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# Original Concept for Base Isolation of Four Residential Houses Unified by One Reinforced Concrete Slab

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**ABSTRACT**

*Seismic isolation technologies are well developed and widely implemented in Armenia due to research and design works of the author of this paper. To date there are about 50 buildings in the country newly constructed or retrofitted by base or roof isolation systems. For each of these buildings their structures of base isolation were located exactly within the limits of the buildings' plans. In the given case for the first time a new and original concept for base isolation of four residential houses unified by one rigid reinforced concrete (R/C) slab is suggested and developed. The paper briefly describes an architectural solution developed based on the proposed concept, but mainly it focused on the detailed structural solutions of four residential houses with load-bearing walls located on R/C rigid slab supported by seismic isolation laminated rubber-steel bearings (SILRSBs).The space below the mentioned slab is used as a basement/parking floor and all structural elements under the level of SILRSBs are designed as the R/C lower pedestals and shear walls to be constructed on the foundations. Proposed new solution gives a possibility to significantly (about two times) reduce the number of SILRSBs in comparison with the known ways of creation of base isolation systems.*

**Key words:** Concrete Slab, Seismic isolation technologies

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## INTRODUCTION

Seismic isolation of structures should be currently considered as common and most effective method of providing protection from earthquake damage, high reliability of buildings and increasing of the quality of human lives. The author of this paper had started the research on these systems in 1993 and then due to his efforts 53 buildings and structures have been designed with application of base or roof isolation systems. Of these designed buildings, the total number of already constructed and retrofitted buildings has reached 45. Some of the already implemented projects are shown in Table 1.The fact deserving attention is that number of seismically isolated buildings per capita in Armenia is one of the highest in the world. This is also confirmed in [15]: "Armenia, with 38 completed isolated buildings and 8 under construction, remains second, at worldwide level, for the number of applications of such devices per number of residents, in spite of the fact that it is a still developing country".

As it is mentioned in the Abstract for each of isolated buildings their structures of base isolation were located exactly within the limits of the buildings' plans. However, below another concept is suggested when several buildings (four in the given case) are unified by one R/Crigid slab which is in its turn provided with the base isolation system. In this case there is no need to locate the SILRSBs exactly under the load-bearing walls of each building.

Similar concept was suggested earlier in [3] (see Table 1 item "j") and in [16]. But in those structural solutions each of the SILRSBs in the seismic isolation systems is located right between the bearing structures below and above it. In contrast to this approach the author proposes an idea when a large R/C rigid slab is supported by SILRSBs and the distance between them in longitudinal and transverse directions may differ (can be much bigger) than the distance between the bearing structures of the buildings to be constructed on this slab. As the first attempt, a complex, which consisted of four buildings with the stone load-bearing walls, was designed for construction on one slab supported by seismic isolators located within the parking/basement floor. Design view of the complex is shown in Figure 1. The buildings are the private houses and besides the parking/basement floor each of them has two living floors and an attic.

**Table -1** Views of some retrofitted and newly constructed buildings in Armenia using seismic isolation systems

| a. | b. | c. | d. |
|---|---|---|---|
|  |  |  |  |
| e. | f. | g. | h. |
|  |  |  |  |
| i. | j. | k. | l. |
|  |  |  |  |
| m. | n. | o. | p. |
|  |  |  |  |

