# World Housing Encyclopedia Report

## Country: Venezuela

Housing Type: Urban non-engineered popular housing on flat terrain

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# 1 General Information

## 1.1 Country

Venezuela

## 1.3 Housing Type

Urban non-engineered popular housing on flat terrain

## 1.4 Summary

This is an urban housing construction type found in the Andean states of Venezuela. In some cities e.g. Mérida this construction accounts for 40% of the total building stock. Typical buildings of this type are two to three stories high. Typically, there are two or three bays in the longitudinal direction (spaced at 3 to 4 m) and four or five bays in the transverse direction (4 to 5 m apart). The main load bearing system consists of reinforced concrete frame (columns and beams) with hollow clay tile masonry infill walls. Roof structure consists of lightweight roofing (zinc and/or acclimatized galvanized sheets) supported by I-shaped steel beams. The roof level of a building is used as a terrace with a one meter high masonry parapet that serves as a guardrail on the slab perimeter. This is a non-engineered construction i.e. these buildings are constructed by the owners. Due to the lack of adequate detailing in the longitudinal and transverse steel reinforcement bars, beam-column connections are inadequate and do not provide the continuity required for adequate seismic performance.

*FIGURE 1: Typical Building*

## 1.5 Typical Period of Practice for Buildings of This Construction Type

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

| Is this construction still being practiced? | Yes | No |
|---|---|---|
| | X | |

## 1.6 Region(s) Where Used

States: Mérida, Táchira and Trujillo in Venezuela, these comprise the Andean states of the country. Percentage of housing covers almost 40% of total building stock in Mérida city.

## 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 | |

*Additional Comments:* See Figure 1

# 2 Architectural Features

## 2.1 Openings

Usually, openings are produced at the front and the back of the building, having door and window openings on the first level and two windows in successive levels. The openings range from 5 to 10% of the overall wall area.

## 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 0.03 meters

## 2.3 Building Configuration

Typical shape of a building plan for this housing type is rectangular, with proportions (width/length) ranging from 1/3 to 1/4.

## 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) | |

## 2.5 Means of Escape

Means of escape are not considered. Only one access door is available and it is protected with an external metallic door (due to high criminality), with more than one lock. Additional staircases in higher buildings are not practical due to proximity between buildings.

## 2.6 Modification of Buildings

Modifications respond to vertical growth, balconies, new windows, staircases for separate access to upper levels. Usually, when a new level is constructed, an external staircase facing the façade is built to permit separate access to upper levels. Windows and balconies are located in the façade and back walls. In lateral walls, windows are built when possible due to lateral proximity between buildings.

# 3 Socio-Economic Issues

## 3.1 Patterns of Occupancy
Number of families depends mostly upon the number of levels (e.g. two levels, two families). An average occupancy pattern is two families (5.40 members/family).

## 3.2 Number of Housing Units in a Building
2 units in each building.

*Additional Comments:* It is estimated average housing units per building.

## 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 | X | |
| 5 to 10 | | |
| 10-20 | | X |
| > 20 | | |
| Other | | |

## 3.4 Number of Bathrooms or Latrines per Housing Unit
Number of Bathrooms: 1
Number of Latrines: 0

*Additional Comments:* Each housing unit has a bathroom. If several housing units are present at a building (average two), there are as many bathrooms as housing units.

## 3.5 Economic Level of Inhabitants

| Economic Status | | House Price/Annual Income (Ratio) |
|---|---|---|
| Very poor | | / |
| Poor | X | 31000/2500 |
| Middle Class | | / |
| Rich | | / |

*Additional Comments:* Annual Income ranges from 2000-3000 Currency: US $

## 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 | |
| Investment pools | |
| Combination (explain) | |
| Government-owned housing | |
| Other | |

## 3.7 Ownership

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

# 4 Structural Features

## 4.1 Lateral Load-Resisting System

Reinforced concrete frames generally provide an acceptable lateral load resistance depending on adequate quality and detailing of structural elements (columns and beams). In this case, the detailing of reinforced concrete columns and beams is inadequate e.g. there is excessive stirrup spacing (same distance of element's section base), inadequate tie anchorage (angle of anchorage is 90º instead of 135º as recommended in seismic codes), and inadequate location of laps in longitudinal reinforcement for columns (laps are provided at bottom of columns in successive stories). Roof structure consists of lightweight roofing (zinc and/or acclimatized galvanized sheets) supported by I-shaped steel beams.

## 4.2 Gravity Load-Bearing Structure

Reinforced concrete frames

## 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) | X |
| | | 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 | |
| | | 25 | With lightweight partitions | |
| | Braced frame | 26 | Concentric | |
| | | 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:* See Figure 2.

