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First Application of Base Isolation in an Existing Residential Building in Istanbul

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ABSTRACT: Many existing buildings which have been constructed in the 70s and 80s in Istanbul, have been found to have inadequate capacity under seismic effects. The reason for such shortcomings are due to changes in design standards towards stricter criteria (higher return period earthquakes), as well as due to poor construction techniques, low quality materials and uncontrolled design and workmanship. Seismic protection through base isolation is an economic and efficient way to retrofit existing buildings. The alternative is a conventional, intrusive retrofitting, which requires strengthening at all floor levels.

For new built major structures, base isolation is a preferred and widely used method in Turkey. For existing structures, the method requires the removal of a portion of the column, while under load, and its replacement with seismic isolators.

The Gurup apartment in Moda district is the first residential building to be retrofitted with base isolation in Istanbul. The isolation system is applied at the basement floor, above the foundation level. The acceleration limit above the isolation level is determined using a pushover analysis, taking the actual properties of the existing upper structure into account. The isolation system, installation method, and its advantages are discussed in detail.

1 INTRODUCTION

The seismically isolated hospital and bridge projects have become popular in recent years in Turkey as well as in high seismic regions around the world. The base isolation method is also preferred in existing structures instead of a conventional retrofitting method due to the application time and requiring a strengthening on the structural elements at the isolation level. To specify the isolation system and define the isolator parameters, two different levels of earthquake are used; design base earthquake with 475 years return period (DBE) and maximum credible earthquake with 2,475 years return period (MCE). The acceleration and displacement limitations for the global system are determined considering the performance level of the related earthquakes.

The application of the isolation system in existing structures is a significantly important process. To avoid differential settlement between the isolators, application method of the isolation system and application sequence requires importance for the existing structures. A specially designed equipment is used during the construction in order to cut the column splice and provide load transfer between lower and upper part of the isolation level. The design and the application details are given in following sections.

The isolation project includes the strengthening of foundation and basement floor columns, isolator design and installation.

2 GENERAL PROPERTIES AND DESIGN DETAILS

2.1 The Structure

The Gurup Apartment is located in Moda district of Istanbul, which is close to the Marmara Sea. The building consists of ten residential floors plus a roof floor with 3,100m^2 total area. The total building height is 30.95m. The structural system has 33 columns with spread footings. The concrete strength is obtained as f'c=18MPa from the core tests with 32 cores and eight numbers of nondestructive tests. The rebar class is determined to be S220 by survey.

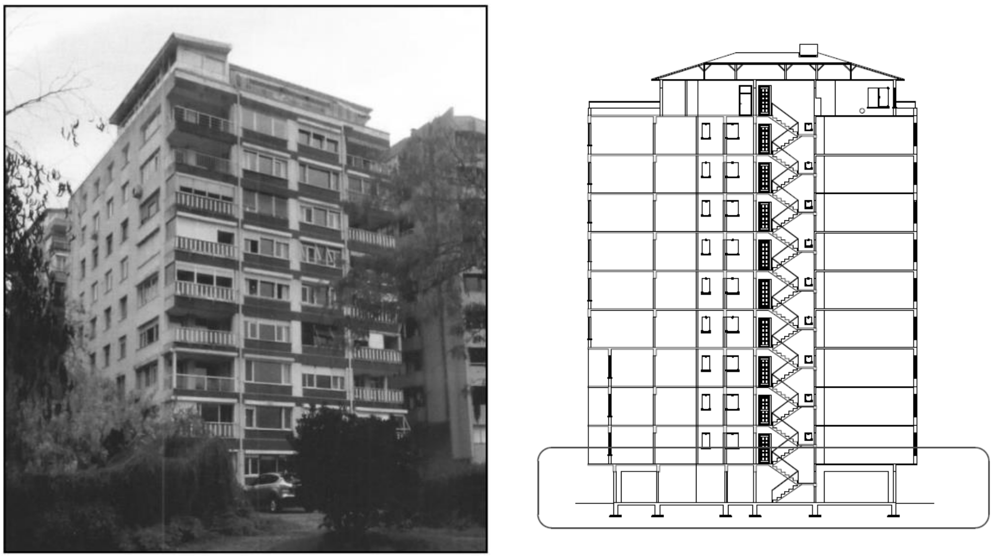

Figure 1. Views of the building and the isolation level.