a - 5-story existing stone apartment building retrofitted by base isolation for the first time in the world without interruption of the use of the building [1,2],
b - 4-story base isolated apartment building with reinforced masonry bearing walls in Huntsman Village [3],
c - 3-story existing stone school building retrofitted by base isolation without interruption of the use of the building [4],
d - 3-story base isolated clinic building [5],
e - 3-story base isolated private house with stone bearing walls and dynamic damper at the level of isolation system [6],
f - 9-story existing roof isolated apartment building protected by means of an isolated upper floor [7],
g - 6-story base isolated hotel/commercial centre building [3],
h - 11-story base isolated building of the multifunctional residential complex “Cascade” [8],
i - 16- and 10-story base isolated buildings of the multifunctional residential complex “Our Yard” [9],
j - 16- and 14-story base isolated buildings of the multifunctional residential complex “Arami” [3],
k - 18-story base isolated buildings of the multifunctional residential complex “Northern Ray” [10],
l - 16- and 13-story base isolated buildings of the multifunctional residential complex “Dzorap”[3],
m - 20-story base isolated business centre “Elite Plaza” [11],
n - 17-story base isolated building of the multifunctional residential complex “Baghramian” [12],
o - 17-story base isolated building of the multifunctional residential complex “Avan” [13],
p - 15-story base isolated building of the multifunctional residential complex “Sevak”[14],
Buildings “d”, and from “f” to “p” have the structural system with R/C bearing frames and shear walls.

**Fig. 1 Design views of four 3-story private houses with stone load-bearing walls to be constructed on one large base isolated rigid R/C slab**

In fact, this proposal/idea has a far going purpose of its application in considerably bigger complexes. For example, there is an on-going project named "Old Yerevan" which is supposed to be implemented in downtown of Yerevan, the capital of Armenia. This project is to recreate Yerevan's architectural look of the end of the 19th century and the beginning of the 20th century. The project architect Levon Vardanyan said the "Old Yerevan" area (about 20,000 $m^2$) will not have dwelling buildings and will serve as a public and cultural center with museums, galleries and fairs of Armenian carpets (Fig.2). The author of the given paper believes that proposed by him idea can be very efficiently used in the projects like this one.

## STRUCTURAL CONCEPT OF THE PROPOSED IDEA

Foundations in the considered complex (Fig. 3) are designed as R/C spread footings with dimensions in plan equal to 800×800 mm and the height – 400 mm connected to each other by the R/C beams with the cross-section of 500×400(h) mm. Above all spread footings the seismic isolators' lower pedestals are envisaged with the cross-section of 600×600 mm and the height – 2.1 m and they connected by the 200 mm thick shear walls as shown in Figure 4. Consequently, the given structural concept provides the possibility to create a needed rigid system below the seismic isolation interface.

