World Housing Encyclopedia

A Resource on Construction in Earthquake Regions

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HOUSING REPORT
Base isolation of confined masonry

Report#	152
Last Updated	
Country	Argentina
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Important

General Information

Building Type:	Base isolation of confined masonry
Country:	Argentina

Author(s):	Noemi Graciela Maldonado Dr. Miguel Eduardo Tornello Ulugbek T. Begaliev
Last Updated:	
Regions Where Found:	This report describes a particular building on the campus of the Technological National University in Mendoza. While confined masonry is a typical construction type in the Mendoza region, representing 70% of the building stock, it is not typical to base isolate such buildings. Although base isolation devices are used extensively in others seismic regions of the world, in Argentina there are few examples. This first building was constructed with the aim of research and the excellent results obtained up to date indicate a potentialfor wider use.
Summary:	Most of the Argentine Republic can be considered seismic. Greater Mendoza is an important socio-economic area in the mid-western region and it has the greatest seismic risk in the country. In the last 200 years or so, there have been important earthquakes affecting building structures. Consequently, new techniques aimed at controlling vulnerability must be developed. An investigation of the application of Basal Seismic Isolation(BSI) on a building 'Students House' belonging to the Technological National University (UTN) has been implemented and is described here. Research of the isolation system for near source motions has been done. The construction of three modules of student houses was completed in 2004, with confined masonry and reinforced concrete for three levels and prestressed slabs. Both buildings have accelerometers to register earthquake effects. The complex was completed with a building of two levels for administration with confined masonry. The aim is to control BSI displacement. The strategy proposed was to add damping to the isolation system within certain limits and the results are compared to a similar fixed base building. To control near source displacements, additional damping is an applicable and economic strategy. Although with this strategy there is increased acceleration , it is far less than in the case of a fixed basebuilding.
Length of time practiced:	Less than 25 years
Still Practiced:	No
In practice as of:	11-13
Building Occupancy:	Residential, 5-9 units
Typical number of stories:	3
Terrain-Flat:	Typically
Terrain-Sloped:	Never
Comments:	The building possesses two important characteristics. First, it is seismically isolated; and the secondly it has been constructe

Features

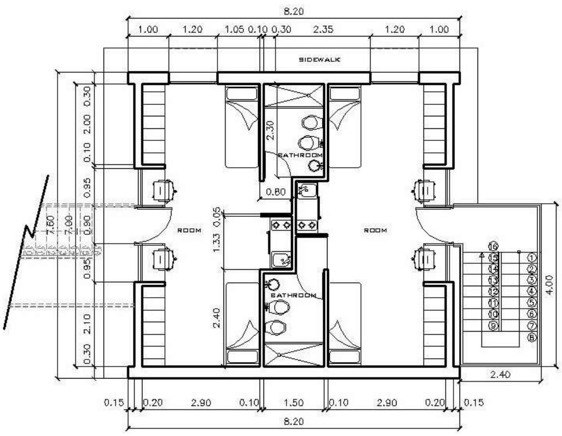
Plan Shape	Rectangular, solid
Additional comments on plan shape	The building has three storeys. The plan of building is rectangular with dimensions, (7.60 x 8.20) m. The architectural configuration is the same in the three levels. In every storey two flats are developed for a maximum of three students in each. Every flat has one bathroom, one office and areas designated for bedrooms. The vertical circulation consists ofexternal (steel stairs) and they link two different buildings. The outer walls are of confined masonry and they are 18 and 27 cm thick. The 18 cm thick walls possess two steel bars inmortar joints. The structure has been designed to transfer the vertical and horizontal loads efficiently. The walls in the East-West direction are 30 cm thick, while the perpendicular walls are 20 cm thick. One of the walls of 30 cm of thickness possesses two windows on each level (dimensions 120 x 120 cm) which represents the 14 % of wall surface.The house reception area penetrates the perpendicular walls. The opening of (280x235) cm represents 33 % of wall surface.
Typical plan length (meters)	8.2
Typical plan width (meters)	7.6
Typical story height (meters)	2.6
Type of Structural System	Other
Additional comments on structural system	The vertical and lateral load-resisting system is reinforced masonry walls.
	The building is constructed of reinforced concrete and reinforced masonry. A layer of reinforced concrete is cast on the face of masonry walls. The foundations are spread footings joint with rigid concrete reinforced beams. The level of the foundation at its base is 200 to 250 cm. below the level of natural ground. All the beams and columns have been designed in reinforced concrete. The slabs are prestressed concrete slabs (thickness 24 cm) with a top layer of reinforcedconcrete (mesh 4.2 mm @ 25 cm) 4 cm thick to guarantee a monolithic and rigid structural diaphragm at floor and roof level. The masonry walls resist vertical and horizontal loads. Walls located in the North-South direction are 20 cm thick and they possess a steel mesh 4.2 mm on both faces in addition to horizontal reinforcement in the mortarbeds(2 6mm every five courses) The base-isolation system used in the building consists of four helicoidal steel spring packages located at the corners of the building, together with four viscous dampers. These types of devices are normally used to isolate industrial equipment or to filter vibrations from vehicular or railroad traffic. Steel springs havethe advantage of well known behavior, they are stable with time,

