

Table of Contents

- A. Country
- ~~B. Seismology~~
- ~~C. The Earthquake~~
- D. General Description of Damage
- E. Description of Damage
- E. Description of Damage in Guatemala City
- F. Buildings
 - 1. Finance Ministry
 - 2. National Theater
 - 3. Terminal Hotel
 - 4. El Camino Real Hotel
 - 5. Hotel Guatemala Fiesta
 - 6. IGSS General Headquarters
 - 7. IGSS Central Office Building
 - 8. IGSS Rehabilitation Hospital
 - 9. General Hospital
 - 10. Catholic School
 - 11. University of the Valley
 - 12. Raphael Landivia Catholic University
 - 13. GUATEL
 - 14. GUATEL Old Guard
 - 15. GUATEL Sanchez Building
 - 16. Customs House
 - 17. National Printing Plant
 - 18. BMW Car Showroom
 - 19. Plymouth Fargo Car Showroom
 - 20. Divine Redeemer Church
- G. Other Structures
 - 1. Bridges
 - 2. Elevated Tanks
 - 3. Eiffle Tower
- ~~H. Water Supply Systems~~
- ~~I. Sewage Disposal Systems~~
- J. Gas
- ~~K. Electrical Distribution Systems~~
- L. Codes and Enforcement
- M. Conclusion

THE GUATEMALA EARTHQUAKE

OF

FEBRUARY 4, 1976

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The Country

Guatemala is located in the center of Central America with Mexico lying directly to the north and El Salvador and Honduras immediately to the south. The Pacific Ocean is on the left while the Caribbean Sea is on the opposite side, sharing some of this eastern border with Honduras. Guatemala is somewhat irregular in its boundaries but measures 513 km north and south, and 432 km east and west at its maximum dimensions. The country claims 42,042 square miles, not counting Beliez, and contains a population of 5.35 million with reportedly 730,991 in Guatemala City. Exports include coffee, cotton and bananas primarily, although the tourist trade clearly constitutes a significant business for the country.

The southwestern part of Guatemala is particularly mountainous, being on what might be considered an extension of the Sierra Madres Range of Mexico. There are 31 principal volcanoes, most of which are found in this area. The capitol itself is located in southwestern Guatemala on a plateau of 1500 meters elevation astride the Continental Divide. Two prominent river valleys lying east and west empty into the Caribbean.

The soil is volcanic ash with partial cementation. Ground cover appears to provide some protection from erosion. Steep ravines, however, infringe on the plateau areas.

In the area of Guatemala City the water table stands at 60 meters.

General Description of Damage

On February 12, the Free Press quoted the following government gathered statistics: killed 17,032; wounded 54,825; residences destroyed in the urban areas 108,225; residences destroyed in the rural areas 113,769; total population without shelter 1,044,441; killed in Guatemala City 3,172; killed in Chimaltenango 9,338; killed in El Progreso 1,700; killed

-2-

in Sacatipequez 1,248. It is evident that most were killed by the adobe and lime-mortar brick walls, and clay tile roofs which collapsed on the population as it lay sleeping. A great human tragedy is difficult to imagine.

Description of Damage in Guatemala City

Buildings. There are 30 high rise buildings in and about Guatemala City; 19 of these were observed to be over six stories in height and located within approximately a four mile radius of the center of the city. There is one multi-story steel frame building which is located in the city's center. The remainder of the high rises are reinforced concrete frame with some concrete shear wall construction.

Most of the engineered construction is reinforced concrete frame with infilled, lime mortar, brick masonry walls which have no reinforcement, although numerous, single story prefabricated steel buildings are being used in and about the city as commercial and industrial establishments and, in one case, as a hospital.

There were four partial collapses involving engineered construction. None of the collapses involved high rise buildings. With few exceptions, the frames in the typical RCC frame construction did not have an opportunity to act due to resistance of the infill walls and apparently low intensity of ground shaking.

With one exception, there are no local records of the earthquake groundmotion. A seismoscope record was located by the USGS team and an attempt is being made to digitize it. Observation of the damage on the Modified Mercalli Scale, 1956 version, corresponded to intensity of no more than VI or VII in the general vicinity of the city.

There were no known fires associated with the earthquake.