## 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 | |
| | Mat foundation | |
| | No foundation | |
| Deep Foundation | Reinforced concrete bearing piles | |
| | Reinforced concrete skin friction piles | |
| | Steel bearing piles | |
| | Wood piles | |
| | Steel skin friction piles | |
| | Cast in place concrete piers | |
| | Caissons | |
| Other | | |

*Additional Comments:* See Figure 2

## 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 | | |
| Steel | Composite steel deck with concrete slab | | |
| 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 | Floor: Composite hollow clay tiles and steel joists Roof: Steel joists and metal sheathing (zinc/aluminum) | X | X |

*Additional Comments:* Floors may be considered as rigid diaphragms. Special inspection must be performed on floor connection with beams, to guarantee transmission of lateral loads. Roof may not be considered as a rigid diaphragm, due to the reduced sections (at most IPN 80), the low connectivity between joists and the lack of connection with the rest of the structure (absence of a collar beam on top of walls in roof level).

## 4.6 Typical Plan Dimensions

Length: 12 - 15 meters
Width: 12 - 15 meters

## 4.7 Typical Number of Stories

2 - 3

## 4.8 Typical Story Height

2.8 meters

*Additional Comments:* This is average.

### 4.9 Typical Span
5.0 meters

*Additional Comments:* Usually typical span range from 3 to 5 meters.

### 4.10 Typical Wall Density
Two possibilities regarding wall density exist depending on position of the building in the block; there are Inner and Corner buildings Wall Density respectively.
Wall density for Inner Buildings:
Floor Number
Total Wall Area longitudinal direction Total Wall Area transverse direction Typical Wall Density long. Dir. Typical Wall Dens. Trans. Dir
1 114.24 56.96 1.28 0.64
2 119 64.72 1.33 0.62
Wall Density for Corner Buildings:
Floor Number Total Wall Area longitudinal direction Total Wall Area transverse direction Typical Wall Density long. Dir. Typical Wall Dens. Trans. Dir
1 108.48 56.96 1.21 0.64
2 114.2 64.72 1.28 0.72

### 4.11 General Applicability of Answers to Questions in Section 4
Description relates to average conditions of buildings, almost 60% of the buildings match average conditions. An important issue here is density of population, with 285 inhabitants/ha. in settlements of this kind.

# 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 | | | | |

*Additional Comments:* Insert additional text if applicable .

## 5.2 Seismic Features

| Structural Element | Seismic Deficiency | Earthquake-Resilient Features | Earthquake Damage Patterns |
|---|---|---|---|
| Wall | No reinforcement is visible throughout the walls (neither horizontal nor vertical). Poor quality mortar and cracked masonry units. | | Cracking in walls, parts of walls collapse, great cracks in windows and doors vertices. |
| Frame (columns, beams) | -Stirrup and tie spacing is not compliant to recommendations of less than d/2 spacing in beams and d/4 in columns, neither in beams nor in columns. Spacing is regular throughout all members and is usually d or more. Anchorage hooks into member cores are generally 90º, and do not comply with the minimum 135º recommendations.-Lap splices in longitudinal column bars are located at the bottom of tie-columns; no special spacing in ties is practiced, producing a potential plastic hinge formation region at the bottom of the column. As sections and reinforcement detailing in beams and columns are identical, the Strong Column/Weak Beam recommendation is not complied establishing the possibility of column hinging and consequently lead to story mechanisms and concentration of inelastic activity at a single level. | | Shear failure in connections between columns and beams, and between columns and foundations, excessive lateral displacements, cracking and spalling concrete columns due to inadequate confinement. |
| Roof and floors | Roof may not be considered as a rigid diaphragm due to the lack of adequate connectivity within its elements and with the walls (absence of a collar beam on top of walls at this level).Connections between floor and frames must be inspected to guarantee adequate linking and load transmission. | | Roof: great movements may be generated in roofs, total dismantelation and consequent collapse may occur. Floors: great movements may inflict damage in confinement and walls. |
| Other | Risk of pounding effect. Not enough gap between adjacent buildings, distance is not greater than 10.0 cm. | | Column failure at level where slabs of neighboring construction pounds. |

*__Additional Comments:__* See Figures 4 and 5

## 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) |
|---|---|---|---|
| 1997 | 10.5N 5.3ºW Depth 9.4 km(Caríaco, Venezuela) | 6.8 | VIII (MMI) |