Gravity load-bearing & lateral load-resisting systems	independent of temperature, and have no creep andnot residual displacements. They have the disadvantage of low damping (2% of critical), and therefore it is necessary touse additional devices for increasing the damping. Because the load capacity of an individual helicoidal spring is limited,for moderate or large loads, the use of packages of springs is required. The number of springs per isolator depends on the static and dynamic demand imposed by service and seismic loads. In this case, because of asymmetry of loads, two isolators are composed of 30 springs, with a load capacity of 921 kN and the other two are composed of 28 springs for a force capacity of 860 kN. The structural system with isolators has natural horizontal frequencies between 1 and 2 Hz and natural vertical frequencies of 3 to 3.5 Hz. For earthquake input excitation the isolation system allows a dynamic motion composed of vertical, horizontal and swaying and rocking motions. Part of the horizontal excitation is transferred to swaying and rocking modes and it is dissipated by the isolation system thus reducing the seismic demands on the superstructure. The viscous damper comprises a container of viscous material. A piston attached tothe upper part is immersed into the viscous material generating viscous forces in three orthogonal directions. The isolation system formed by spring isolators and viscous dampers has linear stiffness in all directions and an almost linear damping as a function of velocity. The design of the viscous damper is a function of maximum and minimum velocity demand that can be expected at the location. The maximum velocities of the selected records are in the range of 0.20 to 1.70 m/s. Viscous damping can be modified easily by changing the number of internal cylinders. In this case, due to the impulsive characteristic of anticipated earthquakes, large damping ratios have been selected in order to control displacements, 26% in horizontal direction and 13% in vertical direction. With these values the horizontal displacements are limited to 150-200 mm and the vertical ones to 30-50 mm, which are compatible with thedisplacements the springs and dashpots are capable of undergoing.
Typical wall densities in direction 1	4-5%
Typical wall densities in direction 2	4-5%
Additional comments on typical wall densities	The typical span of the roofing/flooring system is 3.50 meters. The length in plan of a typical span is 3.50 meter in East-West direction and 2.50 meter in North-South direction. The walls in the East-West direction are 30 cm thick, while the perpendicular ones are 20 cm thick. One of the walls 30 cm thick possesses two windows on each level (dimensions 120 x 120 cm) that represent the 14 % of wall surface. The housing reception area is located in the the perpendicular walls. The opening of 2.80x2.35 m. represents a 33 % of the wall surface.
	A typical house has 6 to 10 windows per floor, with

