World Housing Encyclopedia Report

Country: Chile

Housing Type: Steel frame buildings with shear walls.

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1 General Information

1.1 Country
Chile

1.3 Housing Type
Steel frame buildings with shear walls.

1.4 Summary
Buildings, dual construction, rigid frames combined with shear walls. X bracing up to 5th floor. Slip formed concrete walls for high rises, up to 5 or 6 parking basements in the latter. Steel decks or precast RC floors. Seismic performance very good. Typically used for apartment buildings or office buildings.

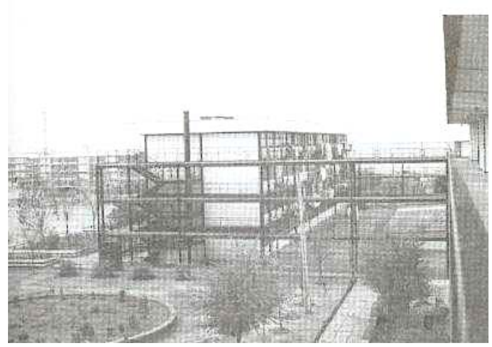

FIGURE 1A: Typical Building: Poblacion Republica popular China, located in Vina del Mar, an area affected by the March 3, 1985 earthquake. These buildings suffered no damage.

1.5 Typical Period of Practice for Buildings of This Construction Type

How long has this construction been practiced	
< 25 years	X
< 50 years	
< 75 years	
< 100 years	
< 200 years	
> 200 years	

Is this construction still being practiced?	Yes	No
	X	

Additional Comments: Since 1965-70.

1.6 Region(s) Where Used
Mainly large cities, Santiago, Concepcion, Valdivia, Temuco, Villarrica. Percentage of total area built below 2%.

1.7 Urban vs. Rural Construction

Where is this construction commonly found?	
In urban areas	X
In rural areas	
In suburban areas	
Both in rural and urban areas	

2 Architectural Features

2.1 Openings

20 to 30%

2.2 Siting

	Yes	No
Is this type of construction typically found on flat terrain?	X	
Is this type of construction typically found on sloped terrain? (hilly areas)		
Is it typical for buildings of this type to have common walls with adjacent buildings?		

The typical separation distance between buildings is 10 meters

2.3 Building Configuration

Rectangular.

2.4 Building Function

What is the main function for buildings of this type?	
Single family house	
Multiple housing units	X
Mixed use (commercial ground floor, residential above)	
Other (explain below)	

Additional Comments: Some buildings include commercial ground floor too.

2.5 Means of Escape

If single-story building there is an additional door besides the main entry. If more than 6-8 floor there is an additional exit stair besides the main stairs, probably pressurized.

2.6 Modification of Buildings

Typical patterns of modification observed: infill balconies, demolishing interior non-structural elements.

3 Socio-Economic Issues

3.1 Patterns of Occupancy

1 family per unit.

3.2 Number of Housing Units in a Building

80 units in each building.

Additional Comments: It is on average. Up to 5 floors, 15-20 units. Up to 20 floors, 150-200.

3.3 Average Number of Inhabitants in a Building

How many inhabitants reside in a typical building of this construction type?	During the day / business hours	During the evening / night
< 5		
5 to 10		
10-20		
> 20	X	X
Other		

3.4 Number of Bathrooms or Latrines per Housing Unit

Number of Bathrooms: 2
Number of Latrines: 0

Additional Comments: 2 bathrooms are widespread but often there are 1 or 2 bathrooms in apartments 60 m^2 and 3 or 4 bathrooms in apartments over 60 m^2.

3.5 Economic Level of Inhabitants

Economic Status		House Price/Annual Income (Ratio)
Very poor		/
Poor	X	/
Middle Class	X	/
Rich	X	/

Additional Comments: House Price/Annual Income ratio: Poor: 4.0 - 4.5, Middle Class: 2.5 - 3.0, Rich: 2.5 - 3.0.