Finance Ministry. The Finance Ministry is located at the intersection of 8th Avenue and 21st Street in Zone 1. The building is a 22 story structure, 19 stories being above ground and three being below as a basement parking garage. There is also a two level penthouse containing mechanical and some communications equipment. It is still under construction but was essentially complete, except for architectural finish work, at the time of the earthquake.

The Finance Ministry is an unusually regular structure, being approximately 73 feet by 222 feet in plan with a typical 12.5 foot story height. The long axis is oriented E-W, comprised of eight bays at 27.8 feet typically. The N-S axis involves three bays at 23 feet, 26 feet and 23 feet, respectively. The core shaft takes up the two central bays, plus a nine foot extension to the south and a small extension to the N, NW corner. There is X-bracing in both bays of the north and south faces of the core but K-bracing in the two east and west faces. In addition, X-bracing occurs in the central bays of the east and west faces of the structure as a whole. Columns rest on a nine foot deep RCC mat footing. The exterior of the building is almost entirely 1/4 inch glass, the plane of which is set out from the plane of the frame by three feet. Office partitions and core shaft construction are cold-formed steel studs with gypsum wallboard. Approximately one inch of mineral wool structural fire proofing had been applied throughout.

The building framing system appeared to qualify as a K=0.8 building in accordance with the Recommended Lateral Force Requirements of the Structural Engineers Association of California. The girder-column flanges are full penetration welds using E60XX electrodes. Girder/column and beam/girder connections are A490, one inch diameter bolts with threads in the shear plane. A five inch concrete slab reinforced by

mesh acts compositely with the beams by means of channel studs and separated by 10 Cm in each case. welded to the top of the beam flanges. All structural steel is A36. The plans called for design, fabrication and erection according to the Seventh Edition of the AISC specification.

The steel came from the USA but was fabricated locally by TIPIC, S.A., a joint ownership consisting of Transformadora Industrial and Pittsburgh DesMoines. A Mexican testing agency inspected the welds; reportedly, some were initially rejected. From visual inspection the quality of the construction appears to be excellent.

No structural damage could be detected and negligible architectural damage occurred. Evidence of some movement by elevator equipment was observed. A very few windows were broken. Some minor pounding occurred at the southeast corner of the building where there was a two story adjacent structure. No cracking was apparent in the wallboard partitions; although the building was still under construction, a large percentage of these appeared to have been installed. Elevator counterweights came out of their guides and several elevator motors in the mechanical penthouse hopped off their pegs where they had sat on rubber isolators and moved about six inches to the north or south. A horizontal hairline crack was visible in the six inch fascia attached to the east side of the building. Some of the lightweight, suspended ceiling tiles were displaced.

National Theater. The National Theater is located near the intersection of 6th Avenue and Diagonal 2 in Zone 1 on a hill just west of the Finance Ministry. It is still under construction although the structure was completed by the time of the earthquake.

From a distance, the structure resembles a vault but is actually three distinct structures, situated on a N-S line

The stage, which is on the south, is roughly in the form of a shell, being approximately a quadrant of a sphere. The three sides are concrete walls with RCC beams running vertically. Some RCC shear wall returns for E-W lateral resistance occur on the north corners. The stage is 18 M deep, 40 M wide and 26.5 M high. A large basement stage is situated below the construction.

The main seating area constitutes the middle structure, together with the balcony of the entrance structure providing a seating capacity of 2280. The open area is 38 M wide in the E-W direction, 33.5 M deep and 18 M high. The E-W lateral force resistance is provided by a relatively flexible truss structure, whose main columns were each fabricated from two 18-1/2 x 1-3/4 inch flange plates and a 24 x 3/8 inch web plate and whose girders are W24 x 100, 8.8 M long, X-bracing filling the bents formed by the columns and girders. There is also X-bracing in the N-S direction between the inner columns.

The northern most structure consists of the entrance and balcony. It is also an RCC shell-like structure, supported in part by large steel columns, each built up from two W shapes and a 1.8 M plate. Most of the anchor bolts on the west side of each column appeared tight but could actually be further tightened by hand, indicating they had been possibly stretched during the quake.

The plans called for A36 steel with welded flanges and bolted webs in primary member connections. Fabrication was performed by TIPIC S.A., under the same arrangements as done for the Finance Ministry. Visual inspection of the welds indicated good fabrication technique.

