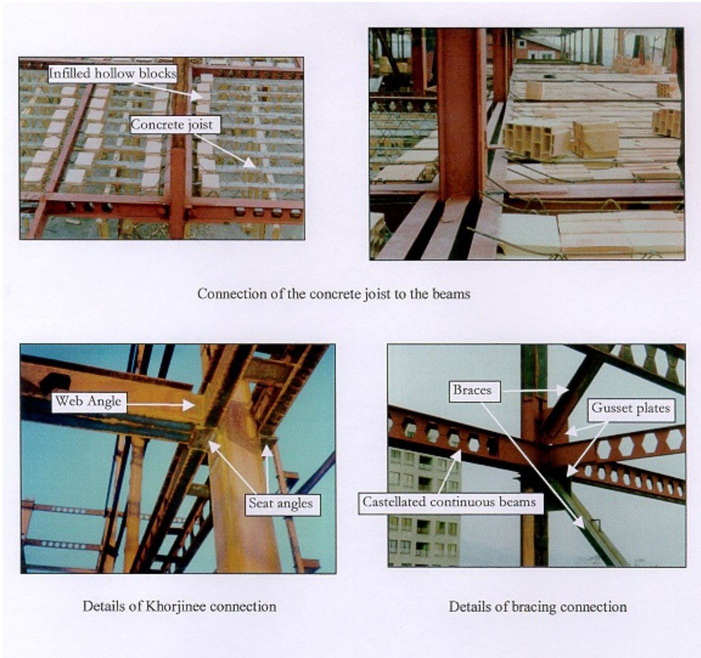
Typical problems associated with this type of construction	
Who typically maintains buildings of this type?	BuilderOwner(s)Renter(s)
Additional comments on maintenance and building condition	

Construction Economics

Unit construction cost	For only load bearing system, the cost of this type of building is about 300,000-400,000 Rials/sq m (150-200 $US/sq m).
Labor requirements	For a typical 4 to 6 stories building needs about 30 to 45 days to complete the load bearing structure.
Additional comments section 3	



A typical floor slab construction



Critical Structural Details

A seismic deficiency: wrong connection detail

Seismic deficiency-use of undefined bracing system

Socio-Economic Issues

Patterns of occupancy	One family usually occupies each housing unit. Each building typically has 4-8 housing unit(s).

Number of inhabitants in a typical building of this construction type during the day	5-10
Number of inhabitants in a typical building of this construction type during the evening/night	10-20
Additional comments on number of inhabitants	
Economic level of inhabitants	Low-income class (poor)Middle-income class
Additional comments on economic level of inhabitants	Ratio of housing unit price to annual income: 5:1 or worse Economic Level: For Poor Class the Housing Unit Price is 12,500 and the Annual Income is 1,000. For Middle Class the Housing Unit Price is 25,000 and the Annual Income is 3,000.
Typical Source of Financing	Owner financedPersonal savingsCommercial banks/mortgages
Additional comments on financing	
Type of Ownership	RentOwn outrightOwn with debt (mortgage or other)
Additional comments on ownership	
Is earthquake insurance for this construction type typically available?	Yes
What does earthquake insurance typically cover/cost	
Are premium discounts or higher coverages available for seismically strengthened buildings or new buildings built to incorporate seismically resistant features?	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
1990	Manjil

Past Earthquakes

Damage patterns observed in past earthquakes for this construction type	
Additional comments on earthquake damage patterns	Walls: Out of plane collapse, Classical X shear cracking. Frames: Buckling of the storey. Roof/Floor:Total/partial collapse. Connections: Excessive rotations, shear failure of the welds, unsitting.

Structural and Architectural Features for Seismic Resistance

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

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

Structural/Architectural Feature	Statement	Seismic Resistance
Lateral load path	The structure contains a complete load path for seismic force effects from any horizontal direction that serves to transfer inertial forces from the building to the foundation.	FALSE
Building Configuration-Vertical	The building is regular with regards to the elevation. (Specify in 5.4.1)	TRUE
Building Configuration-Horizontal	The building is regular with regards to the plan. (Specify in 5.4.2)	TRUE
Roof Construction	The roof diaphragm is	TRUE

	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.	TRUE
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);	N/A
Foundation-Wall Connection	Vertical load-bearing elements (columns, walls) are attached to the foundations; concrete columns and walls are doweled into the foundation.	TRUE
Wall-Roof Connections	Exterior walls are anchored for out-of-plane seismic effects at each diaphragm level with metal anchors or straps.	FALSE
Wall Openings		N/A
Quality of Building Materials	Quality of building materials is considered to be adequate per the	TRUE

	requirements of national codes and standards (an estimate).	
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

