World Housing Encyclopedia

A Resource on Construction in Earthquake Regions

an initiative of
Earthquake Engineering Research Institue (EERI) and
International Association for Earthquake Engineering (IAEE)

HOUSING REPORT

Load-bearing wall buildings protected with the "sliding belt" base isolation system

Report#	76
Last Updated	
Country	Kyrgyzstan
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Important

General Information

Building Type:	Load-bearing wall buildings protected with the "sliding belt" base isolation system
Country:	Kyrgyzstan
Author(s):	Jacob Eisenberg Svetlana Uranova Marat Abdibaliev Ulugbek T. Begaliev
Last Updated:	
Regions Where Found:	There are about 30 base isolated buildings in Bishkek (Kyrgyzstan). In 1982, two 3-story brick masonry wall buildings were built in the area with high seismicity (9-10 per MSK scale). A residential block (microdistrict) of 9-story concrete large panel buildings protected with seismic isolation belt was built in the period 1983-1990. Several 9-story large panel concrete buildings were built in the center of Bishkek. One of the buildings is also equipped with a dynamic damper. Some buildings with seismic isolation belt were built in Kazahkstan and Russia (Kamchatka).
Summary:	Sliding belt is a base isolation system developed for seismic protection of buildings by reducing and limiting the level of seismic forces. The sliding belt system is installed at the base of the building, between the foundation and the superstructure. The foundation is usually made of cast-in-situ concrete and the superstructure is typically a loadbearing wall structure, either 9-story large concrete panel system or 3-story brick masonry construction. Once the earthquake base shear force exceeds the level of friction force developed in the sliding belt, the building (superstructure)starts to slide relative to the foundation. It is expected that the lateral load transferred to the superstructure is approximately equal to the frictional force that triggers the sliding of the structure. The sliding belt consists of the following elements: a) sliding supports, including the 2 mm thick stainless steel plates attached to the foundation and 4 mm Teflon (PTFE) plates attached to the superstructure, b) reinforced rubber restraints for horizontal displacements (horizontal stop) and c) restraints for vertical displacements (uplift). A typical large panel building with plan dimensions 39.6m x10.8 m has 63 sliding supports and 70 horizontal and vertical restraints. The sliding belt scheme was developed in CNIISK Kucherenko (Moscow) around 1975. The first

	design application in Kyrgyzstan was made in 1982. To date the system has been applied on over 30 buildings in Bishkek, Kyrgyzstan. All these buildings are residential buildings and are presently occupied. Base isolated buildings of this type have not been exposed to the effects of damaging earthquakes as yet.
Length of time practiced:	Less than 25 years
Still Practiced:	Yes
In practice as of:	
Building Occupancy:	Residential, 50+ units
Typical number of stories:	9
Terrain-Flat:	Typically
Terrain-Sloped:	3
Comments:	

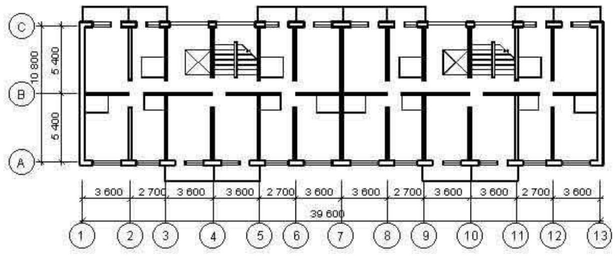
Features

Plan Shape	Rectangular, solid
Additional comments on plan shape	Typical shape of a building plan of this housing type is rectangular.
Typical plan length (meters)	50.4
Typical plan width (meters)	10.8
Typical story height (meters)	3
Type of Structural System	Structural Concrete: Precast Concrete: Large panel precast wallsOther: Seismic Protection Systems: Building protected with base-isolationOther: Seismic Protection Systems: Building protected with seismic dampersOther
	Lateral load-resisting system: Lateral load-resisting system includes the superstructure (e.g. large reinforced concrete panel construction or brick masonry construction) and the foundation. The sliding belt is installed at the base of the building, between the foundation and the superstructure. The sliding belt consists of the following elements: a) sliding supports, including the stainless steel plates attached to the foundation and the Teflon (PTFE) plates attached to the superstructure, b) reinforced rubber restraints for horizontal