The central structure had holes punched in the N-S walls adjacent to the more rigid balcony of the entrance structure extending in from the north. The debris of the locally shattered brick masonry walls littered the stairwells on both east and west sides of the structure. No other distress from the earthquake was apparent in the theater.

A 1/4 inch wide ground crack, running N-S was visible several meters to the east of the theater.

Terminal Hotel. The Terminal Hotel is located at the intersection of 4th Avenue and 9th Street in Zone 4. It is a six story building, with penthouse, RCC beam and column, flat slab construction containing brick masonry, lime mortar infill walls. The long axis of the building is oriented N-S. A soft story occurs at the second level on the south end of the building. There are two rows of columns in the E-W direction and six in the N-S, spaced at 6 M centers both ways. A 2.6 M overhang on the east and west sides makes the building 11.2 M wide in the area of the soft story.

The building collapsed in the area of the soft story, the four columns at the second level on the south end having completely failed allowing the levels above to move down in a rigid body mode. The open framing in the southern part of the penthouse also failed but did not collapse. There was no discernable horizontal rotation of the south end of the upper four floors with respect to those at the north end.

Columns in the soft story were 22 by 22 inches with four #8 bundled at each corner. Ties consisted of #3 smooth stirrups at ten inches closing to four inch spacing near the beam.

Inspection of the horizontal construction joint in the wall

forming the west face of the first two stories revealed evidence of movement. No permanent relative E-W displacement could be discerned.

El Camino Real Hotel. The El Camino Real Hotel is a ten story modern high rise hotel located at the corner of Avenue Reforma and 14th Street in Zone 10. In plan, the structure is formed by the section of a circular arc with relatively small curvature, the longitudinal axis of the building being the portion of the arc and being oriented E-W. The building is divided in two by a vertical construction joint of 3.75 inches.

There are N-S RCC shear walls on each end of each building and an RCC lattice construction on the E-W faces. This lattice is in a diamond shape at 3.25 M centers horizontally per unit. The elements of the lattice are 8 inches wide by 22 inches deep. There is one #8 bar at each corner and two #5 at the midpoint of each long side. A #3 stirrup at 10 inches encloses the bars. Brick masonry walls in the same plane as the windows are located behind the lattice on the N-S faces. These do not appear to be structurally continuous through the first floor. The lattice, on the other hand, appears to be structurally connected to a footing, the top of which is visible several feet below the adjacent ground level.

The lattice members in the ground story level, whose tops sloped to the west, were shattered. This failure was more pronounced on the south face of the building. There appeared to be no permanent offset in the elements. Some #8 bars were slightly buckled. At the second level, there was considerable cracking in walls separating rooms but not pronounced fall-out of masonry units. Bathroom tile and glass was broken.

Hotel Guatemala Fiesta. The Guatemala Fiesta Hotel is a 15 story, modern high rise building under construction located at the intersection of 13th Street and First Avenue in Zone 10.

The long axis of the building is oriented N-S.

The construction is RCC frame with RCC shear walls. There did not appear to be any structural damage, though most exterior infill walls showed horizontal cracks at their tops and bottoms. Close inspection was prevented by guards.

IGSS General Headquarters. The General Headquarters for health services is a thirty-nine year old, four story building without basement and elevators located at the intersection of 9th Avenue and 15th Street in Zone 1. The building is 36.5 M by 27.3 M in plan with the short dimension oriented N-S. There is an interior court of 18.2 by 9.1 M with the long dimension oriented N-S. The construction is RCC beam and column with RCC slab. Columns are typically 18 inches square spaced at 6.1 M N-S and 12.2 M E-W. Interior walls are nine inch brick masonry with lime mortar.

Some cracking occurred in the interior walls. Plaster fell off interior walls and exterior of east building walls. Utilities were functional, however, and glass was unbroken. A concrete tank on the north side of the roof was one half full at the time of inspection.

IGSS Central Office Building. The IGSS Central Office Building is an eight story building with basement and penthouse located at 7th Avenue and 22nd Street in Zone 1. The long axis of the main building is oriented N-S. The floor construction is steel joist with metal deck and concrete slab. The substantial RCC frame exhibited no damage and there was no broken glass visible. Two of the three elevators worked. Reportedly, there was no piping damage. The RCC columns supporting the hyperbolic paraboloid portion of the penthouse were badly damaged, however, and most of the floor to roof glass was broken. The HP structure pounded in a N-S direction against an adjacent beam-column masonry wall

structure on which a concrete water tank was situated. This tank sustained some cracking, leaking out all the water. A small number of ceiling tiles were displaced throughout the structure but furniture and material atop desks was generally in place. Some overturned plants were observed.