Wall Openings	a total average size of 3.0 m2. The position of these openings is variable, but usually is approximately 0.8 to 1.0 m from the floor level in rooms and from 1.8 to 2.0 m in bathrooms.
Is it typical for buildings of this type to have common walls with adjacent buildings?	No
Modifications of buildings	Typical modifications include closing off the balconies and demolishing the interior walls to rearrange the apartments or to change the use. Often, additional stories are added without a building permit and without taking into account the load-bearing capacity of the structure.
Type of Foundation	Other Foundation
Additional comments on foundation	The foundation consists of spread footings joined by continuous reinforced concrete foundation beams The level of foundation of the base is of (-200 to 250 cm) with regard to the level of the natural ground. The isolation devices are located on the rigid beams that connect the bases of the footings.
Type of Floor System	Other floor system
Additional comments on floor system	The floor system is comprised of prestressed concrete slabs (hollow core). They are 1.20 meters wide and 7.00 meters long. They are 24 cm thick with a top layer of reinforced concrete (mesh 4.2 mm @ 25 cm) 4 cm thick to guarantee a monolithic and rigid floor diaphragm. The roofing systems is the same as floor systems, both are composed of prestressed reinforced concrete plates. They are 1.20 meter wide and 7.00 meters long. They are 24 cm thick with a top layer of reinforced concrete (mesh 4.2 mm @ 25 cm) of 4 cm thick to guarantee a monolithic and rigid structural element at the roof level.
Type of Roof System	Roof system, other
Additional comments on roof system	The roof system is precast hollow core slabs.
Additional comments section 2	The seismic vulnerability in this building type is due to the fact that the ground floor is used for commercial purposes and the upper levels for residences. Sometimes heavy items are stored on the upper floors when the entire building is used for commercial activity. In a typical building of this type, there are no elevators and 1-2 fire-protected exit staircases. The only means of escape is the main entrance door; there is only one staircase in each building.

View of confined masonry buildings (North)

View of confined masonry buildings (South)



Plan of BSI Building

Building Materials and Construction Process

Description of Building Materials

Structural Element	Building Material (s)	Comment (s)
Wall/Frame	Walls: clay brick and artisan brick and somereinforced concrete. Although not standardpractice in Argentina, masonry walls are linedwith mesh and then a layer of concrete toincrease their strength and ductility.	Reinforcedconcrete: H17 (17MPa) Clay brick:Compressivestrength 2.50MPaMasonry mortar mix: 1:3 (cement:sand)Concrete mix: 1:2:3(cement:sand:gravel)Dimensions of masonry units: 130x80x60 forwalls of 30 cm of thickness and 260x170x80for walls of 20 cm of thickness.The internal divisionsare of plaster plate.The wall and floorcoverings are ceramicmaterials.

Foundations	Reinforced concrete. Over the foundationstructure the isolator device and viscousdampers are located.	Reinforced concrete: H17 (17MPa)Concrete mix: 1:2:3(cement:sand:gravel)Dimensions of foundations: Spreadfootings(900x200x100) cm. with continuousbeams (40 wide x150 deep) cm.
Floors	Prestressed concrete slabs with reinforcedconcrete topping	Reinforced concrete: H17 (17MPa) Prestressed concrete : H30(30 MPa)Concrete mix:1:2:3 (cement: sand: gravel)Lengths of 750 cm for prestressed concreteslabs and 200 cm thickness for solid slabs.
Roof	Prestressed concrete slabs with reinforcedconcrete topping	fe28=20 MPa fe=400 MPa 1:2:4 The concrete compressive strength is often less than 20 MPabut is sufficient in comparison with the slab rigidity
Other	Reinforced concrete	Reinforced concrete: H17 (17 MPa)Concrete mix:1:2:3 (cement: sand: gravel)Dimension beams:(20x30) cm, (30x30) cmand (20x45) cm. Dimension columns: (20x30)cm and (20x40) cm.

Design Process

Who is involved with the design process?	EngineerArchitectTechnologist
Roles of those involved in the design process	The building was designed by architects and structural engineers. The diverse phases of building construction were inspected by two architects, two engineers and three students of engineering. The inspection was present from the beginning to the end of the works. The architects and engineers took part in all phases of the work, from the design to construction and completion. Also university civil engineering students collaborated in the design and constructionof the buildings.
Expertise of those involved in the design process	The expertise required for the design and construction of this type is available. Building designs were prepared by design institutes. The academic background of the designers is the same as for conventional construction. It is not required to have designers with high academic degrees e.g. M.Sc. and Ph.D. on theteam. Construction of base isolated buildings and the approval of the designs were controlled by research institutes (State Experts) like any other new construction performed in accordance with the Building Code requirements.