3.6 Typical Sources of Financing

What is the typical source of financing for buildings of this type?	
Owner Financed	X
Personal Savings	X
Informal Network: friends and relatives	
Small lending institutions/microfinance institutions	
Commercial banks / mortages	X
Investment pools	
Combination (explain)	
Government-owned housing	
Other	X

Additional Comments: Ministry of Housing gives low interest loans for poor or low middle class owners

3.7 Ownership

Type of Ownership/Occupancy	
Rent	X
Own outright	
Own with Debt (mortgage or other)	X
Units owned individually (condominium)	X
Owned by group or pool	X
Long-term lease	
Other	

__Additional Comments:__ Some buildings may belong to institution

4 Structural Features

4.1 Lateral Load-Resisting System

Dual construction, shear walls combined with rigid steel frame.
Up to 5 stories x or v or ^ braced shear walls.
Over 5 stories - reinforced concrete slip or jump formed walls.

4.2 Gravity Load-Bearing Structure

Steel deck slabs, prestress concrete slabs, reinforced concrete slabs.
Steel beams, normally composite.
Steel columns and shear walls.

4.3 Type of Structural System

Material	Type of Load-Bearing Structure	#	Subtypes	
Masonry	Stone masonry walls	1	Rubble stone (field stone) in mud/lime mortar or without mortar (usually with timber roof)	
		2	Massive stone masonry (in lime or cement mortar)	
	Earthen walls	3	Mud walls	
		4	Mud walls with horizontal wood elements	
		5	Adobe block or brick walls	
		6	Rammed earth/Pise construction	
	Unreinforced brick masonry walls	7	Unreinforced brick masonry in mud or lime mortar	
		8	Unreinforced brick masonry in mud or lime mortar with vertical posts	
		9	Unreinforced brick masonry in cement or lime mortar (various floor/roof systems)	
	Confined masonry	10	Confined brick/block masonry with concrete posts/tie columns and beams	
	Concrete block masonry walls	11	Unreinforced in lime or cement mortar (various floor/roof systems)	
		12	Reinforced in cement mortar (various floor/roof systems)	
		13	Large concrete block walls with concrete floors and roofs	
Concrete	Moment resisting frame	14	Designed for gravity loads only (predating seismic codes i.e. no seismic features)	
		15	Designed with seismic features (various ages)	
		16	Frame with unreinforced masonry infill walls	
		17	Flat slab structure	
		18	Precast frame structure	
		19	Frame with concrete shear walls-dual system	
		20	Precast prestressed frame with shear walls	
	Shear wall structure	21	Walls cast in-situ	
		22	Precast wall panel structure	
Steel	Moment resisting frame	23	With brick masonry partitions	
		24	With cast in-situ concrete walls	X
		25	With lightweight partitions	X
	Braced frame	26	Concentric	X
		27	Eccentric	
Timber	Load-bearing timber frame	28	Thatch	
		29	Post and beam frame	
		30	Walls with bamboo/reed mesh and post (wattle and daub)	
		31	Wooden frame (with or without infill)	
		32	Stud wall frame with plywood/gypsum board sheathing	
		33	Wooden panel or log construction	
Various	Seismic protection systems	34	Building protected with base isolation devices or seismic dampers	
	Other	35		

Additional Comments: Typical buildings have shear wall, light weight partitions and some concentric brace frames.

4.4 Type of Foundation

Type	Description	
Shallow Foundation	Wall or column embedded in soil, without footing	
	Rubble stone (fieldstone) isolated footing	
	Rubble stone (fieldstone) strip footing	
	Reinforced concrete isolated footing	X
	Reinforced concrete strip footing	X
	Mat foundation	X
	No foundation	
Deep Foundation	Reinforced concrete bearing piles	X
	Reinforced concrete skin friction piles	
	Steel bearing piles	X
	Wood piles	
	Steel skin friction piles	
	Cast in place concrete piers	
	Caissons	
Other	Floating deep foundations	X