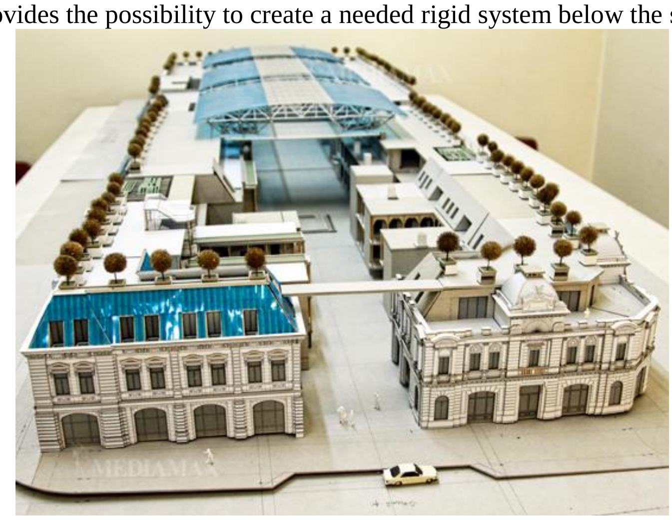

**Fig. 2 View of the model of "Old Yerevan" project**

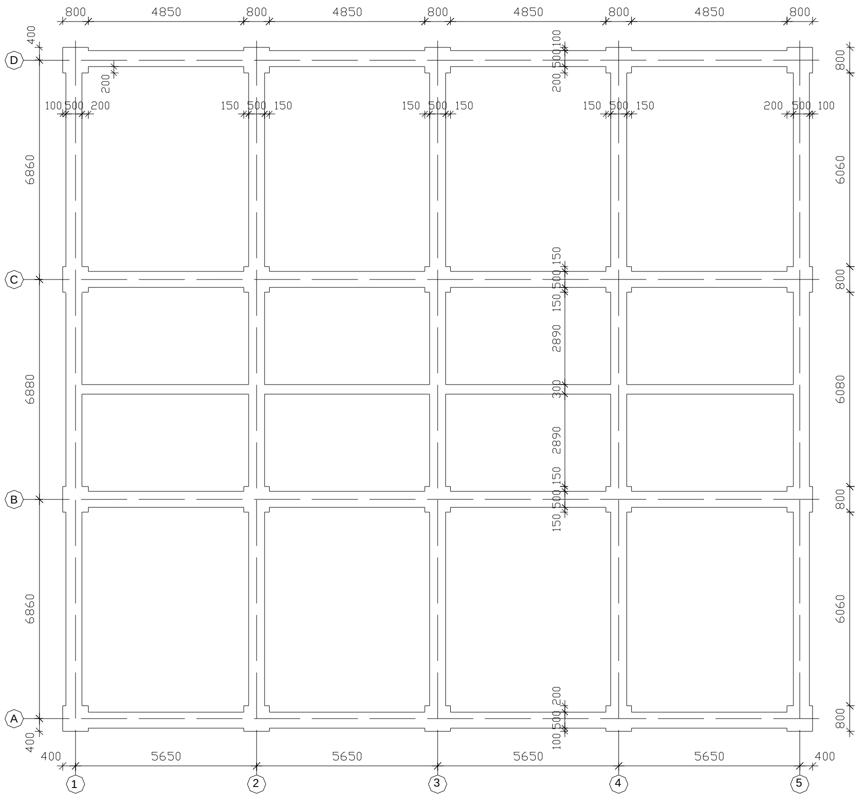


**Fig. 3 Plan of the foundations of four residential houses unified by one base isolated R/C rigid slab**

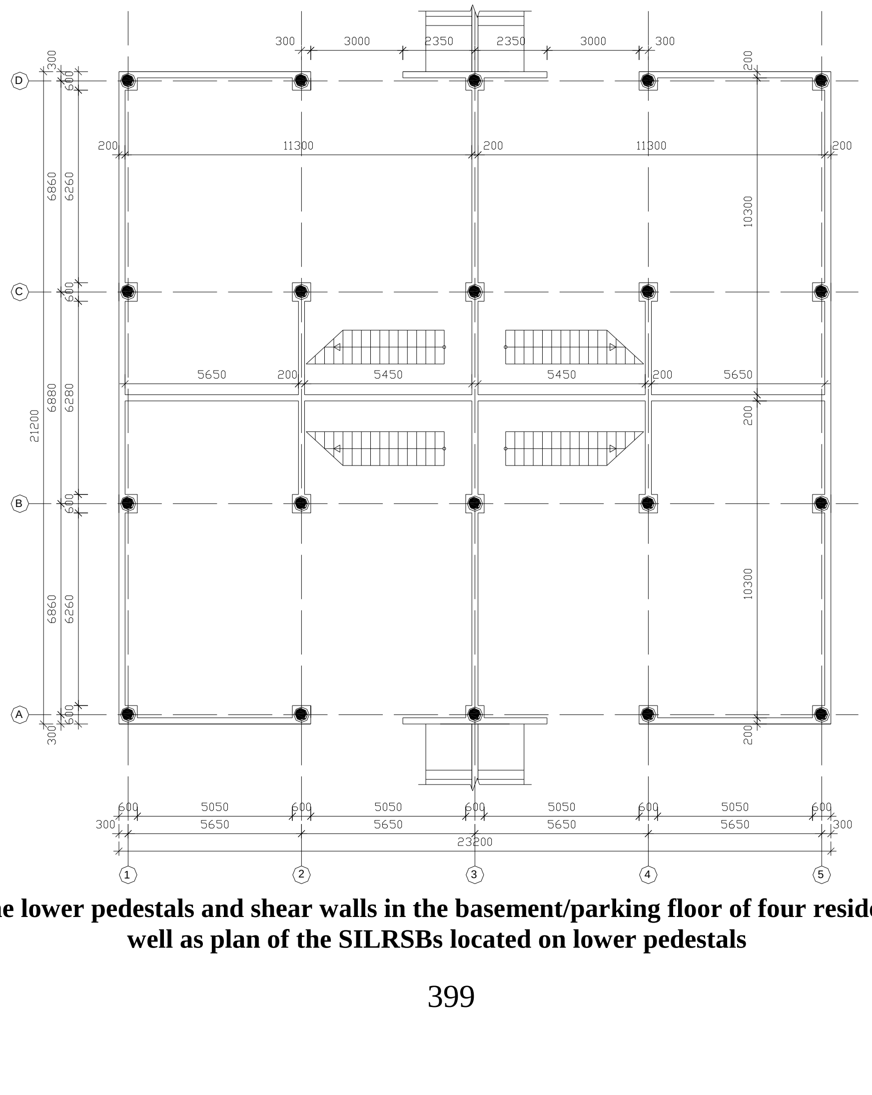


**Fig. 4 Plan of the lower pedestals and shear walls in the basement/parking floor of four residential houses, as well as plan of the SILRSBs located on lower pedestals**

Then above this interface the rigid R/C slab (Fig. 5), which unifies all four residential houses (Fig. 6)and has dimensions equal to 23.2×21.2 m, is going to be constructed. From these drawings, it is easy to notice that the distance between the SILRSBs in longitudinal and transverse directions is bigger than the distance between the load-bearing walls of the residential floors. Each of the buildings has four exterior 500 mm thick walls and two interior 400 mm thick walls made of tuff stones. The buildings have rectangular plan with outside dimensions equal to11×10 m. The second and third floors' R/C slabs have thickness equal to 120 mm and the height of these floors is equal to 3.0 m. Other dimensions related to the basement/parking floor are given in its vertical elevation 1-1 (Fig. 7).
Special attention needs to be paid to the stairs leading to the basement/parking floor of each building. These are the single-flight stairs which have their own supports permitting to separate them at the level of seismic isolation interface (see Fig. 7), thus, providing the gaps between the stairs (in fact the gaps between the substructure and superstructure). Similar gaps are designed for the stairs leading from the yard to the first living floor entrance. There is also main200 mm high gap envisaged around the perimeter of the basement/parking floor between the marks -0.55 and -0.75.