Construction Process

Who typically builds this construction type?	Builder
	The buildings have been constructed for students' residences. The building with base isolation can be compared with the same building but a fixed base, located a few meters away. Three buildings have

Roles of those involved in the building process	been constructed near each other, with equal construction characteristics but one with base isolation. The percentage of reduction of the accelerations measured on the roofs of the buildings were:Earthquake 2005/09/09, 66%; 2006/08/05, 82%; 2007/09/15, 85%, 2008/10/16, 80%; 2009/05/08, 77%; 2010/02/27, 84% and 2012/06/18, 69%.
Expertise of those involved in building process	The expertise required for the design and construction of this type is available. Building designs were prepared by design institutes. The academic background of the designers is the same as for conventional construction. It is not required to have designers with high academic degrees e.g. M.Sc. and Ph.D. on theteam. Construction of base isolated buildings and the approval of the designs were controlled by research institutes (State Experts) like any other new construction performed in accordance with the Building Code requirements.
Construction process and phasing	During construction typical building tools and equipment were used. 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	Inadequate design, poor quality of construction.

Building Codes and Standards

Is this construction type address by codes/standards?	Yes
Applicable codes or standards	This construction type is addressed by the codes/standards of the country. For reinforced concrete structures we applied the national code CIRSOC 201. To evaluate the effect of the earthquakes on the building we applied the Code of earthquake resistant Constructions of the Province of Mendoza, 1987. To evaluate the capacity of the masonry wall we applied the Code of earthquake resistant Constructions of the Province of Mendoza, also. Finally in order to compare results also there was used the national code INPRES-CIRSOC 103. The Province of Mendoza for many years, has used code different from the national code. Nevertheless in recent years the codes have been unified and have been adopted at a national level (INPRES-CIRSOC). The INPRES-CIRSOC codes provide regulations regarding design and construction for earthquake conditions. The local regulations, Code ofResistant Constructions of Mendoza have been enforced since 1987, in different town councils of the Province of Mendoza.
Process for building code enforcement	The enforcement of the building code for public buildings in Algeria is done by the Controle Technique de la Construction (CTC). After the architectural plans have been prepared, their conformity to the building codes (CBA93, RPA99, etc.) must be approved by the CTC. The approval is related to the phases of the construction and the quality of the building materials. However, code

	enforcement is not required by Planning Services for private housing. As a result, the construction can proceed with only architectural plans. There is no inspection or quality control enforced during the construction.

Building Permits and Development Control Rules

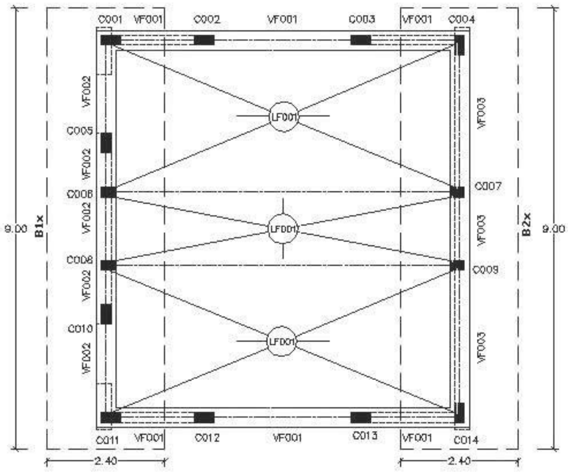
Are building permits required?	Yes
Is this typically informal construction?	No
Is this construction typically authorized as per development control rules?	Yes
Additional comments on building permits and development control rules	This type of construction is an engineered, and authorized as per development control rules. The municipality authorities examine and approve the projects (architectural, structure and installations). In Argentina the code on seismic isolation and dissipation of energy is in progress. Therefore to approve the construction of the building the authority used the code of Chile (NChOf273). Building permits are required to build this housing type.

Building Maintenance and Condition

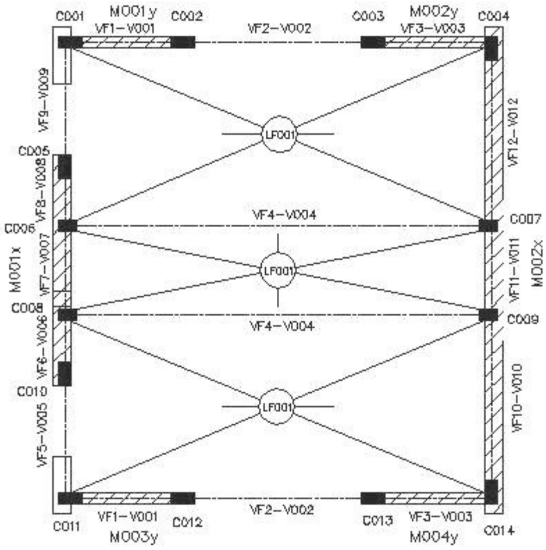
Typical problems associated with this type of construction	These constructions are inherently very weak against earthquake loading.
Who typically maintains buildings of this type?	Owner(s)
Additional comments on maintenance and building condition	The maintenance is performed either by the owner (city) or (periodically) by a contractor a maintenance firm.