4.5 Type of Floor/Roof System

Material	Description of floor/roof system	Floor	Roof
Masonry	Vaulted		
	Composite masonry and concrete joist		
Structural Concrete	Solid slabs (cast in place or precast)		
	Cast in place waffle slabs		
	Cast in place flat slabs		
	Precast joist system		
	Precast hollow core slabs		
	Precast beams with concrete topping		
	Post-tensioned slabs	X	
Steel	Composite steel deck with concrete slab	X	X
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 single roof		
	Wood planks or beams that support clay tiles		
	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	Composite steel deck without concrete slab		X

Additional Comments: Floor and roof are considered as rigid diaphragm

4.6 Typical Plan Dimensions

Length: 10 - 20 meters
Width: 10 - 20 meters
Additional Comments: This is for buildings with number of story up to 5 floors. In high rise buildings typical plan dimensions are from 20 m - 20 m to 30 m - 30 m.

4.7 Typical Number of Stories

3 - 24
3 to 5 and 6 to 24

4.8 Typical Story Height

3.0 meters

Additional Comments: Story height ranges from 2.7 m to 3 m.

4.9 Typical Span
7.5 meters

Additional Comments: Span variation: 7.5 -10 m.

4.10 Typical Wall Density
1% to 2% in each direction

4.11 General Applicability of Answers to Questions in Section 4
The values informed are for typical steel buildings, when necessary a division has been done between buildings up to 5 floor or higher. Steel construction represent less than the 2% of the total area built in Chile per year.

5 Evaluation of Seismic Performance and Seismic Vulnerability

5.1 Structural and Architectural Features: Seismic Resistance

Structural/ Architectural Feature	Statement	True	False	N/A
Lateral load path	The structure contains a complete load path for seismic force effects from any horizontal direction that serves to transfer inertial forces form the building to the foundation.	X		
Building configuration	The building is regular with regards to both the plan and the elevation.	X		
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.	X		
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.	X		
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.	X		
Wall and frame structures-redundancy	The number of lines of walls or frames in each principal direction is greater than or equal to 2.	X		
Wall proportions	Height-to-thickness ratio of the shear walls at each floor level is: 1) Less than 25 (concrete walls); 2)Less than 30 (reinforced masonry walls); 3) Less than 13 (unreinforced masonry walls).	X		
Foundation- wall connection	Vertical load-bearing elements (columns, walls) are attached to the foundations; concrete columns and walls are doweled into the foundation.	X		
Wall-roof connections	Exterior walls are anchored for out-of-plane seismic effects at each diaphragm level with metal anchors or straps.	X		
Wall openings	The total width of door and window openings in a wall is: 1) for brick masonry construction in cement mortar: less than 1/2 of the distance between the adjacent cross walls; 2) for adobe masonry, stone masonry and brick masonry in mud mortar: less than 1/3 of the distance between the adjacent cross walls; 3) for precast concrete wall structures: less than 3/4 of the length of a perimeter wall.			X
Quality of building materials	Quality of building materials is considered to be adequate per requirements of national codes and standards (an estimate).	X		
Quality of workmanship	Quality of workmanship (based on visual inspection of few typical buildings) is considered to be good (per local construction standards).	X		
Maintenance	Buildings of this type are generally well maintained and there are no visible signs of deterioration of building elements (concrete, steel, timber).	X		
Other				

5.2 Seismic Features

Structural Element	Seismic Deficiency	Earthquake-Resilient Features	Earthquake Damage Patterns
Wall	None	Regular buildings in plan and height good design and construction practice	No damage in serious earthquakes in 1960 (M 9.5) and 1985 (M 7.8)
Frame (columns, beams)	None		
Roof and floors	None		

5.3 Seismic Vulnerability Rating

	Vulnerability					
	High (Very Poor Seismic Performance) A	B	Medium C	D	E	Low (Excellent Seismic Performace) F
Seismic Vulnerability Class					<	0

0 - probable value
< - lower bound
> - upper bound

6 Earthquake Damage Patterns

6.1 Past Earthquakes Reported To Affect This Construction

Year	Earthquake Epicenter	Richter magnitude(M)	Maximum Intensity (Indicate Scale e.g. MMI, MSK)
1985	Llolleo	7.8	VIII (MMI)
1960	Valdivia	9.5	XI (MMI)