Additional comments on structural system	displacements (horizontal stop), and c) restraints for vertical displacements (uplift). The steel plates are 2 mm thick; the plate width is approximately equal to the foundation width, and the length depends on the size of the Teflon plate located at the center (usually projects by 150 mm on each side). The dimensions of Teflon plates are usually 400 mm x 400 mm for 9-story buildings and 200 mm x 200 mm for 5-story buildings; typical plate thickness is 4 to 6 mm. Horizontal stops consist of rigid reinforced structure with steel plates and a rubber damper. Vertical stops consist of steel anchor bolts. A typical large panel building (plan dimensions 39.6m x10.8 m) is equipped with 63 sliding supports and 70 horizontal and vertical restraints. A gap between rubber damper and sliding support for a 9-story building is usually 50 mm; this means that the horizontal stops will be activated once the building has moved by 50 mm in the horizontal direction. The recommended "seismic gap" ranges from 100 to 120 mm. In buildings constructed in Bishkek 300 mm gap was provided. No special provisions were made for flexible water supply and electrical facilities in the buildings protected with this system. Once the earthquake base shear force exceeds the level of frictional force developed in the sliding belt (approximately equal to 10% of the building weight), the building (superstructure) starts to slide relative to the foundation. The design recommendations state that the frictional coefficient value for Teflon-steel sliding is 0.1 (unless a different value is obtained by the tests). However, it should be noted that once the sliding is initiated, building continues to vibrate and restraints get activated as well. The analysis is based on rather complex formulas based of research studies that have been modified for the design practice. Simplified design calculations are not commonly used in the design of this construction type; comprehensive analysis is deemed required. Seismic design of the superstructure is performed based on the results of the dynamic analysis. The level of seismic forces (seismic demand) is reduced as compared to the conventional buildings by up to 50%. The sliding belt scheme was developed by CNIISK Kucherenko in Moscow around 1975; other institutes in the former Soviet Union also contributed to the development. Late L. S. Kilimnik was the leader in the development of the seismic belt system. The first design applications of seismic belt scheme were made in Bishkek in 1982. Two types of tests, static tests under horizontal loads and dynamic tests of full-scale buildings using the vibration equipment, were conducted in 1980. The design recommendations for base isolated buildings of this type were developed based on the results of these tests. Gravity load-bearing system: Gravity load-

	bearing structure is a conventional building construction, either large panel construction or brick masonry construction. Majority of base isolated buildings of this type are large panel concrete buildings with monolithic joints (seria 105). This construction type was described in detail in another contribution from Kyrgyzstan (by S. Uranova and U. Begaliev). Brick masonry buildings are 3-story high and are equipped with the reinforced concrete members and steel mesh, typical for brick masonry construction in the former Soviet Union. It should be noted, however, that the construction of conventional 3-story high brick masonry construction was otherwise not permitted in high seismic zones (intensity 9 to 10 on the MSK scale).
Gravity load-bearing & lateral load-resisting systems	
Typical wall densities in direction 1	10-15%
Typical wall densities in direction 2	10-15%
Additional comments on typical wall densities	Total wall area/plan area is about 0.14. Wall density in two principal directions is not equal; in one of the directions wall density is less by 20 to 30% as compared to the other direction.
Wall Openings	Wall openings are same as in typical large panel buildings. Usually, for a 3.6m long panel, a window size is 1.82m(width)x1.53m(height); for 2.7m long panel - window size is 1.24m(width)x1.53m(height). The size of a door is 0.9m(width)x2m(height). The size of a balcony door (together with window) is either 2.25m or 1.66 m(width) or and 1.9m (height). Overall window and door areas make up to 20% of the overall wall area. There are 16 windows for a building with 10.8m x 25.2m plan dimensions.
Is it typical for buildings of this type to have common walls with adjacent buildings?	No
Modifications of buildings	Typical patterns of modification include the perforation of walls with door openings and the creation of door opening instead of the window.
Type of Foundation	Shallow Foundation: Reinforced concrete strip footing
Additional comments on foundation	Foundation include seismo-isolation sliding belt
Type of Floor System	Other floor system

Additional comments on floor system	Structural Concrete: Precast solid slab panels
Type of Roof System	Roof system, other
Additional comments on roof system	Structural Concrete: Precast solid slab panels
Additional comments section 2	When separated from adjacent buildings, the typical distance from a neighboring building is 10 meters.



