



# World Housing Encyclopedia Report

Country: Russian Federation

Housing Type: Buildings protected with "disengaging reserve elements"  
(vyklyuchayu-shchiesya svyazi)

Contributors:

Jacob Eisenberg  
Svetlana Uranova  
Ulugbek T. Begaliev

Primary Reviewer:

Svetlana Brzev

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# 1 General Information

## 1.1 Country

Russian Federation

## 1.3 Housing Type

Buildings protected with "disengaging reserve elements" (vyklyuchayu-shchiesya svyazi)

## 1.4 Summary

This building type is characterized with a special system of a seismic protection called "Disengaging Reserve Elements" (DRE). DRE are installed at the ground floor level of a building, which is typically a RC frame structure. The upper part of the building, usually 9-story high, is a load-bearing wall structure, either of large panel RC construction or brick masonry construction. DRE consist of a "rigid structure" (usually RC wall panel) connected to the adjacent RC frame members by means of disengaging restraints. Disengaging restraints are sacrificial reserve elements (fuses) which serve as restraints for the "rigid structures". Typical restraints are steel plates joined together by means of rivets or steel bolts, steel bars, concrete prisms or cubes, etc. Initially, at the lower ground motion level, DRE and RC frame work together; at that stage, disengaging elements transfer lateral loads to rigid structures. DRE is an adaptive seismic protection system and its unique feature is the variable (self-adjusting) rigidity and periods of vibration during an earthquake with the purpose to avoid the resonance. The system was developed by Prof. J. Eisenberg. The development started in 1970 and the first building protected using the DRE system (vyklyuchayu-shchiesya svyazi) was constructed in 1972 in Sevastopol, Ukraine (former Soviet Union). This system is widely used in seismic prone areas of Russia and Kyrgyzstan. In Russia, there are around 140 buildings protected with this system; out of them, 120 buildings were built in North Baykal-city in 1974-76 (Baykal-Amur Railway Road), and the remaining buildings were constructed in Siberia, Kamchatka in 1980s and 1990s. There are several dozens of buildings protected with this system in Kyrgyzstan, Kazakhstan, Tajikistan, and Georgia. Majority of buildings protected with this system have residential function and are occupied at the present time. Buildings of this type have not been exposed to the effects of damaging earthquakes as yet.



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	X
< 50 years	
< 75 years	
< 100 years	
< 200 years	
> 200 years	

Is this construction still being practiced?	Yes	No
	X	

### 1.6 Region(s) Where Used

This system is widely used in seismic prone areas of Russia and other states of the former Soviet Union. In Russia, there are around 140 buildings protected with this system; out of them, 120 buildings were built in North Baykal-city (Neriungry, Severobaikalsk) in 1974-76 (Baykal-Amur Railway Road), and the remaining buildings were constructed in Siberia, Kamchatka in 1980s and 1990s. There are several dozens of buildings protected by means of this system in Kyrgyzstan, Kazakhstan, Tajikistan, and Georgia. The first building protected using this system was constructed in 1972 in Sevastopol, Ukraine (former Soviet Union).

### 1.7 Urban vs. Rural Construction

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

## 2 Architectural Features

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### 2.1 Openings

Walls at the ground floor level (where "Disengaging Reserve Elements" are installed) are not load-bearing structures. The overall window area is on the order of 15 to 35% of the exterior wall area; overall door area is approximately 10% of the interior wall area. At the upper floor levels, the overall window and door areas account for approximately 20% 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)		X
Is it typical for buildings of this type to have common walls with adjacent buildings?		X

The typical separation distance between buildings is 10 meters

### 2.3 Building Configuration

Typical shape of a building plan for this housing type is rectangular.

### 2.4 Building Function

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

*Additional Comments:* Majority of the buildings are residential buildings. A few buildings (3-4) are used as a kindergarten and school. The first building protected this system (built in Sevastopol, Ukraine) is a bank.