*Additional Comments:* See Figure 6

# 7 Building Materials and Construction Process

## 7.1 Description of Building Materials

| Structural Element | Building Material | Characteristic Strength | Mix Proportions/ Dimensions | Comments |
|---|---|---|---|---|
| Walls | Hollow Clay Tile Cement Mortar | 3.0 MPa N/A | W/H/L (mm.) 100/250/350 120/250/350 150/200/350 200/200/350 N/A | |
| Foundations | Reinforced Concrete | Structural Steel Rods Concrete N/A | W/H/L (mm.) 1000/400/1000 | |
| Frame | Reinforced Concrete | Structural Steel Rods Concrete N/A | N/A | |
| Floors | Clay tiles Steel joists | N/A Structural Steel | W/H/L (mm.) 60/350/600 60/350/800 IPN 80 (h: 80 mm) IPN 100 (h:100 mm) | |
| Roof | Steel Joists Ties Metal sheathing (zinc/aluminum) | Structural Steel Mild steel | IPN 80 (h:80 mm) 2 X 1 inches W/L (mm.) 830/4000 | |

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

The builder lives in this construction type.

## 7.3 Construction Process

Construction process is performed in vertical phases, i.e. a level at a time. Common practice is to build foundations and columns for the first level, leaving columns longitudinal steel bars to be spliced. After concrete curing, walls are built. Beams are built over walls, and afterwards the first slab (hollow clay tiles with steel joists) is constructed. The owner typically builds with at most two helpers. All process is performed at the building site with ordinary building tools, no special machinery or equipment is used.

## 7.4 Design/Construction Expertise

No professionals (Architects and/or Engineers) are involved in the design and construction process. Builders mainly count on some experience in building construction. Semi-skilled level seems to suit adequately the expertise of the builders.

## 7.5 Building Codes and Standards

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

## 7.6 Role of Engineers and Architects

As an auto-constructed type, construction professionals (Architects and/or Engineers) are involved neither in the design nor in the construction process. Professional intervention is unaffordable for the inhabitants of these settlements.

## 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 |

*Additional Comments:* Phasing in construction depends on money availability, these resources are obtained from savings and the cooperation of other family members. Usually the inhabitants collaborate in the building process.

## 7.9 Building Maintenance

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

## 7.10 Process for Building Code Enforcement

Official authorities are carrying no process or strategy for building code enforcement.

## 7.11 Typical Problems Associated with this Type of Construction

Inexistent seismic detailing features in reinforced concrete works. Connections between floors and structural frames do not guarantee lateral force transmission and may induce displacement of slabs with respect to the frames generating damage to columns. Parapets in uppermost levels represent a dangerous collapsible feature. The absence of collar beams and horizontal reinforcement in uppermost walls may produce out-of-plane inertial loads. Gap between adjacent buildings (not greater than 10.0 cm.) identifies risk of pounding effect.

# 8 Construction Economics

## 8.1 Unit Construction Cost (estimate)

Unit construction cost: 87000 Bs. (120 US$) per $m^2$ of built-up area.

## 8.2 Labor Requirements (estimate)

For each level, with a three workers team, 45 to 55 days are required to complete the construction.

# 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 | | |

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

# 10 Seismic Strengthening Technologies

## 10.1 Description of Seismic Strengthening Provisions

| Type of intervention | Structural Deficiency | Description of seismic strengthening provision used |
| --- | --- | --- |

*Additional Comments:* To the moment, seismic strengthening provisions have not been performed, neither in design nor in retrofitting.

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

No.

## 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

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FEMA310 "Handbook for the Seismic Evaluation of Buildings -A Pre-standard-", Federal Emergency Management Agency, Washington, D.C., 1998.