Typical Floor Plan

Building Materials and Construction Process

Description of Building Materials

Structural Element	**Building Material (s)**	**Comment (s)**
Wall/Frame	Wall: Reinforced concrete	Characteristic Strength- Concrete: 30-35 MPa (cube compressive strength) Steel: 390 MPa (steel yield strength)
Foundations	Reinforced concrete	Characteristic Strength- Concrete: 10-15 MPa (cube compressive strength) Steel: 295 MPa (steel yield strength)
Floors	Reinforced concrete	Characteristic Strength- Concrete: 30-35 MPa (cube compressive strength) Steel: 390 MPa (steel yield strength)
Roof	Reinforced concrete	Characteristic Strength- Concrete: 30-35 MPa (cube compressive strength) Steel: 390 MPa (steel yield strength)

Other		

Design Process

Who is involved with the design process?	EngineerArchitectOther
Roles of those involved in the design process	Design of buildings of this construction type was done completely by engineers and architects. Researchers also participated in the development of design documentation. Engineers played a leading role in each stage of construction.
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 eg. M.Sc. and Ph.D. on the team.

Construction Process

Who typically builds this construction type?	Builder
Roles of those involved in the building process	
Expertise of those involved in building process	Construction of base isolated buildings and the approval of the designs was controlled by research institutes (State Experts) like any other new construction performed in accordance with the Building Code requirements.
Construction process and phasing	Specialized construction companies make precast concrete elements and perform casting of concrete in-situ. Precast elements are fabricated at the plants. In case of precast foundation and superstructure construction, steel and Teflon plates are installed at the plant. Horizontal restraints (rubber dampers) and vertical restraints are installed at the site. The main construction equipment is the same as in the case of conventional concrete construction and it includes crane, welding equipment and concrete mixers. This building is not typically constructed incrementally and is designed for its final constructed size.
Construction issues	

Building Codes and Standards

Is this construction type address by	Yes

codes/standards?	
Applicable codes or standards	SNiP II-7-81. Building in Seismic Regions.Design code The first (still most recent) code/standard addressing this type of construction was issued 1981. SNiP II-7-81. Building in Seismic Regions. Design code. CNIISK. Recommendations for Design of Buildings with Seismic Isolation Belt and Dynamic Vibration Dampers, Moscow, 1984.
Process for building code enforcement	Building permit will be given if the design documents have been approved by the State Experts. State Experts check the compliance of design documents with pertinent Building Codes. According to the building bylaws, a building cannot be used without the formal approval of a special committee. The committee gives the approval if design documents are complete and the construction has been carried out in compliance with the Building Codes.

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	

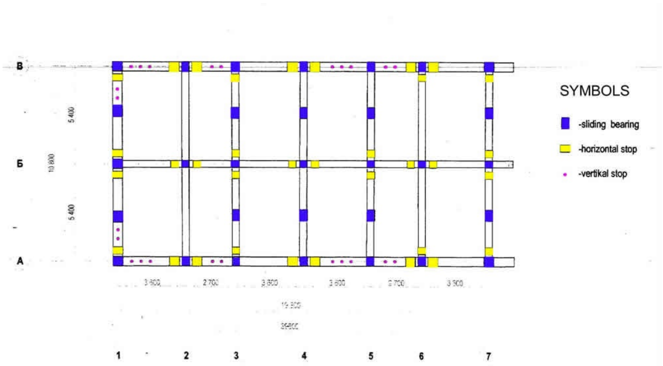
Building Maintenance and Condition

Typical problems associated with this type of construction	Installation/construction of sliding belt is a rather complex technological problem as compared to the conventional construction.
Who typically maintains buildings of this type?	BuilderOwner(s)Renter(s)
Additional comments on maintenance and building condition	