### 2.5 Means of Escape

There is one stair in one building unit. Usually a building consists of 1-4 building units.

### 2.6 Modification of Buildings

The modifications at the lower floor levels usually include non-structural (exterior and interior) walls. Typical modifications at the upper floors include perforation of walls with door and windows openings, and/or partial removal of walls.

### 3 Socio-Economic Issues

#### 3.1 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.

#### 3.2 Number of Housing Units in a Building

60 units in each building.

*Additional Comments:* Number of units varies from 32-64

#### 3.3 Average Number of Inhabitants in a Building

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

#### 3.4 Number of Bathrooms or Latrines per Housing Unit

Number of Bathrooms: 1

Number of Latrines: 0

#### 3.5 Economic Level of Inhabitants

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

*Additional Comments:* 40% poor, 60% middle class

#### 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	X
Small lending institutions/microfinance institutions	
Commercial banks / mortgages	
Investment pools	
Combination (explain)	
Government-owned housing	X
Other	

*Additional Comments:* 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.

#### 3.7 Ownership

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

## 4 Structural Features

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### 4.1 Lateral Load-Resisting System

Lateral load-resisting system consists of a concrete frame at the ground floor level and the load-bearing wall structure (either large precast panel construction or brick masonry wall construction) above the ground floor level. Ground floor structure is therefore substantially more flexible as compared to the structure above. Special devices called "Disengaging Reserve Elements" (DRE) are installed at the ground floor level. DRE consist of a "rigid structure" connected to the adjacent RC frame members by means of disengaging restraints. Lateral stiffness of a "rigid structure" is substantially larger as compared to the other elements e.g. concrete columns. Typically, "rigid structures" are RC wall panels (Type 2 Figure 4B). The "rigid structure" does not carry any gravity loads. Alternatively, "rigid structures" consist of spatial elements; see Type 1 Figure 4A). Disengaging restraints are sacrificial reserve elements (fuses) which serve as restraints for the "rigid structures". Typical restraints are steel plates joined together by means of rivets or steel bolts, steel bars, concrete prisms or cubes, etc. Initially (at the lower ground motion levels), DRE and RC frame system (at the ground floor level) work together as a rigid structure; at that stage, disengaging elements transfer lateral loads to rigid structures (RC panels). The initial fundamental period of vibration is typically on the order of 0.3 -0.45 sec, depending on the number of stories and a structural system. However, once the lateral load exceeds the prescribed level (depending on the site seismicity and other factors), disengaging elements get broken and disconnected from the "rigid structures". At that stage, due to the suddenly increased flexibility, a building changes vibration period to a higher value of about 0.8-1.0 sec. As a result, resonance effects are avoided and seismic loads is reduced. After an earthquake, disengaging restraints need to be replaced by new elements, however the cost is not high and the replacement is not complex.

It is considered that the seismic load in buildings protected with the DRE system is reduced to 1/2 of the level expected for a conventional building. Buildings with the DRE system are designed for lower level of seismic forces as compared to conventional buildings. Buildings with the DRE system were exposed to dynamic loads which simulate earthquake effects using the vibration equipment. Design recommendations for buildings protected with DRE system were developed based on numerous experimental and analytical investigations.

The system was developed by Prof. J. Eisenberg. The development started in 1970 and the first building protected using the DRE system (vyklyuchayu-shchiesya svyazi) was constructed in 1972 in Sevastopol, Ukraine (former Soviet Union).

### 4.2 Gravity Load-Bearing Structure

Gravity load-bearing structure is RC frame at the ground floor level and large precast panels or brick masonry wall construction at the upper floor levels. In Russia, upper stories in majority of buildings protected with this system are of large panel RC construction of various series (e.g. 308), and in Kyrgyzstan upper stories are of reinforced brick masonry construction.

