Journal of World Architecture

Review Article

Restoration of an Ottoman Historical Building in Istanbul

Vail Karakale

Department of Civil Engineering, Faculty of Engineering, Marmara University, Goztepe Kampusu, Kadikoy, 34722 Istanbul, Turkey

Abstract: Preservation of historical buildings is an important issue to save our cultural heritage is both a record of life and history. In recent years, the Turkish government starts urban transformation projects that include renewal and restoration of some historical buildings belongs to the Ottoman period. This paper presents the details of a restoration project of a historical building in Istanbul. The selected restoration and strengthening technique aim to save the original architectural fabric of the building that has been changed among the past decades. The building is used as a chest diseases clinic in Istanbul University hospital. The building was built at the late Ottoman period and composed of four building blocks. The structural system of the buildings is mainly unreinforced masonry walls. Seismic performance analysis results of the building before and after the proposed restoration scheme indicated that the resorted building is able to withstand future earthquakes safely.

Keywords: *restoration; historical buildings; architectural fabric; heritage; seismic*

Publication date: January 2018

Publication online: 31st January 2018

Corresponding Author: Vail Karakale, vail.karakale@marmara.edu.tr

0 Introduction

Urban renewal has always been among the priorities of urban agenda in Turkey, especially after the 1999 Marmara earthquake. In recent years, the Turkish government starts urban transformation projects that include renewal and restoration of some historical buildings belongs to the Ottoman period. People have always had the need to refer to their history to ensure the continuity of a common identity that evolves over time. Heritage is a collective property which tells the history of a people, a city, or a territory, and is transmitted from one generation to the next. In this paper, one of the Turkish government projects to save heritages is presented. In this project, a clinic historical building at Istanbul University hospital is restored to save its original architectural fabric. In the period of 1960–1980 due to unplanned modernization, the building suffers some changes by adding additional story and remove of its domes. The original historical photograph and current photograph of the building are shown in Figure 1a and b, respectively. It is clear from the photographs that the building loss it original architectural fabric. The aim of the project is to get back the building to its originality and to strength it if needed to withstand future earthquakes. The following sections show the details of building description, material tests, restoration technique, seismic performance analysis results, and drawing details.

1 Building architectural plans and restoration project

The building consists of blocks named A, B, and C, respectively, as it is shown in Figure 2c. Block A in its current situation consists of basement floor, ground floor, and upper 2 typical floors, block B is one story less than block A and block C is a corridor block that connects block A and B. The building built in the late Ottoman period; each story is about 3.9 m clear height and total plan area of the building is 1467 m^2. In the period of 1960–1980 due to unplanned modernization, the building suffers some changes by adding additional story and remove of its domes. The original architectural plans and elevation views were prepared in this research project and presented in Figure 2.

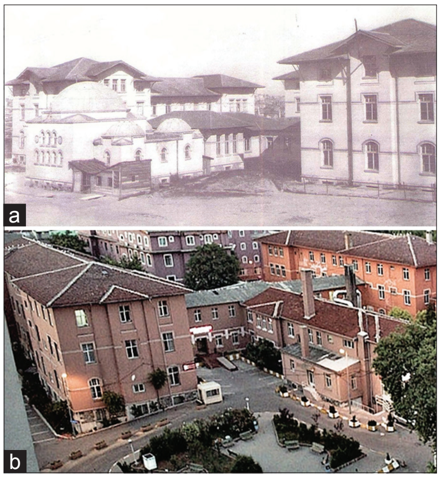

Figure 1. Photographs show changes of the original architectural fabric (a) old photograph of the case study building in 1920 and (b) recent photograph of the case study building

The aim of the restoration project is to get back the building to its original architectural fabric by removing one story from blocks A and B and adding domes to block B. Furthermore, to save building blocks from future earthquakes it is proposed to separate the building blocks from each other by expansion joints. Separating the blocks will ensure that each block will behave separately and will not effect by the other blocks behavior during future earthquake shakings. It is also proposed to strengthen the corridor block C by installing steel frames from inside. The frame's new footings were rigidly connected to the existing building foundation using epoxy anchored bolts. At each story level, the beams of the frames were rigidly connected to the existing floor slabs by shear connectors as shown in Figure 3a. The frames do not have any connection with the unreinforced masonry (URM) bearing walls, and they are in parallel to the peripheral bearing walls from the interior side. The dimensions, cross-sections, and connection details of one of these frames are presented in Figure 3b and c. In addition to the parallel steel frames, some of the URM walls were strengthened by repointing technique.