Additional Comments: There were many connections of the type that failed in Northridge, Loma Prieta and Kobe. No damage in any of them. Probable causes: # Chilean Building Code allows maximum drift about 1/2 of USA. # Periods are approximately 0.05N instead of 0.1N (N=floors) # No jumbo W sections are used # Beams and columns are welded to stress relieved plates. A good example of good behavior are the seven 4 story-buildings from Poblacion Republica Popular China, located in Viña del Mar. They are 46 X 10.6 m in plan, have moment resisting frames in both directions and 12 cm reinforced concrete slab. In the longitudinal direction the span is 4.6 cm. The buildings were designed according to NCh428.Of 57 with A42-27ES steel.

7 Building Materials and Construction Process

7.1 Description of Building Materials

Structural Element	Building Material	Characteristic Strength	Mix Proportions/ Dimensions	Comments
Walls/foundations	Reinforced concrete Rebars	25-30 MPa 420-280 MPa		
Foundations				
Frame	Structural Steel	250 MPa (36 ksi)		
Roof and floors	RC slabs Steel beams	25-30 MPa 250 MPa		

Notes:
1. Concrete compression strength, steel ultimate strength and steel yield strength
2.

7.2 Does the builder typically live in this construction type, or is it more typically built by developers or for speculation?

Built by developers and sold to users

7.3 Construction Process

Developer hires architects, engineers and construction firms

7.4 Design/Construction Expertise

Architects have 5 university years and typically over 5 years of experience.
Engineers have 6 university years and typically over 5 years of experience.
Construction companies are headed by engineers or architects. Experience about 10 years.
The same for fab shops.
In steel frame buildings, review of design and independent inspection are typical.

7.5 Building Codes and Standards

	Yes	No
Is this construction type addressed by codes/standards?	X	

Title of the code or standard: Chilean seismic codes NCh433.Of96 and NCh2369 are mandatory. AISC and ACI codes corrected to meet seismic codes are applied.
Year the first code/standard addressing this type of construction issued: 1957
National building code, material codes and seismic codes/standards: NCh433.Of96, seismic design for buildings; NCh2369.Of01 seismic design of industrial buildings, NCh428.Of57code design for steel structures.
When was the most recent code/standard addressing this construction type issued? 1957, but now there is a draft to modify that code that partially follows AISC and AISI.

7.6 Role of Engineers and Architects

Architects and engineers must visit the job and provide general supervision. They usually must approve construction contracts.

7.7 Building Permits and Development Control Rules

	Yes	No
Building permits are required	X	
Informal construction		X
Construction authorized per development control rules	X	

7.8 Phasing of Construction

	Yes	No
Construction takes place over time (incrementally)	X	
Building originally designed for its final constructed size	X	

7.9 Building Maintenance

Who typically maintains buildings of this type?	
Builder	
Owner(s)	X
Renter(s)	X
No one	
Other	

7.10 Process for Building Code Enforcement

Design review by peers (may belong to design firm) is normal.
Independent inspection is normal in steel framed buildings.

7.11 Typical Problems Associated with this Type of Construction

Erection tolerances due to lack of experience of erectors.

8 Construction Economics

8.1 Unit Construction Cost (estimate)

Low cost apartments, up to 5 floors, UF 10/m² (US $300/m²)
Normal, up to 5 floors, UF 20/m² (US $600/m²)
High-rises, 30/m² (US$900/m²)

8.2 Labor Requirements (estimate)

1.5 to 2.5 floors/month

9 Insurance

9.1 Insurance Issues

	Yes	No
Earthquake insurance for this construction type is typically available	X	
Insurance premium discounts or higher coverages are available for seismically strengthened buildings or new buildings built to incorporate seismically resistant features		X

9.2 If earthquake insurance is available, what does this insurance typically cover/cost?

Repairs to same conditions before the earthquake.
Occasionally time lost.

10 Seismic Strengthening Technologies

10.1 Description of Seismic Strengthening Provisions

Type of intervention	Structural Deficiency	Description of seismic strengthening provision used

Additional Comments: It has not been required in steel framed buildings

10.2 Has seismic strengthening described in the above table been performed in design practice, and if so, to what extent?