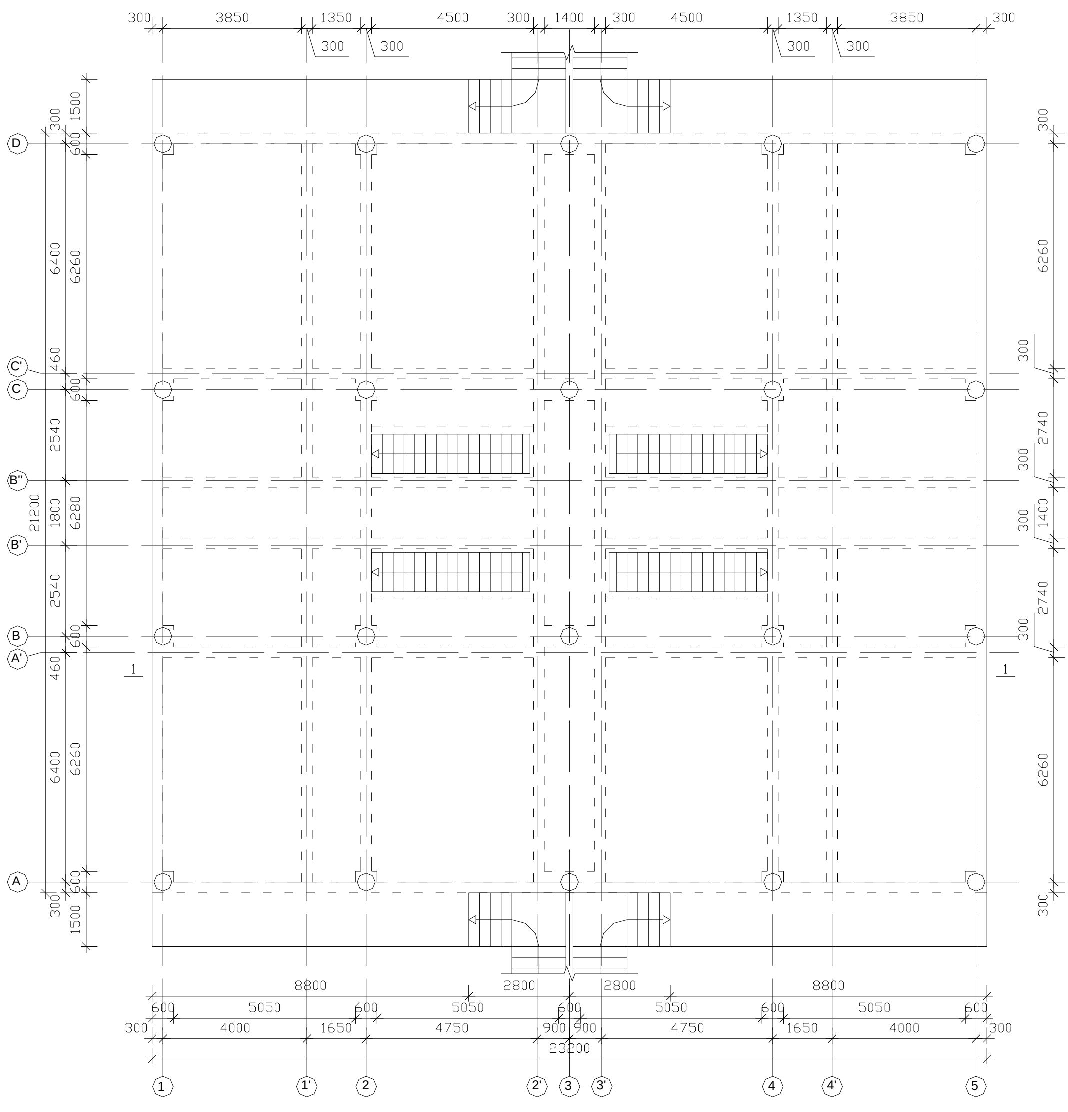


**Fig. 5 Plan of the R/C upper pedestals, beams and the rigid slab above the seismic isolation interface of four residential houses**

It is obvious that if each of the buildings in this complex would be constructed separately then at least nine SILRSBs would be needed to create its seismic isolation system. This means that for four of such separate buildings the total number of the needed SILRSBs will be equal to 36. But in the proposed solution only 20 SILRSBs are used. Of course, many different questions may arise by the readers of this paper, but everyone should conceive this idea broadly.