2 Material tests and earthquake hazard

Tests were conducted *in situ* and the laboratory to determine the material properties of the building walls. Three *in situ* tests were conducted on specimens at ground floor, first floor, and second-floor walls to determine mortar joint shear strength of the walls.

Tests were conducted according to American society for testing and materials (ASTM) C1531-09 standard using methods B (ASTM C1531 – 09, 2009)[1]. Loads were applied *in situ* to each test specimen using a hydraulic jack, and at each load, step displacements were measured and recorded using a data acquisition system as shown in Figure 4a. Using test results and the formulations in ASTM C153-09 standard, the average mortar joint shear strength of the walls was calculated and equal to 0.55 MPa. Furthermore, one wall specimen was sampled from the building ground floor and tested in the laboratory under axial compression. The test was conducted according to ACI 530.1 standard as shown by the testing setup presented in Figure 4b. Test results indicated that the compressive strength of the wall specimen was 9.3 MPa and the modulus of elasticity was about 520 MPa. Soil boring and laboratory tests were conducted to determine the geotechnical soil properties at the building site. From these tests, the allowable bearing strength was 1.6 kg/cm^2 and the soil type according to Turkish Earthquake Resistant Design Code (TERDC) (TERDC, 2007) was Z3[2]. According to soil properties, deterministic seismic hazard assessment was conducted to determine the spatial distribution of the design basis earthquake ground motion for the site that would result from a deterministic (scenario) earthquake. The 5%-damped elastic response spectrum was obtained and plotted in Figure 5.

3 Seismic performance evaluation

The existing structural system of the case study building consists mainly of URM bearing walls. This system was mainly designed to carry gravity loads only. To predict analytically the seismic performance of the building before restoration project, a finite element (FE) model was established using ETABS software[3]. In this model, shell elements were selected for modeling of the URM bearing walls, and floor slabs. Beams and columns were modeled as frame elements. A three-dimensional view of the model before restoration project is shown in Figure 2c. The live loads on the slabs were taken in accordance with the Turkish design loads code (TS498, 1997)[4]. Material properties of elements were defined according to the test results obtained in Section 3. Static linear analysis, modal analysis, and response spectrum analysis were performed. The results of the modal analysis showed that first mode period of block A and B before restoration project was 0.47 s and 0.33 s, respectively, as shown in Figure 6a and 6c, respectively. In response spectrum analysis, the spectrum function given in Figure 5 was used. The structure was analyzed