10.3 Was the work done as a mitigation effort on an undamaged building, or as repair following earthquake damage?

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

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

10.6 What has been the performance of retrofitted buildings of this type in subsequent earthquakes?

11 References

Monge, J., Campino S., Sharpe, R., (1985) "Edificios de Acero" in "El sismo de marzo 1985, Chile" ed. J. Monge.

12 Contributors

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13 Figures

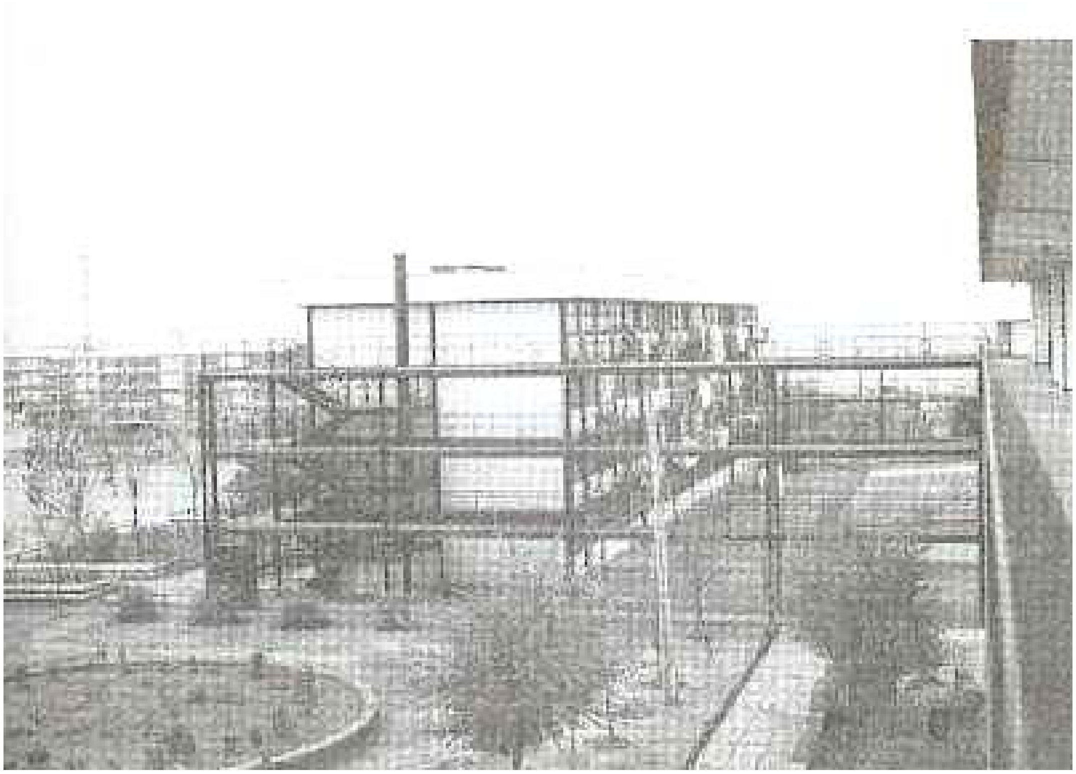

FIGURE 1A: Typical Building: Poblacion Republica popular China, located in Vina del Mar, an area affected by the March 3, 1985 earthquake. These buildings suffered no damage.

FIGURE 1B: Typical Building: Poblacion Republica popular China, located in Vina del Mar, an area affected by the March 3, 1985 earthquake. These buildings suffered no damage.