### 4.3 Type of Structural System

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

*Additional Comments:* There is a moment-resisting RC frame at the ground floor level and load-bearing wall system (precast large panel construction - type 22 or brick masonry wall construction-type 9) at the upper floor levels. Note that brick masonry construction was not completely unreinforced - reinforced concrete elements were added at certain locations in the walls.

#### 4.4 Type of Foundation

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

Additional Comments: Type of foundation depends on soil conditions.

#### 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)	X	X
	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		
Structural Concrete	Precast hollow core concrete slabs	X	X

Additional Comments: Precast solid slabs (large panel construction), hollow core slabs (masonry construction)

#### 4.6 Typical Plan Dimensions

Length: 54 - 54 meters

Width: 54 - 54 meters

#### 4.7 Typical Number of Stories

9

#### 4.8 Typical Story Height

3 meters

#### 4.9 Typical Span

3-6 meters

#### **4.10 Typical Wall Density**

15% - 15%

Total wall area/plan area is about 0.15. 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. Walls at the ground floor level are not load-bearing structures.

#### **4.11 General Applicability of Answers to Questions in Section 4**

This contribution describes over 140 design applications of the disengaging reserve element system, mainly used in prefabricated large panel concrete construction and brick masonry construction.

## 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 from the building to the foundation.	X		
Building configuration	The building is regular with regards to both the plan and the elevation.	X		
Roof construction	The roof diaphragm is considered to be rigid and it is expected that the roof structure will maintain its integrity, i.e.. shape and form, during an earthquake of intensity expected in this area.	X		
Floor construction	The floor diaphragm(s) are considered to be rigid and it is expected that the floor structure(s) will maintain its integrity, during an earthquake of intensity expected in this area.	X		
Foundation performance	There is no evidence of excessive foundation movement (e.g. settlement) that would affect the integrity or performance of the structure in an earthquake.	X		
Wall and frame structures-redundancy	The number of lines of walls or frames in each principal direction is greater than or equal to 2.	X		
Wall proportions	Height-to-thickness ratio of the shear walls at each floor level is: 1) Less than 25 (concrete walls); 2) Less than 30 (reinforced masonry walls); 3) Less than 13 (unreinforced masonry walls).	X		
Foundation- wall connection	Vertical load-bearing elements (columns, walls) are attached to the foundations; concrete columns and walls are doweled into the foundation.	X		
Wall-roof connections	Exterior walls are anchored for out-of-plane seismic effects at each diaphragm level with metal anchors or straps.	X		
Wall openings	The total width of door and window openings in a wall is: 1) for brick masonry construction in cement mortar: less than 1/2 of the distance between the adjacent cross walls; 2) for adobe masonry, stone masonry and brick masonry in mud mortar: less than 1/3 of the distance between the adjacent cross walls; 3) for precast concrete wall structures: less than 3/4 of the length of a perimeter wall.	X		
Quality of building materials	Quality of building materials is considered to be adequate per requirements of national codes and standards (an estimate).		X	
Quality of workmanship	Quality of workmanship (based on visual inspection of few typical buildings) is considered to be good (per local construction standards).		X	
Maintenance	Buildings of this type are generally well maintained and there are no visible signs of deterioration of building elements (concrete, steel, timber).		X	
Other				

### 5.2 Seismic Features

Structural Element	Seismic Deficiency	Earthquake-Resilient Features	Earthquake Damage Patterns
Wall- upper floor levels	A conventional building of large panel concrete construction or brick masonry construction: poor quality of panel joints and inadequate masonry strength		Damage of load-bearing structure is possible; however it is expected to be less as compared to buildings without the disengaging elements.
Frame - ground floor level	Similar reinforced concrete frame: Poor quality of concrete, breach of reinforcement in particular, the "as constructed" reinforcement locations do not match with the design; inadequate length of lap splices in steel rebars; inadequate confinement in the highly loaded areas.		Damage of sacrificial elements (restraints) that are replaced after the earthquake.
Roof and floors			
Disengaging Reserve Elements	Quality and precision in the construction of the Disengaging Reserve Elements	Disengaging Reserve Elements are effective in reducing seismic demand in the building.	