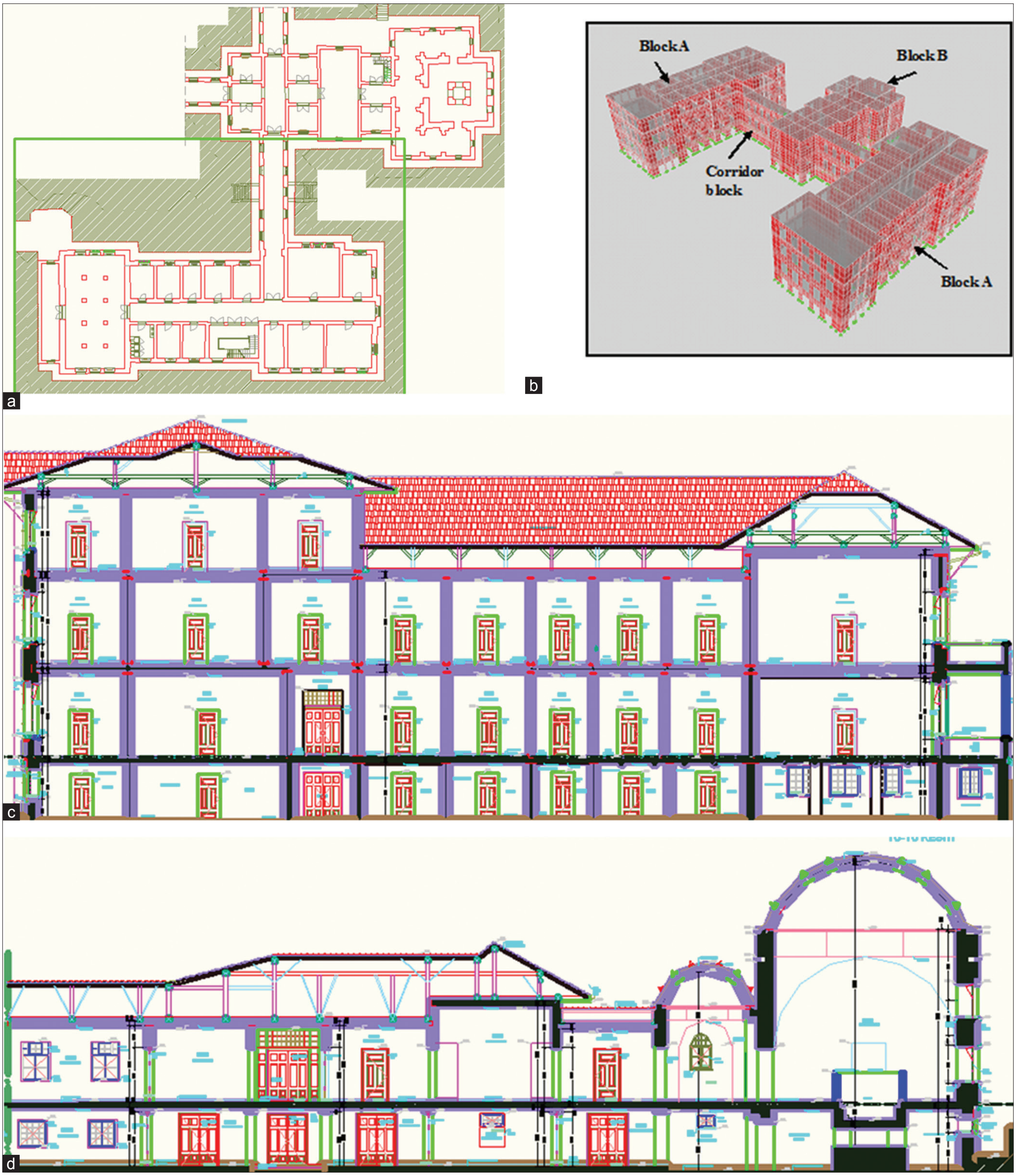

Figure 2. Plane and cross-section details (a) plan view, (b) three-dimensional finite element model before restoration, (c) cross-section of block A in the proposed restoration, (d) cross-section of block B in the proposed restoration

under a load combination of response spectrum load cases and gravity load cases, as specified in the Turkish earthquake code TERDC 2007.

According to TERDC-2007 code, a building importance factor 1.5 and an earthquake load reduction factor R = 2 are used in the analysis. The performance assessment includes a study of maximum internal forces and stresses in several structural elements and then the results are compared with the strength values of the materials. Some of the analysis results are shown in Figure 7a. Figure 7a