Construction Economics

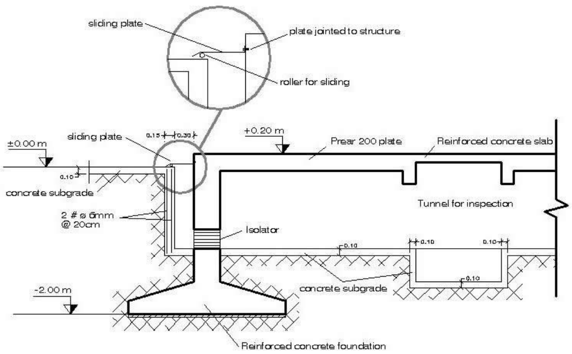
Unit construction cost	The unit construction cost of the building is of approximately $US 650. The entire area of the building is of approximately 185 square meters. In this area six flat are included. Therefore the entire cost of the building is of $US120--250. To the value of the building it is necessary to add the cost of the isolation devices. This cost is $US 20.000 approximately.
Labor requirements	Each housing unit in rural area takes around 8-12 man-months (counting skilled man-months only) for construction. Only one or two skilled artisans are used, while the remaining are unskilled workers.
Additional comments section 3	These buildings were constructed using the following construction materials:2. Exterior walls (2 layers); one layer is made using regular concrete and the other one is made of lightwight concrete (for the purpose of heat insulation).3. Interior walls are made of regular concrete.



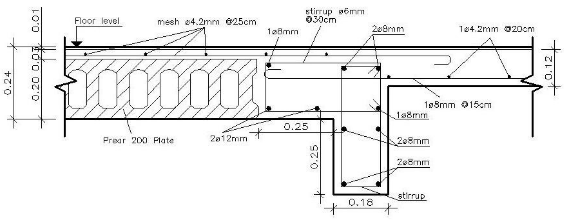
Plan of Footings of BSI Building



Structural Design of Typical Building (plan)



View of Details of Isolation of Building



Details of prestressed concrete plate and reinforcedconcrete at roof level

View of System of Isolation in BSI Building

Socio-Economic Issues

	Each building typically has 5-10 housing unit(s). In every level of the building two flats lodge between 4

Patterns of occupancy	and 6 students. There are 6 flats for the building. The buildings are inhabited by engineering students. They are also used for teachers visiting the University.Some students work and study therefore they only use the flat to have lunch, dinner and to sleep. The students who only do academic activities occupy the flats during the day and at noon they meet at the University. All the flats areinhabited. The number of inhabitants during the evening and night is 11-20. The students who occupy the residence live out of the City of Mendoza as do the teachers visiting the University, therefore all of them occupy the residence during the evening and night. The students who occupy the residence are not the same every year. This is the reason why the residence is very dynamic in terms of the number and types of people who occupy it.
Number of inhabitants in a typical building of this construction type during the day	10-20
Number of inhabitants in a typical building of this construction type during the evening/night	10-20
Additional comments on number of inhabitants	The buildings of the students' residences are not inhabited by typical families but only by students. Every flat of the building is occupied by 2-3 engineering students. The visiting professors are not accompanied by their families. Every flat can be occupied by a maximum of 2 teachers.
Economic level of inhabitants	Middle-income class
Additional comments on economic level of inhabitants	In general the students are from middle class families who live out of the city of Mendoza . Children who belong to upper class families in general rent apartments or buy them.
Typical Source of Financing	Government-owned housing
Additional comments on financing	The students' residence was financed by the Government of the Province of Mendoza. For the construction of the Students' Residence, the Provincial Institute of Housing granted a 30 year loan to the University.
Type of Ownership	Owned by group or pool
Additional comments on ownership	The University owns the students' residences. Students pay a minimal amount of rent.
Is earthquake insurance for this construction type typically available?	Yes
	Earthquake insurance for this construction type is typically unavailable. For seismically strengthened existing buildings or new buildings incorporating seismically resilient features, an insurance premium discount or more complete coverage is unavailable. In general, strengthening of buildings by