Immediately adjacent to the taller office building is a three story building separated from the first by a seismic joint. The long axis of this RCC frame building is E-W. The structure pounded the taller one to the east, sustaining a broken slab and a partially fractured column in the course of the events. In this same area, the columns also exhibited some structural distress at the floor and ceiling level.

A one story theater of RCC beam and column construction with masonry infill walls is contiguous to the west side of the second structure, but, again separated by a seismic joint. Masonry walls were cracked and considerable number of ceiling tiles fell.

IGSS Rehabilitation Hospital. The IGSS Rehabilitation Hospital is a seven building complex of typically one story 18.2 M by 39.5 M pre-manufactured steel buildings oriented with the long axis N-S. Rod bracing had been installed in the roof and tiles appeared to be asbestos. Walls are brick masonry. Interior partitions are not supported at the top, only the sides, or corners. Walkways supported by cold-formed steel bents interconnected the buildings.

Occasional windows were broken in longitudinal walls. Two end walls were cracked, not having been well anchored to the frame. Slight movements of frames was evident against infill interior brick partitions, which, with two exceptions, exhibited no cracking. Occasional ceiling tile was displaced. One unit has a basement in which medicine was stored on 2 M

high unbraced racks. Much of the medicine slid off the racks during the earthquake. One rack, heavily loaded with paper, was deformed by racking approximately 20° to the south.

The utilities were functioning and the complex was operating temporarily as a general hospital.

General Hospital. The General Hospital is a complex of RCC beam and column frame structures with infill masonry walls located in the northwestern part of the city. At the time of the earthquake a large, three story unit was near completion, some of the infill masonry walls not having been put in place.

Considerable architectural damage was sustained by the new construction, in some areas the masonry walls falling out and spalling taking place at the tops and bottoms of columns. Some attempt had been made through nominal reinforcement to anchor the infill walls to the floors and ceilings. In several instances this practice was successful in preventing the major portion of the wall from completely falling over, even though much of the masonry had already fallen out of the wall.

The General Hospital was one of the few buildings in which settlement was noticed. Approximately seven Cm differential settlement was measured in the N-E unit.

Catholic School. The Catholic school is a complex of buildings located on Diagonal 2 in Zone 12. Of the five buildings in the immediate area, three are RCC and two are prefabricated steel.

The three RCC are multistory and approximately 10 M by 145 M in plan dimensions, the long dimensions being oriented E-W. The second level of the central 55 M long section of the northern most, three story unit, collapsed, moving slightly to the south as it did so. The columns of this building are 15 inches wide in their E-W dimension and are spaced at 5 M along an E-W line. The floor construction in the building is waffle slab. Canopies 3 M wide extend from the floors on the south side of the building, for this collapsed section only. Stairwells brace the 30 M long end units. The other two RCC frame buildings, which are oriented in the same direction immediately to the south, are two stories in height with steel joist metal deck floor system topped with a concrete floor slab. Joists span a N-S direction. Verandas in these buildings are supported by steel pipe columns. Neither of the buildings appeared to have sustained structural damage, although masonry infill walls were cracked.

The large steel building is located 33.4 to the southeast of the partially collapsed unit. It is one story in height measuring 48.6 M by 21.3 M with the long dimension oriented N-S. The walls consist of brick masonry. The roof is constructed of cold-formed steel panels with three 16 foot bays being rod-braced. No cracking was visible in the walls. A few broken windows were seen in the top of the south end wall. Some damage to the west wall occurred when an elevated concrete walkway flexed and pounded the wall of the building.

There was no damage to the 14.6 M by 15.2 M rod braced one

story steel building situated 3 M from the south wall of the larger steel building. The frames in this case were oriented N-S.

University of the Valley. The University of the Valley is an American school complex located in Zone 15. Included are several RCC hyperbolic paraboloid shell roof units which rest on 12 inch by 30 RCC columns at 10.9 M centers. The long dimension of the column is oriented N-S. Typically, seven HP are contiguous in a row oriented E-W. Brick masonry N-S shear walls are located at the east and west ends of the buildings and partial height walls in the north and south elevations.