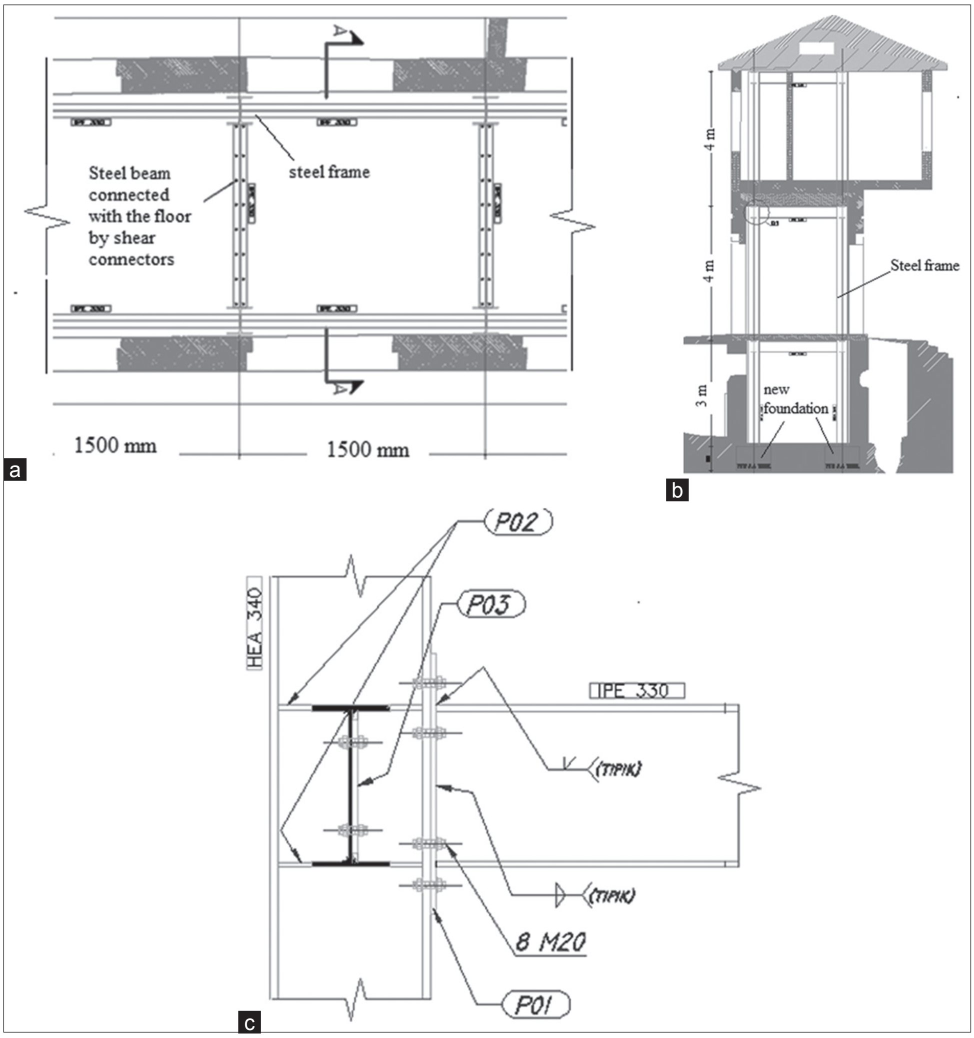

Figure 3. Details of the steel frame used in strengthening the corridor block (a) plan view shows the steel frame used to strengthen the corridor block, (b) section A-A, (c) steel beam-column connection details

shows the shear stress distribution in block B basement floor walls under the effect of vertical and lateral loads in Y direction. From Figure 7a, it is observed that the maximum shear stress in the walls exceeds the mortar joint shear strength capacity. Hence, the building needs a restoration project. In the restoration project, to get back the building to its original architectural fabric, one story from blocks A and B was removed, and domes were added to block B. As a result, the total mass of the building was reduced. Furthermore, building blocks A and B were separated from the corridor block C by expansion joints. Moreover, the corridor block C was strengthened using steel frames[5-7]. The frames were designed to withstand most of the seismic forces acting on block C. The FE model of the existing building was modified to form the building model after restoration, as shown in Figure 6b. Linear static modal, response, and spectrum analysis were performed on the strengthened model using the same load values and load combinations used for the non-strengthened model. The results of the modal analysis showed that the first mode period of block A and B after restoration project was 0.36 s and 0.21 s, respectively, as shown in Figure 6b and 6d, respectively. Furthermore, the maximum shear stresses in the URM walls were less than the allowable shear stress limits, as shown in Figure 6b. It can be observed from Figure 6 that the maximum shear stresses in the walls reduced by 40% after the restoration project. Hence, the building after restoration is able to withstand future earthquake loads safely.

4 Conclusions

Historic buildings and monuments are an important part of our cultural heritage that must be protected, and their sustainability ensured, especially when earthquakes occur. The restoration project proposed in this research was successful in saving the original architectural fabric