What does earthquake insurance typically cover/cost	incorporating seismic features is not common. Some government-financed retrofit projects were recently completed for some strategic buildings in the capital city Algiers. The government also finances strengthening of damaged public buildings following an earthquake.As there is no insurance, the owners of individual housing may be given symbolic aid from the government if damage is slight. If the damage is heavy, repairing and strengthening is financed by the government as was the case after the 2003 Boumerdes earthquake. Earthquake insurance is not available for this building type.
Are premium discounts or higher coverages available for seismically strengthened buildings or new buildings built to incorporate seismically resistant features?	Yes
Additional comments on premium discounts	
Additional comments section 4	It is not common that owners purchase earthquake insurance.

Earthquakes

Past Earthquakes in the country which affected buildings of this type

Year	Earthquake Epicenter
2008	San Juan
2007	Mendoza
2006	Mendoza
2006	San Juan
2005	San Juan
1985	Mendoza

Past Earthquakes

Damage patterns observed in past earthquakes for this construction type	Recent ground motions in the region have been of low magnitude. In general they have not produced serious damage in buildings of this type. The accelerations registered in the base isolated building are, in most cases, up to four times less than that the registered in the same building but of fixed base. In the isolated building have been registered under the fixed base building accelerations. Earthquakes recorded in the following reductions are observed, for example in the earthquake 2005/09/09, 66%; 2006/08/05, 82%; 2007/09/15, 85%, 2008/10/16, 80%; 2009/05/08,

	77%; 2010/02/27, 84% and 2012/06/18, 69%.
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.	TRUE
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 considered to be rigid and it is expected that the roof structure will maintain its integrity, i.e. shape and form, during an earthquake of intensity expected in this area.	TRUE
Floor Construction	The floor diaphragm(s) 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	TRUE

	earthquake.	
Wall and Frame Structures-Redundancy	The number of lines of walls or frames in each principal direction is greater than or equal to 2.	TRUE
Wall Proportions	Height-to-thickness ratio of the shear walls at each floor level is: Less than 25 (concrete walls); Less than 30 (reinforced masonry walls); Less than 13 (unreinforced masonry walls);	TRUE
Foundation-Wall Connection	Vertical load-bearing elements (columns, walls) are attached to the foundations; concrete columns and walls are 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.	N/A
Wall Openings		TRUE
Quality of Building Materials	Quality of building materials is considered to be adequate per the requirements of national codes and standards (an estimate).	TRUE
Quality of Workmanship	Quality of workmanship (based on visual inspection of a few typical buildings) is considered to be good (per local construction standards).	TRUE
Maintenance	Buildings of this type are generally well maintained and there are no visible signs of deterioration of building elements (concrete, steel, timber).	TRUE

Building Irregularities

Additional comments on structural and architectural features for seismic resistance	The building possess a low vulnerability index. The fact of having base isolation seismic implies that the building is not vulnerable to seismic loads. The structural configuration in plan and elevation of the building also reduces vulnerability. The materials also are adapted to control the vulnerability of the building.

Vertical irregularities typically found in this construction type	No irregularities
Horizontal irregularities typically found in this construction type	No irregularities
Seismic deficiency in walls	A conventional building of large panel concrete construction or brick masonryconstruction: poor quality of panel joints and inadequate masonry strength.
Earthquake-resilient features in walls	Suitable wall thickness controls the distortion. Walls with horizontal and vertical steel to improve the ductility.
Seismic deficiency in frames	Lack of seismic resistance, as the structural elements are designed for gravity load only. The main deficiencies include: - column cross-section not sufficient to provide earthquake resistance. - absence of stirrups in beam-column joints. - lack of infilled masonry walls at the ground floor, thus creating a soft storey effect (see Fig. 10 and 11) - excessively large stirrup spacing in columns. - poor quality of materials and workmanship.Partial or total collapse of the building due essentially to excessive displacement (P-delta effect) at the ground floor level. The characteristic damage patterns include: failure of the top portion of columns at the ground floor level, development of plastic hinges in the columns (ground floor), crushing of columns due to axial compression, shear failure in column-beam joints.
Earthquake-resilient features in frame	The beams and columns have suitable steel shear reinforcement to allow for energy dissipation and to avoid brittle collapse.
Seismic deficiency in roof and floors	#NAME?
Earthquake resilient features in roof and floors	Possess 26 cm thicknesses to guarantee rigid diaphragms. High rigidity allows inertial forces to be distributed to the vertical resistant walls in an efficient way.
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