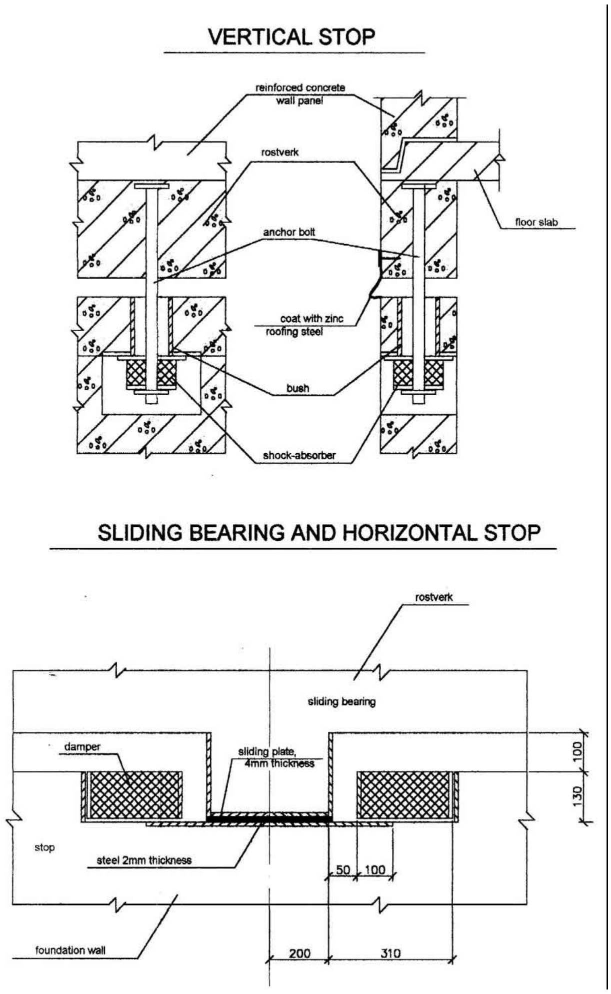
Construction Economics

	For load-bearing structure only (including the seismic belt) the cost is about 230$/m.sq. For a

Unit construction cost	similar prefabricated concrete panel building (seria 105) without a seismic belt the construction cost would be US$ 150-200/m.sq. Therefore, the increase in unit cost due to the installation of seismic belt is in the range from 15 to 50 %.
Labor requirements	It would take from 8 to10 months for a team of 15 workers to construct a load-bearing structure.
Additional comments section 3	



Sliding Belt: Plan View



Sliding Belt: Structural Details

Socio-Economic Issues

Patterns of occupancy	In general, in a building of this type there are 3-4 housing units per building unit ("Block-Section"). One family occupies one housing unit. Depending on the size of the building (number of stories), 32 to 64 families occupy one building.
Number of inhabitants in a typical building of this	

a typical building of this construction type during the day	>20
Number of inhabitants in a typical building of this construction type during the evening/night	>20
Additional comments on number of inhabitants	
Economic level of inhabitants	Low-income class (poor)Middle-income class
Additional comments on economic level of inhabitants	50% poor, and 50% middle class inhabitants occupy buildings of this type Ratio of housing unit price to annual income: 1:1 or better
Typical Source of Financing	Owner financedPersonal savingsGovernment-owned housing
Additional comments on financing	Until 1990 (the breakdown of the Soviet Union), the financing for buildings of this type had been provided by the Government. At the present time, all new and existing apartment buildings are privately owned.
Type of Ownership	RentOwn outrightUnits owned individually (condominium)
Additional comments on ownership	These buildings were constructed at the time of the former Soviet Union and the construction was sponsored by the Government. However, at the present time all apartments are owned by the residents.
Is earthquake insurance for this construction type typically available?	No
What does earthquake insurance typically cover/cost	
Are premium discounts or higher coverages available for seismically strengthened buildings or new buildings built to incorporate seismically resistant features?	No
Additional comments on premium discounts	
Additional comments section 4	

Earthquakes

Past Earthquakes in the country which affected buildings of this type

Year	Earthquake Epicenter

Past Earthquakes

Damage patterns observed in past earthquakes for this construction type	This building type was tested by special vibration equipment that applied loads equal to design seismic loads.
Additional comments on earthquake damage patterns	Damage of bearing structures of upper floors less than in similar buildings without seismic protection systems.