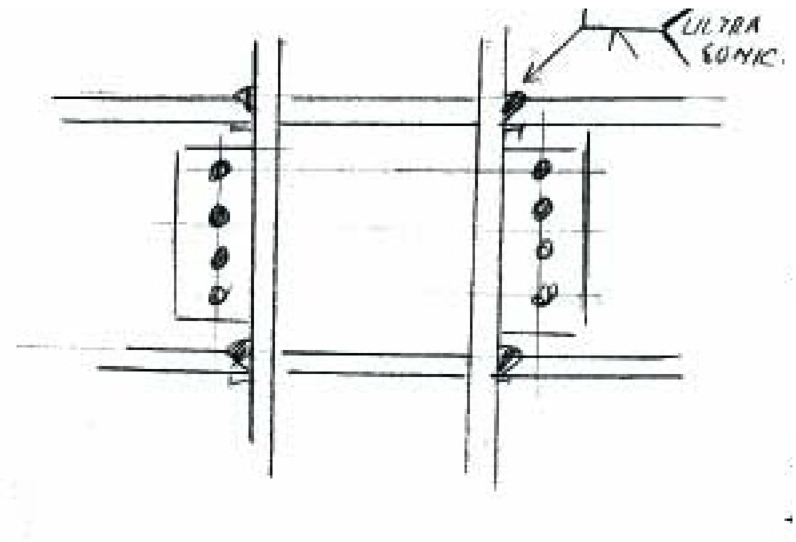

FIGURE 2A: Critical Structural Details

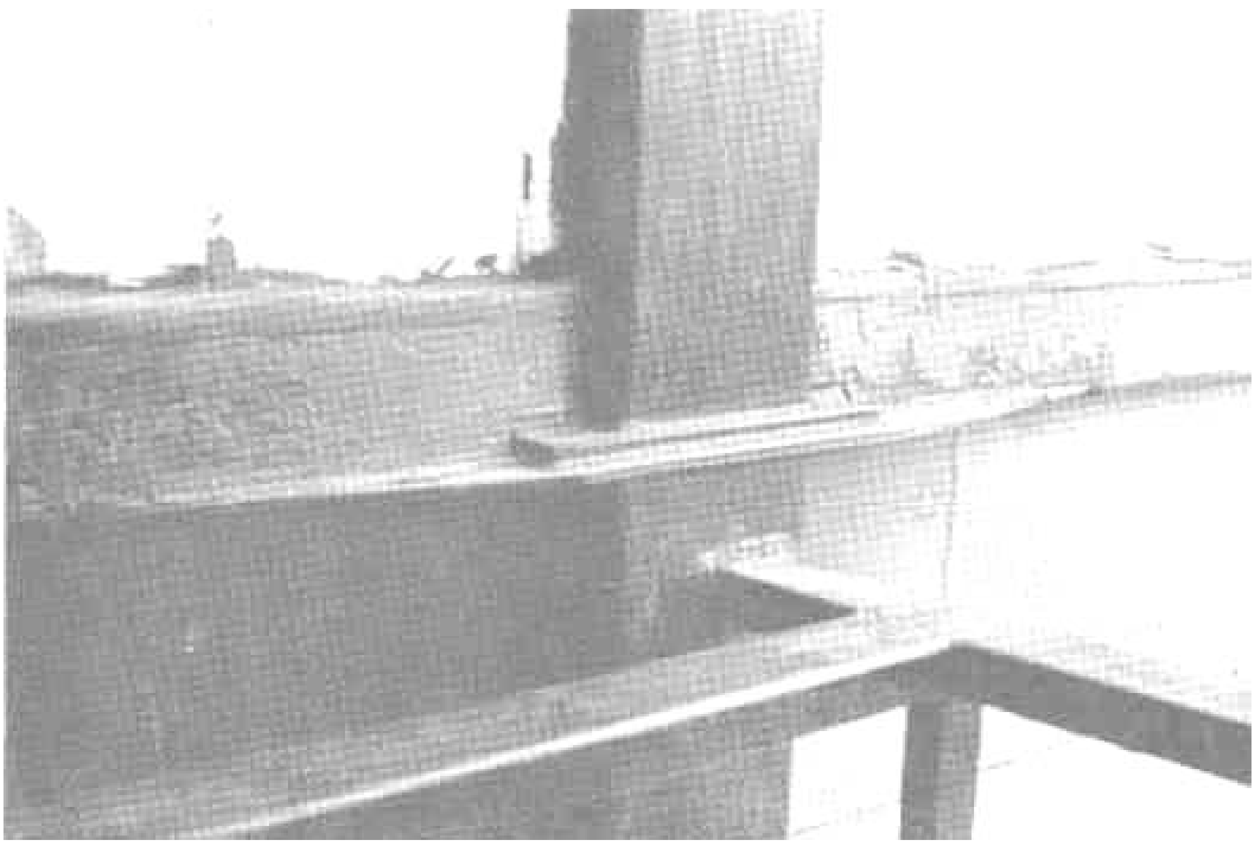

FIGURE 2B: Critical Structural Details : beam column connection The beam springer is welded to the column at the shop, so at the site weld connections are done out damage exposed zones