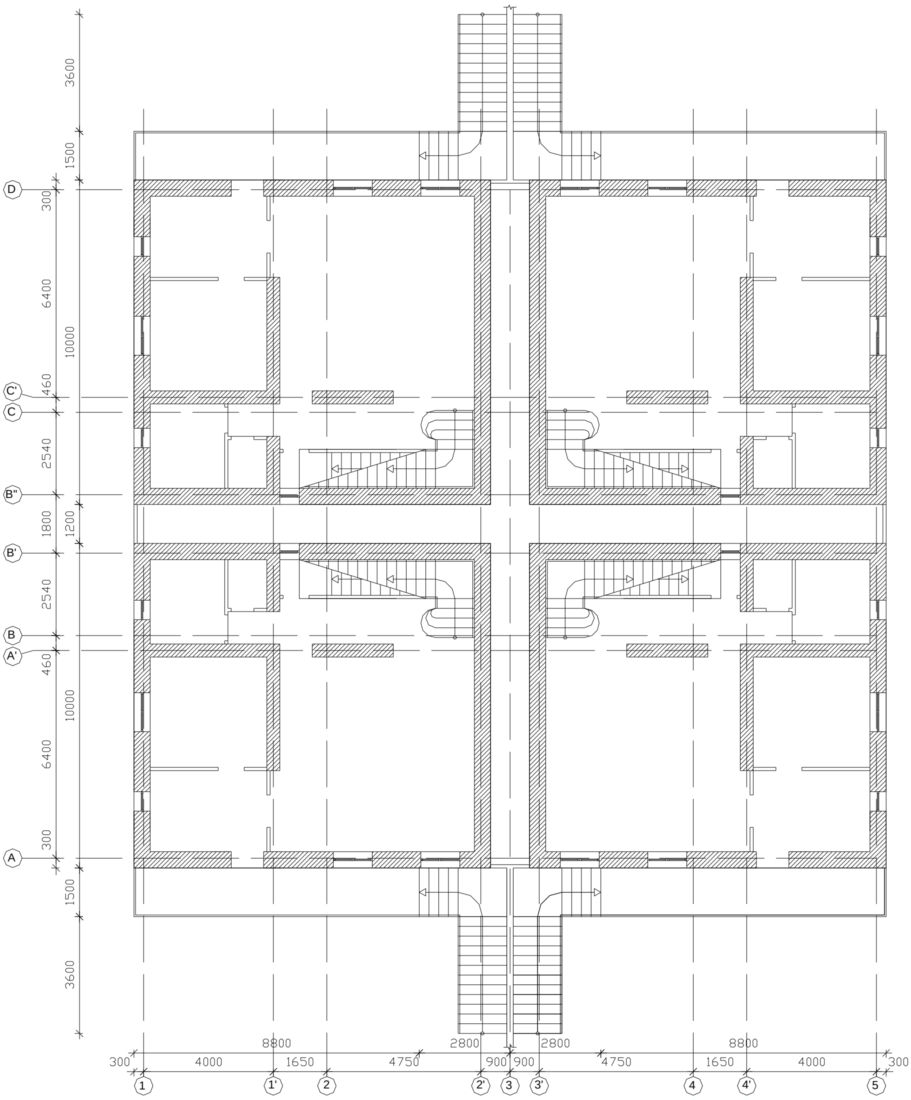


**Fig. 6 Plan of the load-bearing walls of four residential houses located on the single R/C rigid slab above the seismic isolation interface**

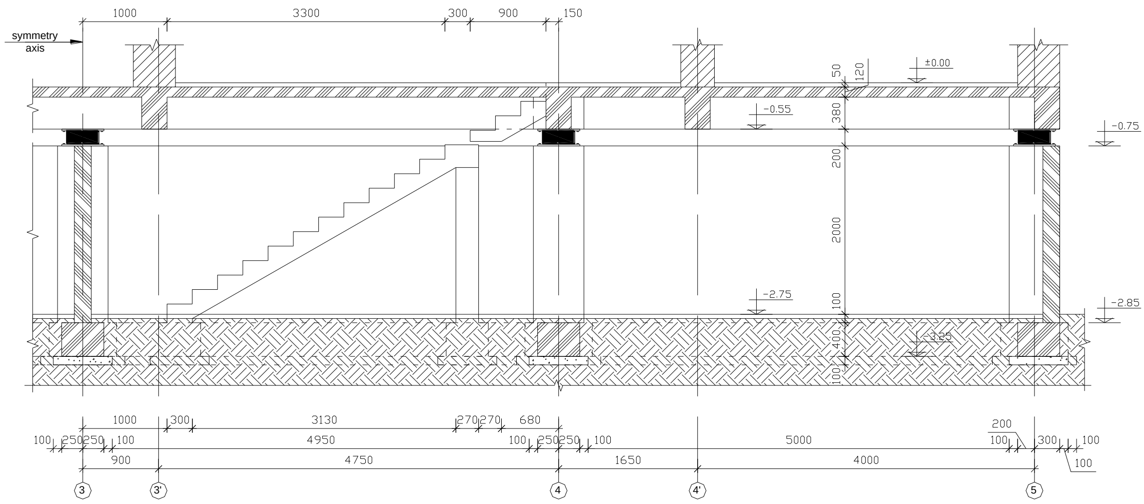


**Fig. 7 Vertical elevation 1-1 of the basement/parking floor of four residential houses showing the seismic isolation system, the main gap around the perimeter of the basement/parking floor and the gap in the single-flight stairs**