2.2 Seismicity and performance criteria

Gurup Apartment is located in Seismic Zone 1 per TSDC (2007), and on soil type B per NEHRP soil class. The spectral acceleration parameters of the considered earthquakes are taken from DLH (2008) based on the site coordinates. The generated spectrums are given in Figure 2.

Two different levels of safety are used for evaluation of the structural elements. First is the "Life Safety Performance" under MCE level, and the second is the "Immediate Occupancy Performance" under DBE level. To specify the project limitations considering performance levels, pushover analysis is performed at two fundamental directions.

The project limitations for using seismic isolation system are determined based on the pushover analysis results, as following:

- Base shear force under DBE level is limited to 13% of total seismic weight for "Immediate Occupancy Performance".
- The maximum displacement under MCE level is limited to 300mm for "Life Safety Performance". However, this displacement is not suitable for building edges due to the retaining walls on the side. After site investigation, the maximum displacement limit value is modified to 280mm, and isolation system is determined with this displacement value.

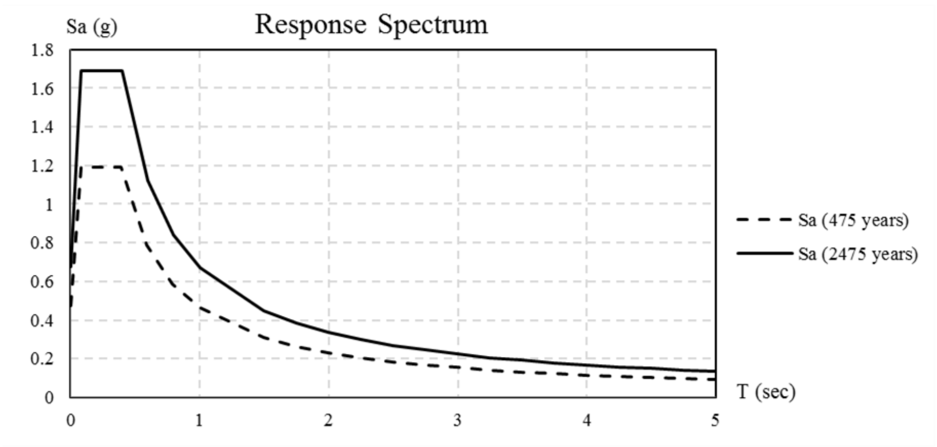

Figure 2. Design spectrums.

2.3 Global system analysis

The isolation system is designed at the foundation level. It consists of the combination of lead rubber bearings (LRB) and sliding type elastomeric bearing (slider). 27 LRBS and six sliders are used in order to make a flexible system and satisfy the acceleration and displacement limits. The slider type bearings are placed at central columns. The number of sliders are determined considering the overall torsional stiffness at isolation level. The isolator is designed per EN 15129 (2009) and TBDY (2018). By the request of the designer and project advisor, the prototype test protocol is prepared according to the TBDY (2018). At the preliminary design stage, isolator characteristics and global system are checked assuming single degree of freedom system (SDOF). After preliminary prototype tests, the global system is analysed with lower and upper bound characteristic using Nonlinear Time History Analysis (NLTHA). In the NLTHA, seven pairs of accellerograms which are chosen from the database of PEER-NGA West 2 are taken into account. The bearing distribution and isolator characteristics are presented in Figure 3.