Additional comments on structural and architectural features for seismic resistance	
Vertical irregularities typically found in this construction type	Other
Horizontal irregularities typically found in this construction type	Other
Seismic deficiency in walls	Due to lack of proper connections between walls and column, beam floor, walls are very vulnerable to seismic forces
Earthquake-resilient features in walls	
Seismic deficiency in frames	Tear of the beam-to-column connections
Earthquake-resilient features in frame	
Seismic deficiency in roof and floors	
Earthquake resilient features in roof and floors	
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	-|	

Building damage in the 1990 Manjil earthquake-collapse caused by the connection failure

Building damage in the 1990 Manjil earthquake-collapse caused by the connection failure

Minor damage due to pounding between two adjacent buildings in the 1990 Manjil earthquake

Failure due to soft story behavior in the 1990 Manjil earthquake

Retrofit Information

Description of Seismic Strengthening Provisions

Structural Deficiency	Seismic Strengthening
Steel frame	Add diagonal steel bracings as required (high cost/high effectiveness/simple construction)
Connections	Strengthening connections by adequate and proper welding (medium cost/medium effectiveness/simple construction)
Foundations	At the location of the new bracing, strengthening of foundation is essential (high cost/medium effectiveness/complex construction)
New Construction	Steel frame: Design steel frame for gravity load and steel bracing for lateral resistant system (medium cost/medium effectiveness) Connections: Provide proper details for connections (low cost/high effectiveness) Foundations: Proper design (low cost/high effectiveness)

Additional comments on seismic strengthening provisions	
Has seismic strengthening described in the above table been performed?	
Was the work done as a mitigation effort on an undamaged building or as a repair following earthquake damages?	
Was the construction inspected in the same manner as new construction?	
Who performed the construction: a contractor or owner/user? Was an architect or engineer involved?	
What has been the performance of retrofitted buildings of this type in subsequent earthquakes?	
Additional comments section 6	

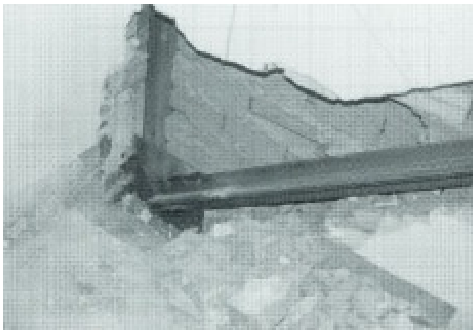
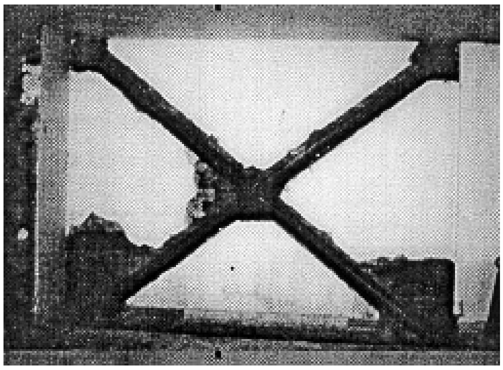
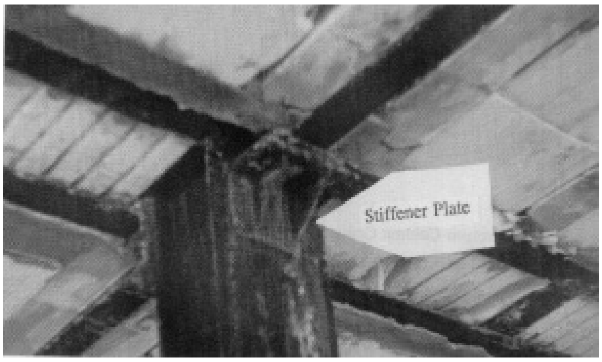


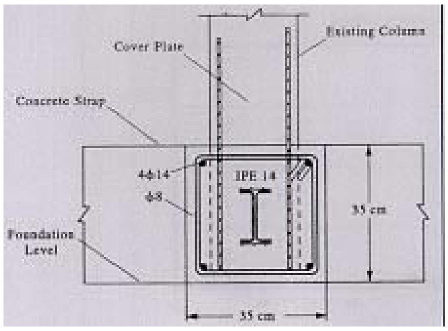
Illustration of Seismic Strengthening Techniques-New Braces Added to the Main Frame



Strengthening of the existing braces



Stiffener plates used for strengthening the connections



Detail used to join footing together through steel tie beam

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