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-	The building is regular	TRUE

Horizontal	with regards to the plan. (Specify in 5.4.2)	
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 earthquake.	TRUE
Wall and Frame Structures-Redundancy	The number of lines of walls or frames in each principal direction is greater than or equal to 2.	TRUE
Wall Proportions	Height-to-thickness ratio of the shear walls at each floor level is: Less than 25 (concrete walls); Less than 30 (reinforced masonry walls); Less than 13 (unreinforced masonry walls);	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	TRUE

	with metal anchors or straps.	
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).	FALSE
Quality of Workmanship	Quality of workmanship (based on visual inspection of a few typical buildings) is considered to be good (per local construction standards).	FALSE
Maintenance	Buildings of this type are generally well maintained and there are no visible signs of deterioration of building elements (concrete, steel, timber).	FALSE

Building Irregularities

Additional comments on structural and architectural features for seismic resistance	
Vertical irregularities typically found in this construction type	Other
Horizontal irregularities typically found in this construction type	Other
Seismic deficiency in walls	Application to large panel construction - Panel joints; quality of construction,especially welding of reinforcing bars from the adjacent panels and filling the gaps between the panels with concrete is not satisfactory in some cases: poor quality of panel joints and brick masonry
Earthquake-resilient features in walls	Due to a large number and uniform distribution of panel joints existing in one building, deficient construction of some joints does not have a major impact on the overall seismic resistance of the building as a whole.
Seismic deficiency in	

frames	
Earthquake-resilient features in frame	
Seismic deficiency in roof and floors	Within the panel joints- quality of construction, especially welding of reinforcing bars from the adjacent panels and filling the gaps between the panels with concrete is not satisfactory in some cases.
Earthquake resilient features in roof and floors	Includ(ing) a large number and uniform distribution of panel joints in one building, deficient construction of some joints does not have a major impact on the overall seismic resistance in the building as a whole
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

Additional comments on seismic strengthening provisions	
Has seismic strengthening described in the above table been performed?	No. Buildings of this type are already strengthened by means of seismic belt.
Was the work done as a mitigation effort on an	

undamaged building or as a repair following earthquake damages?	N/A.
Was the construction inspected in the same manner as new construction?	N/A.
Who performed the construction: a contractor or owner/user? Was an architect or engineer involved?	N/A.
What has been the performance of retrofitted buildings of this type in subsequent earthquakes?	N/A.
Additional comments section 6	

References

CNIISK. Recommendations for Design of Buildings with Seismic Isolation Belt and Dynamic Vibration Dampers, Moscow, 1984. (in Russian)

King, Stephanie, Vitaly Khalturin and Brian E. Tucker. Seismic Hazard and Buildings Vulnerability in Post-Soviet Central Asia Republics. Proceedings of the NATO Advanced Research Workshop on Earthquake Risk Management Strategies for Post-Soviet Central Asian Republics, Almaty, Kazakhstan, Kluwer Academic Publishers, Dordrecht, Netherlands, 1999.

Uranova, S.K., and Imanbekov, S.T. Building and Construction Design in Seismic Regions-Handbook. Kyrgyz NIIP Stroitelstva, Building Ministry Kyrgyz Republic, Bishkek, Kyrgyz Republic, 1996 (in Russian).

Eisenberg, J. et al. Seismoisolation in Russia and former USSR Countries: Recent Developments. Proceedings of the International Post-SMiRt Conference Seminar, Cheju, Korea, Korea Earthquake Engineering Research Center, Seoul, Korea, 1999,Vol.1, p. 99-115.

Eisenberg, J. et al. Applications of Seismic Isolation in the USSR. Proceedings of the Tenth World Conference on Earthquake Engineering, Balkema, Roterdam, Vol.4, 1992, p. 2039-2044.

Eisenberg, J. and Bealiev, V.S. Operating Experience in Designing and Construction of the System of Special Seismic Isolation of Buildings and Constructions in the former Russia. Proceedings of the Eleventh World Conference on Earthquake Engineering, Pergamon, Elsevier Science Ltd., Oxford, England, 1996, Disc 1, Paper No. 263.

Experimental Buildings with Seismic Protection in Petropavlovsk-Kamchatskiy (in Russian)

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