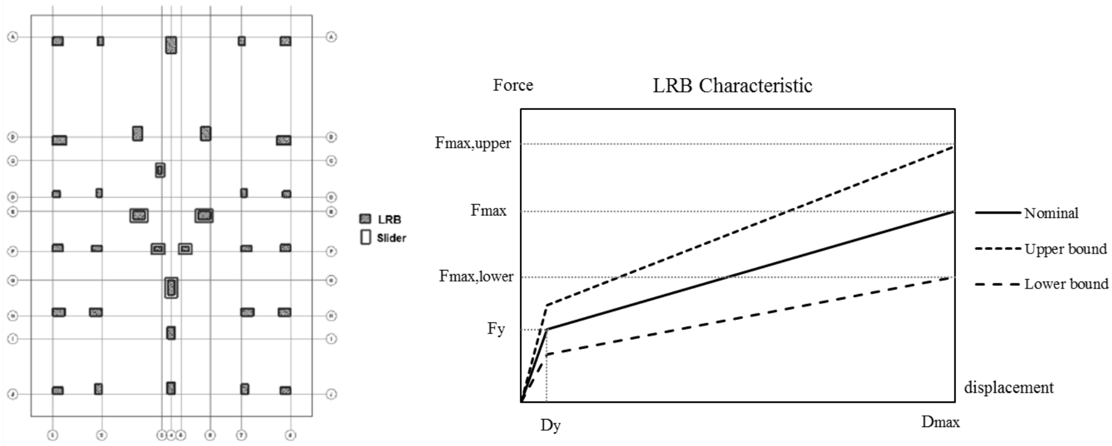

Figure 3. Bearing layout and isolator characteristic.

In the SDOF system, effective isolator parameters (nominal) are used in the calculation.

The effective period is calculated as:

$$T_{eff} = 2\pi\sqrt{\frac{W}{\sum K_{eff} \cdot g}} \tag{1}$$

In expression (1) W is the seismic weight and K_{eff} is the effective stiffness of the isolator. The calculation details are summarized in Table 1.

Table 1. Results of the global system using the Single Degree of Freedom System.

Isolator numbers:	27 LRB	
Seismic weight:	W = 39,500kN	
	DBE level	MCE level
Period: T (sec)	T_D=2.0sec	T_M=2.3sec
Effective stiffness of isolator:	$K_{eff,D}$=1.5kN/mm	$K_{eff,M}$=1.1kN/mm
Effective damping:	$\zeta_{eff,D}$=29.0%	$\zeta_{eff,M}$=23.0%
Damped acceleration:	$S_{a,D}$ =0.12g	$S_{a,M}$ =0.18g
Damped displacement:	$S_{d,D}$=120mm	$S_{d,M}$=230mm (one direction)

In the prototype tests, the compression stiffness, horizontal cyclic characteristics and lateral capacity of the isolators are evaluated. The prototype tests are performed at SISMALAB Taranto, Italy while the Factory Production Control tests (FPC) are performed at Isolab of Freyssinet Products Company in Pavia, Italy.

After getting test results, the lower and upper bound values related to test results are updated. Thereafter NLTHA is performed using the lower and upper bound characteristics of the isolators for DBE and MCE levels to check the bearing displacement and total base of the global system. According to NLTHA results, the acceleration of the global system under DBE level is less than the acceleration limit, and the average displacement of the seven accellerograms is Sd=160mm which is much less than the displacement limit. The isolator test diagram for the compression test and horizontal cyclic test are given in Figure 4.

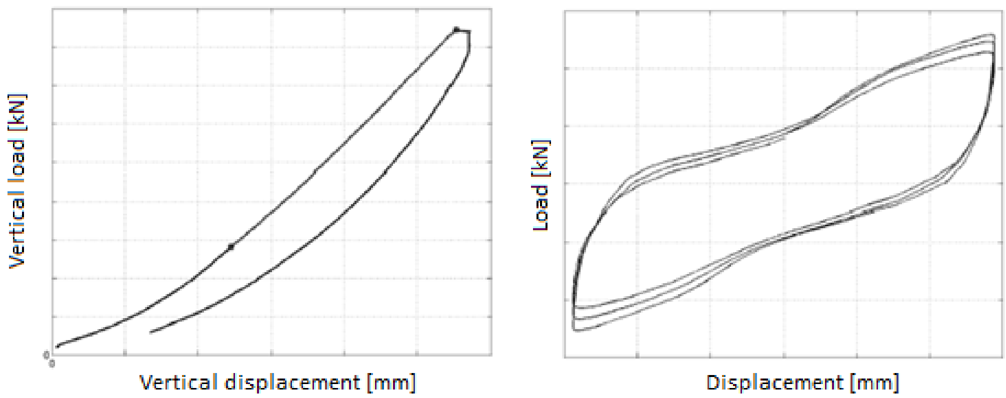

Figure 4. Diagrams of Compression test (left) and Horizontal Cyclic Test (right).