### 5.3 Seismic Vulnerability Rating

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

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

## 6 Earthquake Damage Patterns

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### 6.1 Past Earthquakes Reported To Affect This Construction

Year	Earthquake Epicenter	Richter magnitude(M)	Maximum Intensity (Indicate Scale e.g. MMI, MSK)
1984	Severobaikalsk	4	5 (MSK)

*Additional Comments:* Buildings protected with the Disengaging Reserve Elements were not damaged in the 1984 earthquake. Buildings of this type were tested by the special vibration equipment and subjected to dynamic loads simulating seismic effects.

## 7 Building Materials and Construction Process

### 7.1 Description of Building Materials

Structural Element	Building Material	Characteristic Strength	Mix Proportions/ Dimensions	Comments
Walls	Reinforced concrete	30-35 MPa ( cube compressive strength) 390 MPa (steel yield strength)		
Foundations	Reinforced concrete	10-15 MPa (cube compressive strength) 295 MPa (Steel yield strength)		
Frame	Reinforced concrete	30-35 MPa (cube compressive strength) 390 MPa (steel yield strength)		
Roof and floors	Reinforced concrete	30-35 MPa (cube compressive strength) 390 MPa (steel yield strength)		
Disengaging Reserve Elements (rigid structure-panels)	Reinforced concrete	30-35 MPa (cube compressive strength) 390 MPa (steel yield strength)		

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

Anyone can live in buildings of this construction type

### 7.3 Construction Process

Construction is performed by builders. Designs are developed in the design institutes. Specialized construction companies make precast concrete elements and perform casting of concrete in-situ. Precast elements are fabricated at the plants. The main construction equipment is the same as in the case of conventional concrete construction and it includes crane, welding equipment and concrete mixers.

### 7.4 Design/Construction Expertise

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 the team. 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.

### 7.5 Building Codes and Standards

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

Title of the code or standard: SNiP II-7-81. Building in Seismic Regions.Design Code

Year the first code/standard addressing this type of construction issued: 1981

National building code, material codes and seismic codes/standards: SNiP II-7-81. Building in Seismic Regions - Design Code Recommendations for Design of Buildings with #Disengaging Reserve Elements# CNIISK, Moscow, 1987.

When was the most recent code/standard addressing this construction type issued? 1981

### 7.6 Role of Engineers and Architects

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.

### 7.7 Building Permits and Development Control Rules

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

### 7.8 Phasing of Construction

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

### 7.9 Building Maintenance

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

### 7.10 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 the pertinent Building Codes. According to the building bylaws, building cannot be used without the formal approval by 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.

### 7.11 Typical Problems Associated with this Type of Construction

Inadequate design, poor quality of construction.

## 8 Construction Economics

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### **8.1 Unit Construction Cost (estimate)**

For load-bearing structure only (including the disengaging elements) the cost is about 210 US\$/m<sup>2</sup>. For a similar prefabricated concrete panel building (seria 105) without disengaging elements the construction cost would be 50-200 US\$/m<sup>2</sup>. Therefore, the increase in unit cost due to the installation of seismic belt is in the range from 10 to 40 %.

### **8.2 Labor Requirements (estimate)**

It would take from 12 to 18 months for a team of 10 workers to construct a load-bearing structure.

## 9 Insurance

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### 9.1 Insurance Issues

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

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

# 10 Seismic Strengthening Technologies

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## 10.1 Description of Seismic Strengthening Provisions

Type of intervention	Structural Deficiency	Description of seismic strengthening provision used
Retrofit (Strengthening)	Building damage - broken disengaging elements	Replacement of the damaged elements with the new ones

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

No. Buildings of this type are already strengthened by means of disengaging reserve elements.

### 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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Recommendations for design of buildings with #Disengaging Reserve Elements# CNIISK, Moscow, 1987.