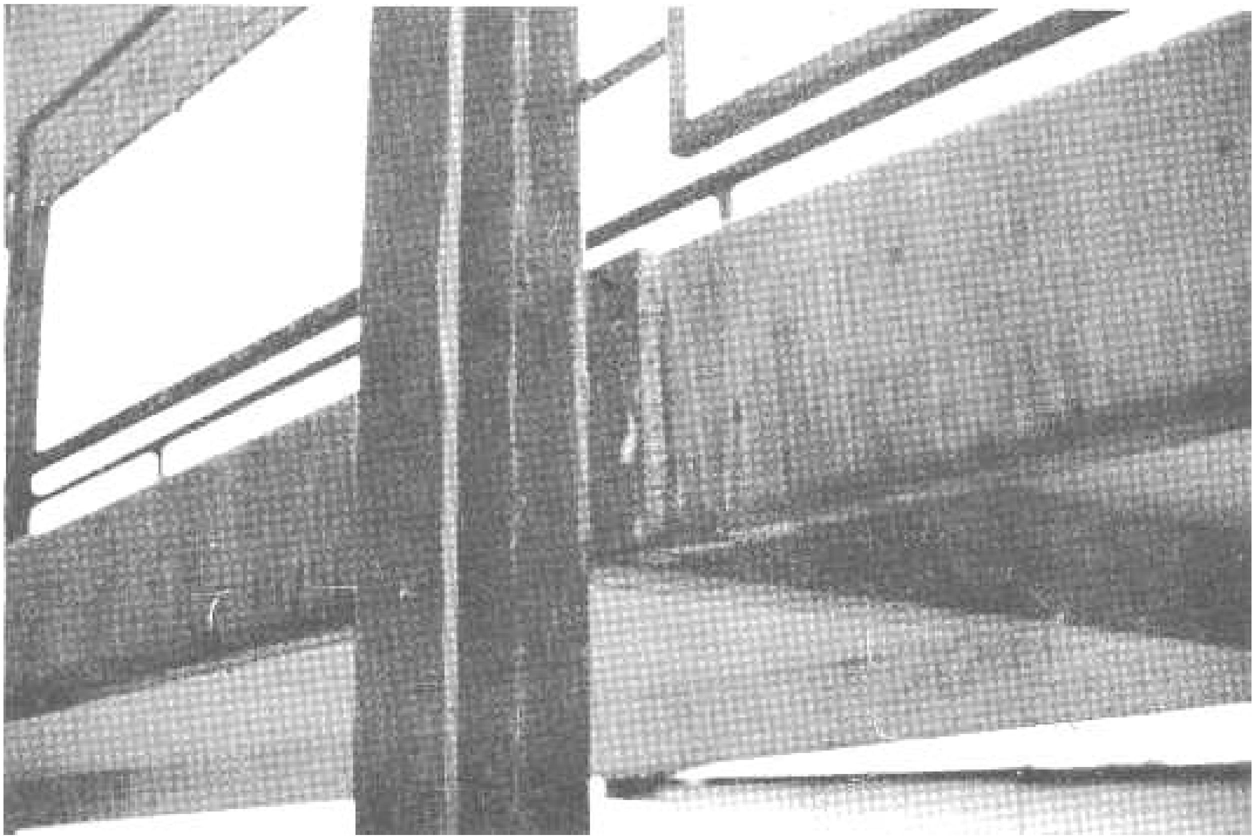

FIGURE 2C: Critical Structural Details--connections.