## CHARACTERISTICS OF SILRSBs CONSIDERED IN THE DESCRIBED COMPLEX

Table 2 summarizes the design details of the considered in this paper SILRSBs. These parameters are widely used for the bearings manufactured in Armenia with application of high damping neoprene rubber. In all base isolated buildings constructed or retrofitted in Armenia the simple recess connection detail to fix the bearings was chosen. Such option necessitates a check that the bearings are safe against roll-out at the maximum horizontal displacement, with a due regard to the reduction in vertical load on some of the bearings attributable to the overturning of the building at large displacements. Geometrical dimensions of the considered SILRSBs are shown in Figure 8.

**Table -2 Design details of the considered SILRSBs**

| Parameters of laminated rubber-steel bearings | Values |
|---|---|
| Number of rubber layers | 14 |
| Number of internal metal plates | 13 |
| Thickness of rubber layers, mm | 9 |
| Thickness of internal metal plates, mm | 2.5 |
| Radius of internal metal plates, mm | 180 |
| Thickness of side cover layer, mm | 10 |
| Thickness of steel end-plate, mm | 20 |
| Thickness of end cover layer, mm | 2 |
| Overall height, mm | 202.5 |
| Overall diameter, mm | 380 |
| Rubber shear modulus | 0.97 |
| Static compressive stress (max), MPa | 8.7 |
| Critical load, kN | 3260 |
| Design vertical load | 1500 |
| Load for internal plate yield, kN | 4800 |
| Horizontal stiffness, kN/mm | 0.81 |
| Horizontal displacement at onset of roll-out, mm | |
| for design vertical load | 300 |
| for min. vertical load | 260 |
| Nominal vertical stiffness, kN/mm | 400 |

Calculations were carried out taking into account the non-linear behavior of SILRSBs with the following input parameters: yield strength – 56 kN; yield displacement – 19 mm; effective horizontal stiffness – 0.81 kN/mm.

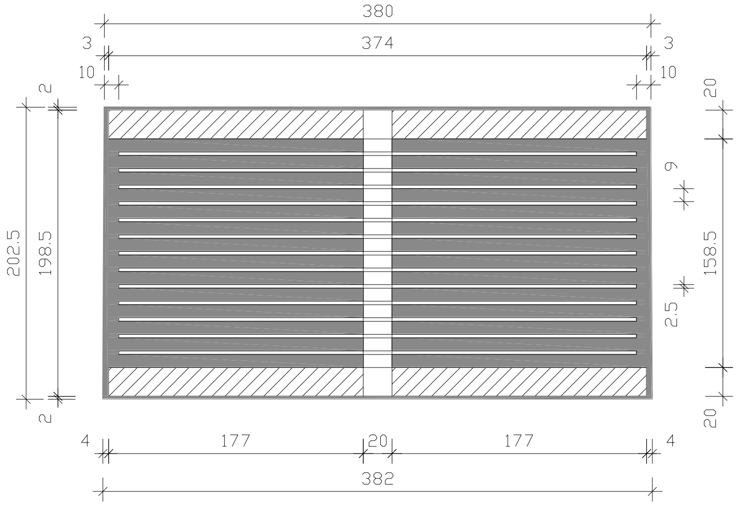


**Fig. 8 Geometrical dimensions of the SILRSBs considered in the described complex**

## CONCLUSIONS

- New and original concept for base isolation of four residential houses unified by one rigid R/C slab, which rests on the SILRSBs, is suggested and developed.
- Proposed idea can be very efficiently used for large blocks of buildings to be newly constructed.
- The main feature of the proposed idea is that the distance between the SILRSBs under the rigid R/C slab in longitudinal and transverse directions can be bigger than the distance between the bearing elements of the superstructure.

- In comparison with the usual way of base isolation the proposed idea brings to significant reduction of the number of needed SILRSBs.
- Proposed idea leads to the more flexible architectural solution and to creation of the larger spaces in the basement/parking floor.

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