## 12 Contributors

Name	Jacob Eisenberg	Svetlana Uranova	Ulugbek T. Begaliev
Title	Pr., Chairman	Engineer	Head of Department
Affiliation	Russian National Committee for Earthquake Engineering		KNIIPC
Address	4 Berezhkovsky Embankment Art 110	107-1222 Harwood Street	Vost Prom ZoneCholponatisky 2
City	Moscow	Vancouver, BC	Bishkek
Zipcode	121059	V6E 152	720571
Country	Russian Federation	Canada	Kyrgyzstan
Phone	007-095-945-36-28	604-696-0563	996-3312-237564
Fax	007-095-174-70-64		
Email	seismo@online.ru	uransv@yahoo.com	utbegaliev@yahoo.com
Webpage			

13 Figures



FIGURE 1: Typical Building



FIGURE 1A: Typical Building - Load-Bearing Masonry Construction (Bishkek, Kyrgyzstan)

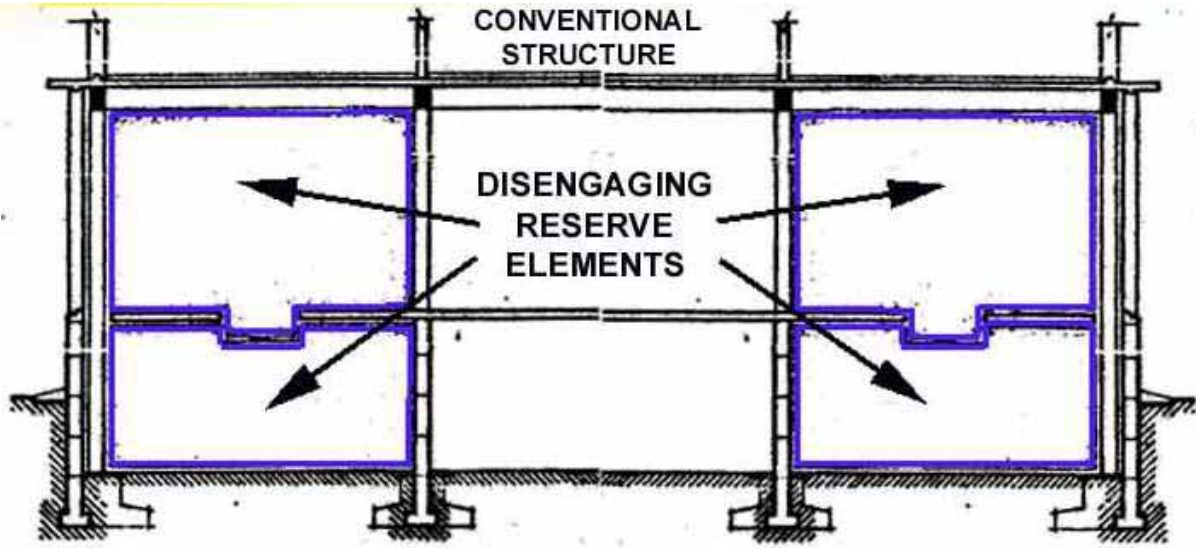


FIGURE 2: Key Load-Bearing Elements

TYPICAL PLAN

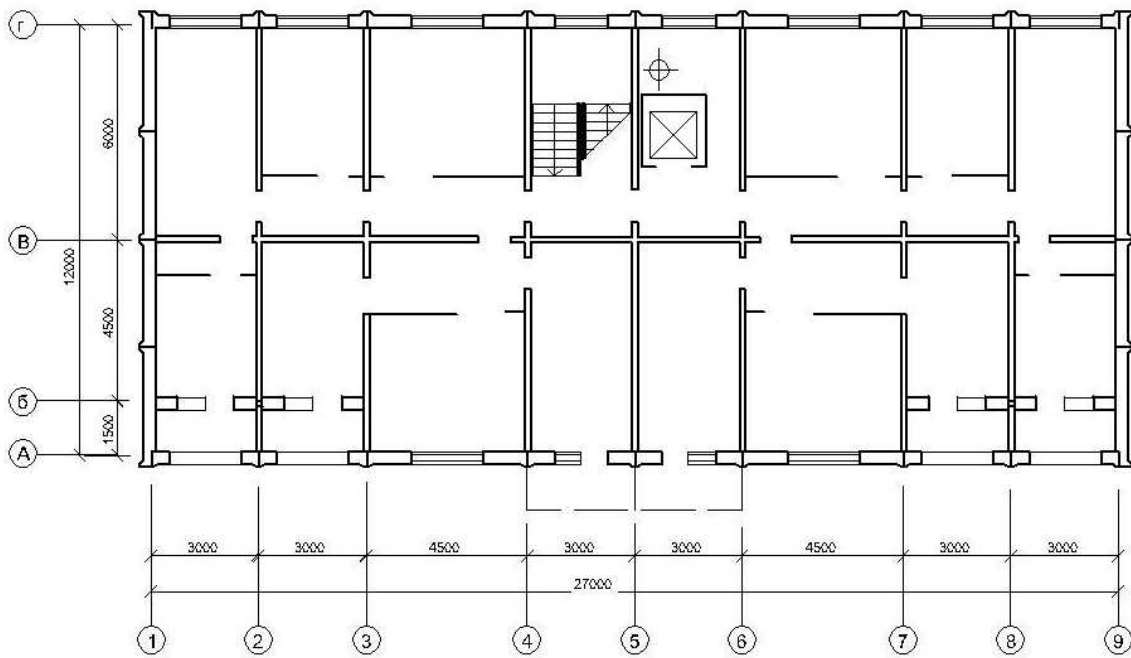
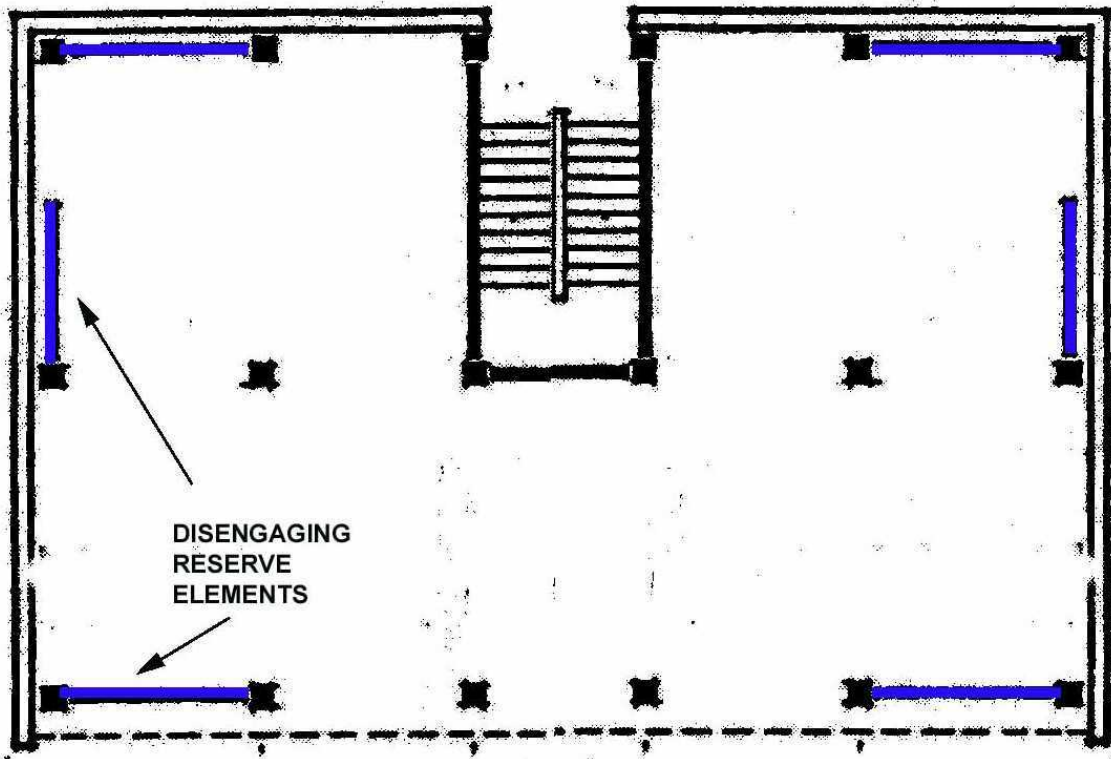