# 12 Contributors

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# 13 Figures

*FIGURE 1: Typical Building*

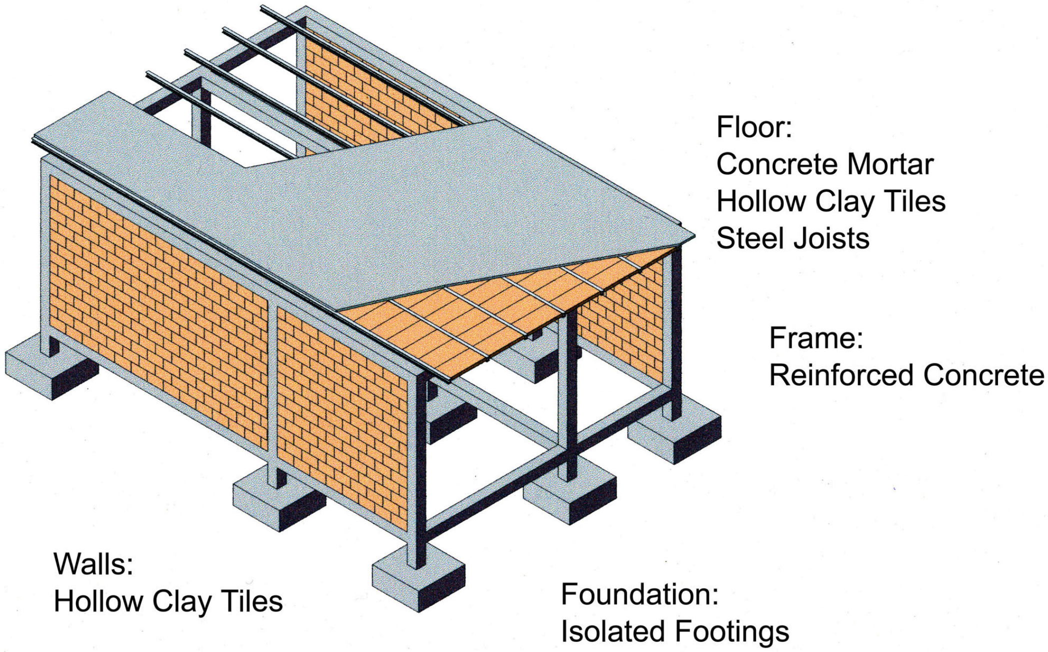


*FIGURE 2: Key Load-Bearing Elements*

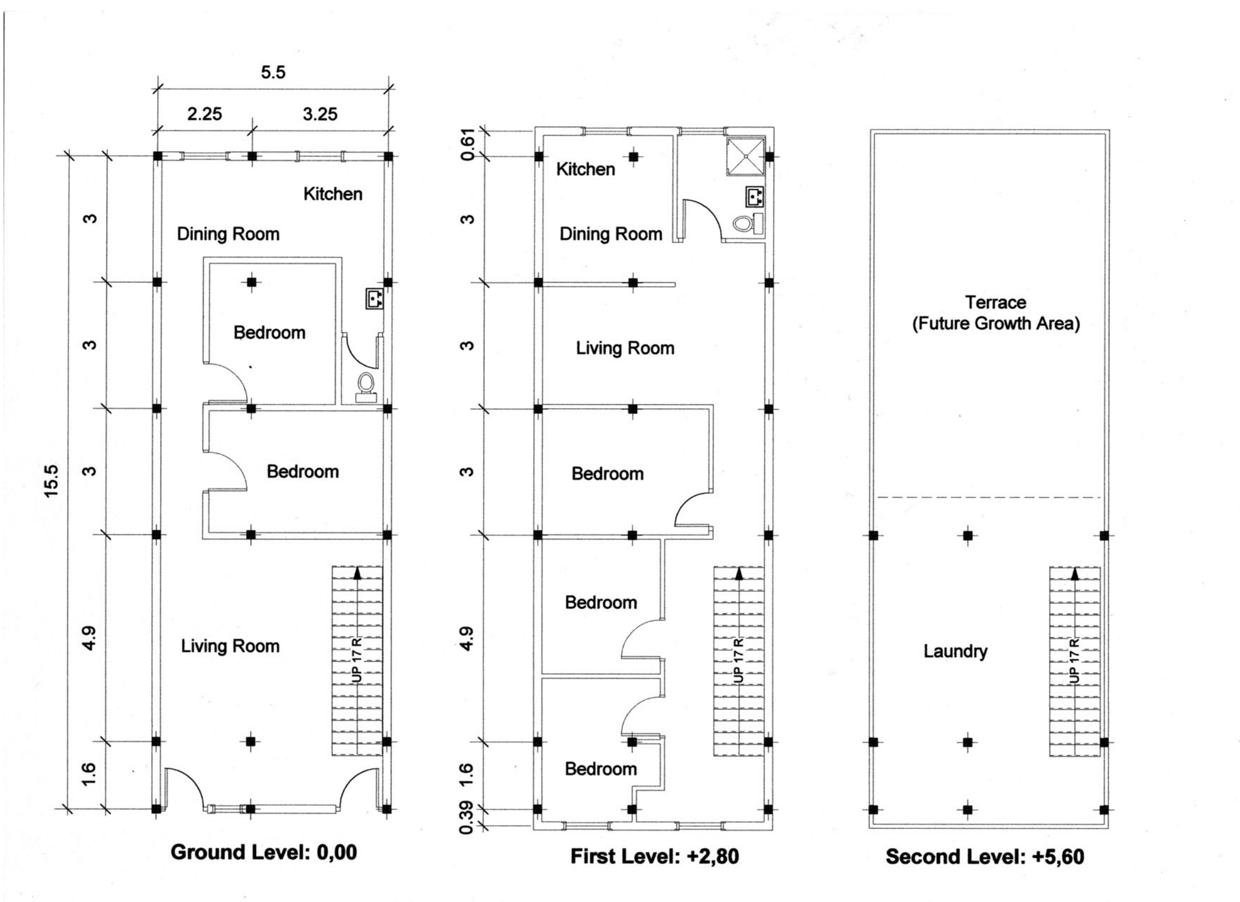

*FIGURE 3: Plan of a Typical Building*

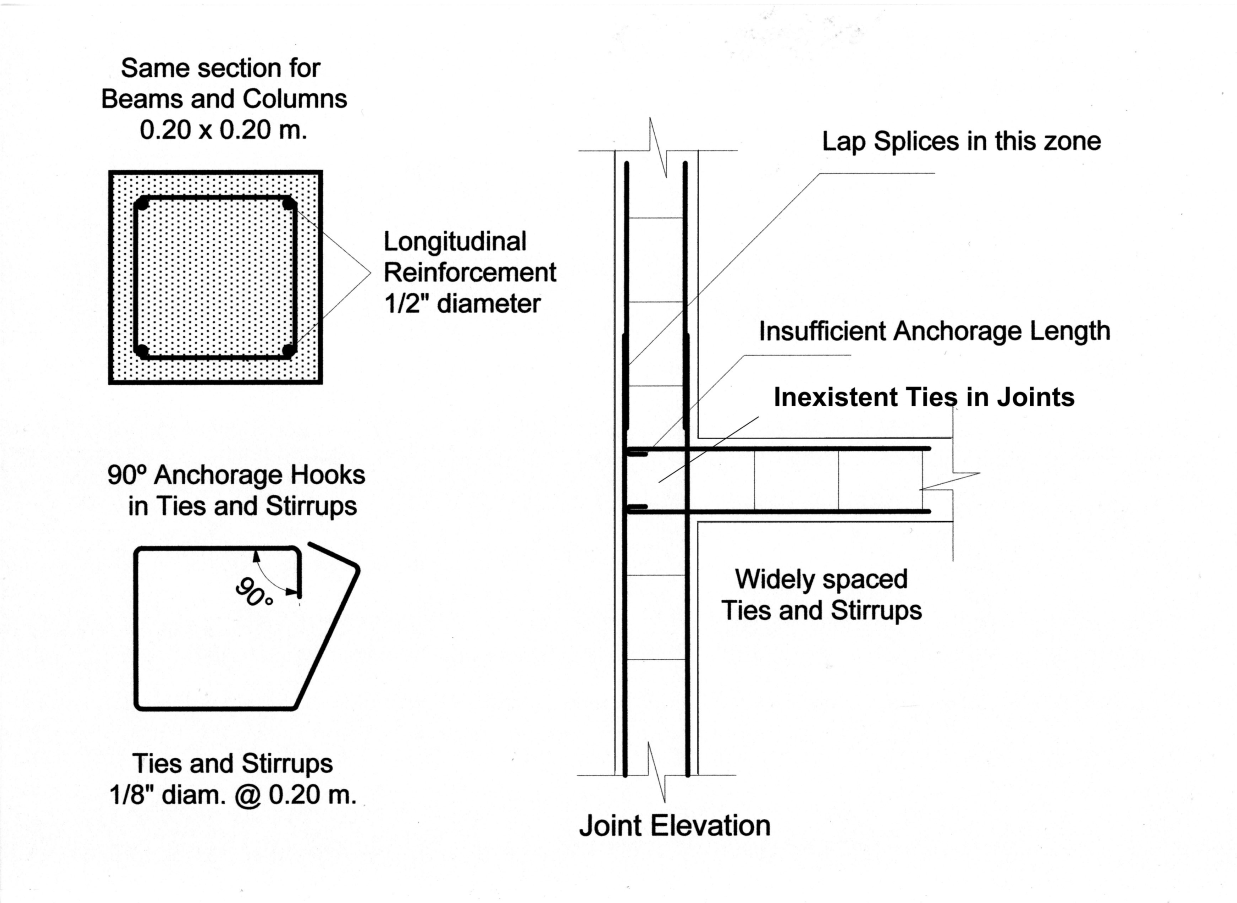


*FIGURE 4: Critical Structural Details*

Inexistent Collar Beam

Ties and Stirrups
widely spaced,
90 º Anchorage hooks

Inadequate connection
between floor and frames

Adjacency and height differences

*FIGURE 5: An Illustration of Key Seismic Features and/or Deficiencies*

*FIGURE 6: A Photograph Illustrating Typical Earthquake Damage (1997 Cariaco earthquake)*