Retrofit Information

Description of Seismic Strengthening Provisions

Structural Deficiency	Seismic Strengthening
Slight crack	Local repair with injection
Columns and beams: heavy cracks, development of plastic hinges, axial compression crushing	Local repair by providing reinforced concrete jacketing; new structural elements added to increase the seismic resistance (shear walls or bracing)
Column designrequirements(RPA99), seeFig.14	Dimensions (b1= w idth, h1= depth): Min (b1 , h1) > 25 cm (seismic zones I and IIa); Min (b1 , h1) > 30 cm (seismic zonesIIb and III); Min (b1 , h1) > he/20 (he = story height); < b1/h1 < 4. Minimum reinforcement ratio (longitudinal bars): 0.8% (zone IIa); 0.9% (zone IIb and III); Transverse reinforcement (ties) should also be provided.
Beam designrequirements(RPA 99), seeFig.14	Dimensions (b= w idth, h= depth): b > 20 cm , h > 30 cm, h/b < 4.0, bmax < 1.5 h + b1. Reinforcement: the minimumlongitudinal reinforcement ratio is 0.5%
Jointrequirements, seeFig.14	Transverse reinforcement (ties) should be continuous through the joints

Additional comments on seismic strengthening provisions	The most commonly used method for strengthening reinforced concrete frame buildings is reinforced concrete jacketing. The addition of new structural elements (such as shear walls or bracings) is rarely used. Construction of new shear walls is a common retrofit method for larger reinforced concrete frame buildings despite its high cost. (Forexample, this was done after the 1999 Ain Temouchent earthquake.) The addition of shear walls results in the increased lateral strength and stiffness of a building. As a result, seismic performance increases significantly as well. The walls are laid in a symmetrical manner to reduce torsional response. The bracing systems are not used very often.
Has seismic strengthening described in the above table been performed?	The first experience related to repairing and strengthening damaged buildings in Algeria was following the 1980 El Asnam earthquake (M 7.3). Also, some buildings strengthened after the previous (1954) El Asnam earthquake performed very well (without damage) in the 1980 Asnam earthquake. The methods described in Section 10.1 were applied. Other projects to strengthen damaged public buildings were undertaken after recent earthquakes such as the 1999 Ain Temouchent earthquake. The strengthening of buildings after the 2003 Boumerdes eq. has started but is not yet finished as of this writing (January 2004). The related seismic strengthening studies were entrusted to local engineering and design offices. The damaged elements were repaired with injection or with reinforced concrete jacketing. New structural elements (shear walls) were added only to the damaged structures of existing public

	buildingsto increase their lateral load resistance.
Was the work done as a mitigation effort on an undamaged building or as a repair following earthquake damages?	This work was done as the repair following the earthquake. In a few cases it was done specifically as part of a mitigation effort for a few undamaged strategic buildings in Algiers.
Was the construction inspected in the same manner as new construction?	The damaged construction is inspected in the same manner as the new construction.
Who performed the construction: a contractor or owner/user? Was an architect or engineer involved?	Owners build their own homes, and architects and engineers are never, or rarely ever, involved. In the aftermath of the 2003 Boumerdes earthquake, the repairing and strengthening operation was financed by the government andperformed by contractors and developers. In this case both the architects and engineers were involved.
What has been the performance of retrofitted buildings of this type in subsequent earthquakes?	Construction which was strengthened following the earthquakes which struck northern Algeria (Tipaza, 1989 and Ain Temouchent, 1999) was not affected by other earthquakes. The 2003 Boumerdes earthquake did not affect those areasso it is not yet known how retrofitted buildings will perform in future earthquakes. However, some vulnerability studies of the strengthened housing were completed, which concluded that strengthened buildings should perform well in future moderate earthquakes.
Additional comments section 6	

Construction of Reinforcement of Footings of BSIBuilding (B1x and B2X)

Construction of Reinforced Masonry

Details of Confined Masonry Walls. Note the layerof reinforcing mesh on the wall that will becovered with concrete in order to improve wallstrength and ductility.

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