FIGURE 3A: Plan of a Typical Building



*FIGURE 3B: Ground Floor Plan Showing the Locations of Disengaging Reserve Elements*

TYPE 1

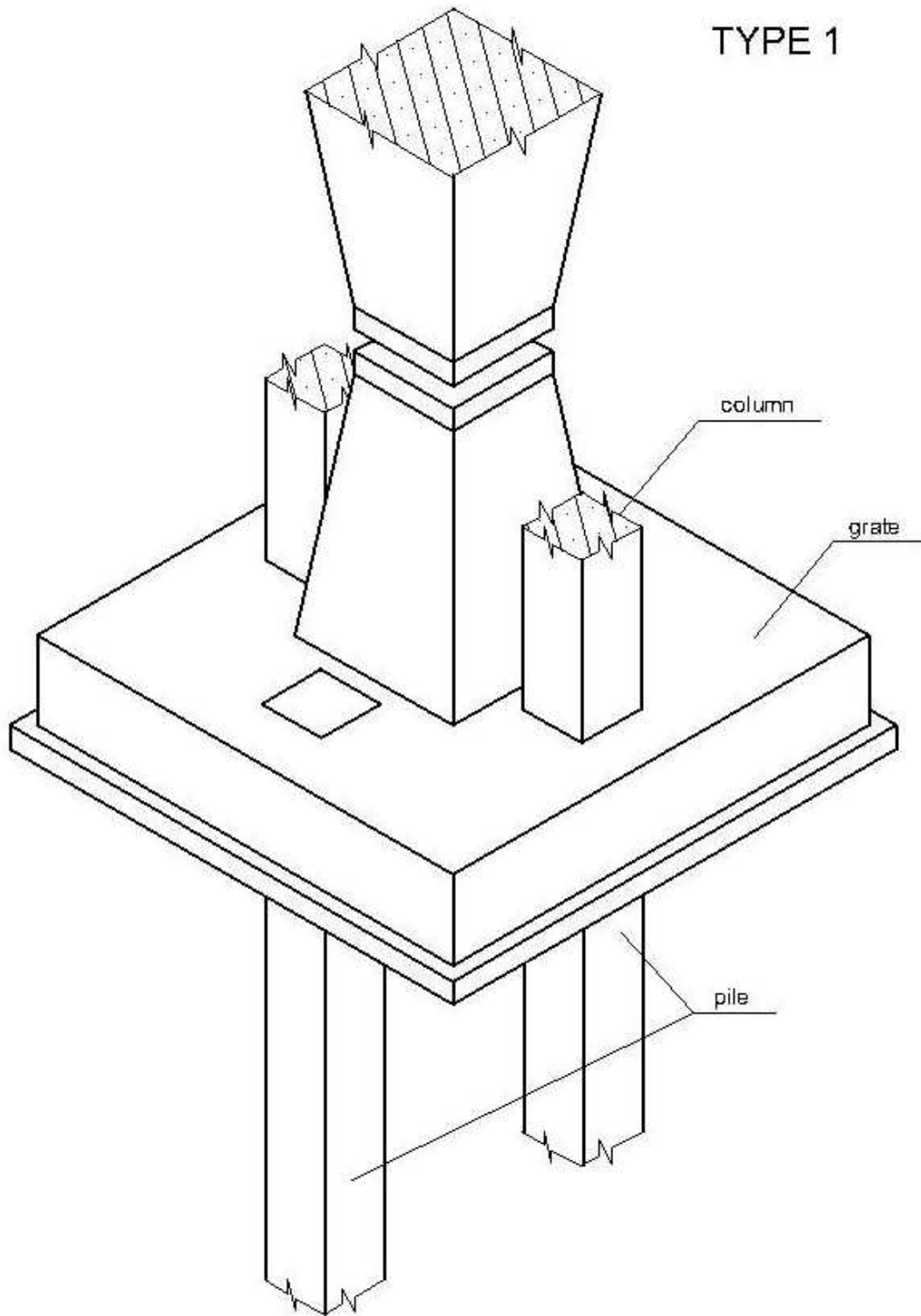