3 APPLICATION DETAILS

The strengthening project consists of strengthening the foundation and base floor columns and the isolator installation. The application starts with removing the concrete cover at all columns at foundation level. Then, the foundation is excavated in order to construct the new mat foundation, which will form a rigid base. The works on the foundation level and columns are presented in Figure 5.

Figure 5. Process on foundation and columns.

After strengthening of columns and pouring of the new mat, the next stage is the installation of the isolators. For the installation, first, the column cutting sequence is determined and checked by the designer. The cutting sequence is an important subject, due to possible differential settlements between the isolators. It may also affect the building stability creating torsion on the global system.

For placing of the isolators in an existing structure, the special installation system named as the "clamp system" is used. The clamp system is shown in Figure 6.

Figure 6. Clamp system.

The jacks are used between the lower and upper supporting system to provide the load transfer between the column parts. The load transfer scheme during installation stage is shown in Figure 7. Before stressing the jacks, displacement-measuring gauges are placed to upper and lower elements to measure the vertical deflection during the installation operation.

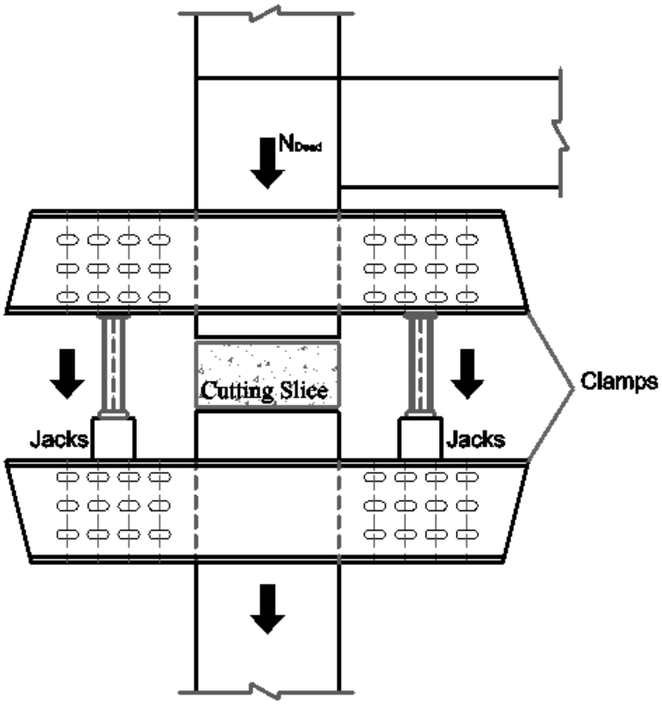

Figure 7. Load transfer scheme during installation.

After stressing the jacks, the column is cut as a slice using special machine, then the cut slice is removed to install the isolator. The stability of the clamp systems is monitored along the cutting operation. The isolator is installed using levelling mortar at the lower and upper connections. When the grout hardens, the jacks are unloaded. This procedure is applied to every vertical element according to the cutting sequence. At the end of the cutting stage, the vertical deflections of all columns are examined within the tolerances in order to verify the application and finalize the installation. The installed isolator is shown in Figure 8. All isolators are installed approximately within 60 days with one team working.

Figure 8. Installed isolator.

4 CONCLUSION

This paper summarizes the design details of the global system, the isolator tests, and installation details of the first isolated existing residential building in Istanbul. Using the isolation system, strengthening is only applied to the foundation and base floor columns. The system is not intrusive and does not require any structural modifications on the upper levels. The tenants can use the apartment during construction. Compared with conventional retrofitting, the base isolation system has proved to be a safe, fast and economic solution in seismic areas. In addition, it is non-intrusive for the upper levels of the existing building.

5 REFERENCES

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