On the south side of two of the seven unit buildings, the columns failed where the low corner of the HP's were supported. The partial height E-W walls in these areas were cracked at the bottom and had begun to fall to the south in some cases.

Nearby, there was a three-sided RCC shear-wall building with prestressed, precast concrete roof spanning north to south, the east side being open. A closure unit had not been cast at the wall-roof intersection at the time of the earthquake. The roof collapsed, breaking and knocking down the north wall.

Also nearby, and several hundred meters to the west were two metal buildings with 4 x 3 inch cold-formed steel columns. There was some minor cracking in the brick masonry walls.

Raphael Landiviva Catholic University. The Raphael Landiviva Catholic University is located in Zone 16 on the east edge of a baranca overlooking the city. The complex includes four, relatively new one story buildings, 7.6 M by 50.1 M each in

plan dimension. The long axis of each building is oriented in a N-S direction with the buildings in eschelon along a N-E/S-W line. An older, wood-frame module is located just north of the second building from the west side. The buildings are on a slope roughly 6-8% to the east. The newer buildings are constructed with RCC columns and beams oriented E-W supporting a prestressed concrete roof, whose beams span the E-W direction. In several cases, the brick infill masonry walls were plastered over at their tops so that it appeared there was an RCC frame. The walls were typically reinforced with a #2 smooth re-bar horizontally in the 5-1/2 inch brick at 20 inch centers. These bars were anchored at the sides. Vertical reinforcement was typically one bar at 1 meter centers, not anchored at the top.

Considerable damage was sustained by the infill walls, which had cracked and fallen out of the frames or away from the columns, particularly in the two westerly modules. These frames exhibited a permanent set to the west in many of the bents. The two modules on the east exhibited less damage probably due to the fact that rooms were smaller and the first building had more offices.

GUATEL. The main GUATEL Building is an RCC beam and column with capitol and flat slab construction located in Zone 1. The longitudinal axis of the building is oriented N-S. The structure has a barrel shell roof whose elements span E-W. Some very minor pounding was noticeable between the shell roof and the contiguous RCC shear wall, stair tower/elevator shaft structure situated on the east side of the primary structure. The seismic separation was 6 cm. No distress was apparent in the primary structure frame, although some spalling was noticed in the N-E corner stairwell column at the foundation.

GUATEL Old Guard. This GUATEL building is located in Zone 3 at 6th Avenue. It is a two story RCC frame in the E-W direction with RCC slab, and some unreinforced masonry walls in the N-S direction. The basement perimeter walls appear to be retaining walls of RCC. The east basement wall was tilted in perceptibly at the top. Old, vertical cracks of 1/16 inch were visible at 3 M centers.

Occasional windows were broken. Some distress was seen in the structural frame. Masonry infill walls were cracked. An RCC canopy located to the west of the building and supported by 5 inch diameter RCC columns with asbestos pipe cover collapsed towards the east.

Equipment was down seven hours due to power outage.

GUATEL Sanchez Building. The GUATEL Sanchez building, located at 8th Avenue and 12th Street in Zone 1, is five stories of substantial RCC beam, column and slab construction without basement, having lime mortar brick walls and RCC parapet. The building is 15.2 M by 20.0 M in plan with its longitudinal dimension oriented N-S. An elevator and stairwell shaft is located in the west central portion of the building.

Very minor cracking was apparent in the exterior walls. Some plaster cracking took place in the interior stairwell, increasing towards the base. Lights functioned at the time of the inspection but no power was on the elevators.

In some buildings, the trusses were heavy timber, which appeared to have been treated. In others, the trusses were light steel. An elevated concrete water tank on an RCC frame which had been braced with hot rolled steel struts on all four sides was located in the center of the complex.

Some of the lower steel chords had punched through the walls. Several lower chords of the timber trusses had failed in tension near the walls. The columns in the area below the tank but immediately above the struts appeared to have been newly shattered. There was no evidence, such as working at the screws or edges, that the roof diaphragm had been heavily loaded.

National Printing Plant. The National printing plant is located at 7th Avenue and 18th Street in Zone 1. It is a three story building 64.4 M by 50.1 M in plan, the short axis being oriented N-S. It has a very small basement with courtyards at the four quadrants, making the building only two stories in those 18.2 M by 18.2 M square areas.