FIGURE 4A: Critical Structural Details - Disengaging Reserve Elements

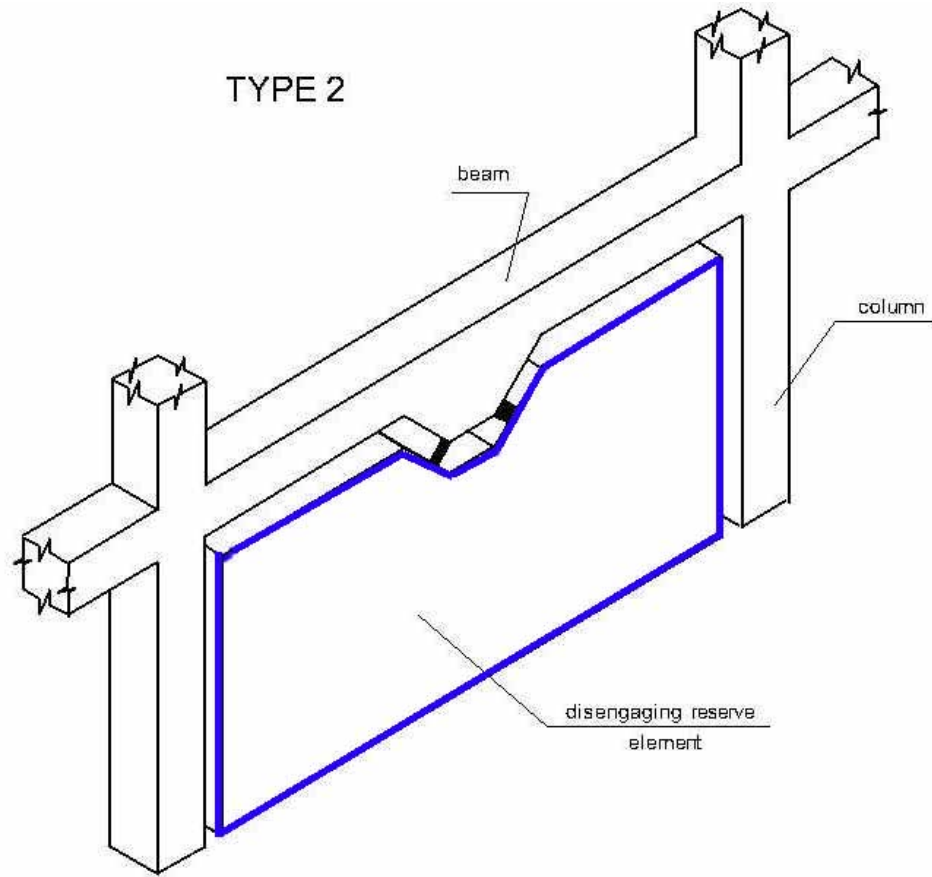


FIGURE 4B: Critical Structural Details - Disengaging Reserve Elements