The building is approximately 70 years old, having gone through the 1917 earthquake. It is constructed with RCC beams, columns and RCC slab. Columns are 24 inches by 24 inches square on 4.6 M centers with some walls as thick as 24 inches.

anchored. Lights and water pump were operable.

BMW Car Showroom. This one story building is located in Zone 4 on Via 5. Brick masonry walls are on the two contiguous south and west faces. Two panes of glass in the two remaining, glass walls were cracked.

Plymouth Fargo Car Showroom. This is a one story light steel building with large areas of exterior glass walls. It is located in Zone 9 in the area of 6th Avenue and Diagonal 12. The roof framing is radial in plan. Several of the panes in the east wall were broken.

Divine Redeemer Church. The Divine Redeemer Church is located near the intersection of 32nd Avenue and Diagonal 12 in Zone 11.

It is a one story building approximately 9.1 M wide by 18.2 M long, the long axis being oriented N-S.

The walls are brick masonry with heavily reinforced masonry columns. The roof construction consisted of one foot of concrete, hollow clay tile and plaster suspended on the bottom chord of relatively light steel trusses spanning the short direction of the building. The top chord of the trusses were braced by diagonal rod bracing, the ends of which fell short of the wall-truss intersection by several feet. An open web type steel joist braced the center of the top chord of each truss by being located in the plane of the top chords and being oriented in a N-S direction along the center line of the building.

The trusses buckled at the center of their top chords, pulling over the adjacent walls.

Inspection of the connections of the strut joist bracing the

top truss chord indicates connection bolts at the bottom chords of the strut had never been installed.

Other Structures

Bridges - Agua Caliente Bridge. The Agua Caliente Bridge is located just north of the city. It is a twenty year old, five span plate girder bridge resting on concrete piers at 30 to 40 meters. The total length is 206 M. Each span was connected by rocking rollers at one end and pinned at the other. Three of the center spans collapsed, failing at the girder supports.

Just downstream from this bridge is a steel truss railroad bridge which appeared from the air to be intact.

Bridges - Periferico Bridge. On the immediate NW outskirts of the city, the Periferico crosses the Rio La Baranca by means of a long span prestressed concrete bridge supported on tall, intermediate piers. The structure was intact, though some pounding was evident at the abutments.

Bridges - Pedestrian Bridges. Numerous steel pedestrian bridges over main thoroughfares showed no signs of damage.

Elevated Tanks. An elevated steel water tank located near 5th Avenue in Zone 11 and holding 8,000 gallons reportedly rocked N-S during the earthquake but exhibited no damage. The tower is braced with rod bracing and anchored to concrete footings with one inch diameter anchor bolts. The capacity of the tank is 12,000 gallons.

Eiffel Tower. A miniature Eiffle Tower is located at the major intersection on Avenue Reforma in Zone 7. It is approximately 23 M wide at its base and 60 M tall. It is

constructed of relatively small dimension steel angles and anchored with one inch diameter anchor bolts. There was no evidence of damage or movement sustained as a result of the earthquake.

Gas

Gas is available only through individual, liquid propane gas units.

There is supposedly a building code of sorts which limits the height of buildings. This document was out of print, however, and a copy not available. Discussions with local consulting engineers revealed that older engineered structures were designed in accordance with pre-1961 Uniform Building Code criteria, while newer structures were being designed with the latest AISC and ACI design specifications. There is no depository for plans.

The engineer is required to sign the drawings. In order to sign the drawings, he must be registered with the College of Engineering, a fraternal organization affiliated with the University of Guatemala. One becomes registered by graduating from the university. Graduates from other universities may become registered but must take an exam to do so.

There are 1300 engineers of various disciplines in the country. Of these, 700 are civil and 30 are structural, that is, one who has a master's degree. Approximately 90% of the buildings were estimated to have been designed locally.

Conclusion

In general, engineered structures performed well during the earthquake, though there was enough wide spread architectural damage from cracking of infill masonry walls that this matter should be recognized as a problem. It could be expected to be worse in an earthquake of greater intensity.

The great human problem that remains is to provide reasonably safe dwelling units to the majority of the population.

Codes and Enforcement

The city reportedly requires a permit to construct a buildi