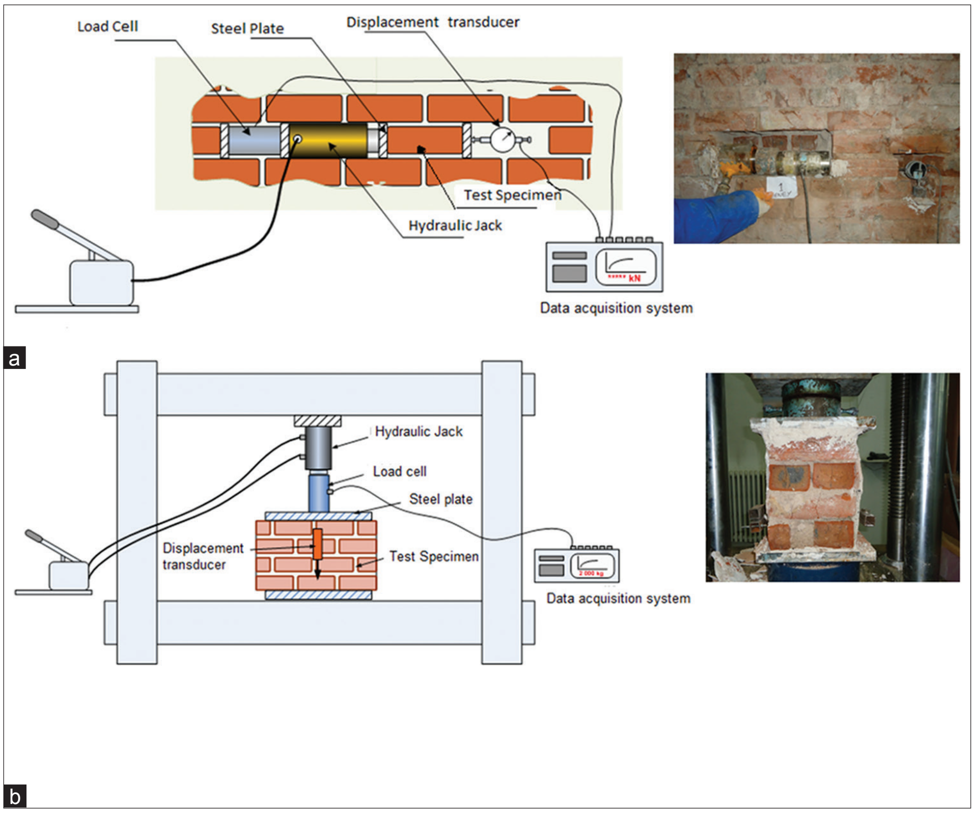

Figure 4. Laboratory and in site material tests (a) *in situ* shear test setup and (b) compression test

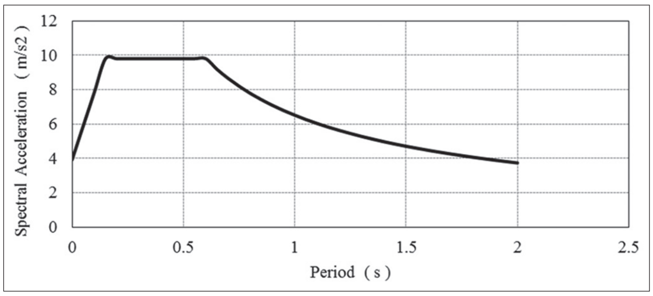

Figure 5. Design response spectrum

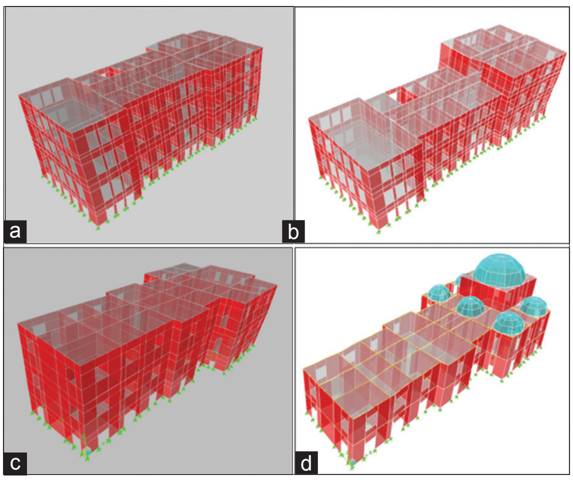

Figure 6. First mode and natural periods before and after restorations (a) block A before restoration T = 0.47 s, (b) block A after restoration T = 0.36 s, (c) block B before restoration T = 0.33 s, (d) block B after restoration T = 0.21 s

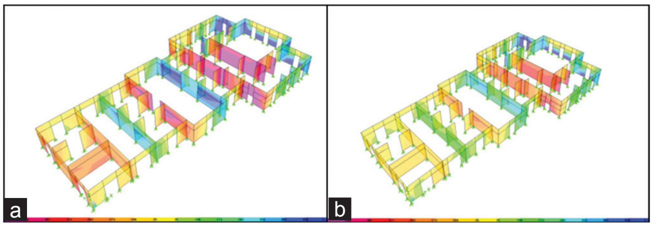

Figure 7. Shear stresses at the basement floor before and after restoration (a) before restoration and (b) after restoration

of the case study historical building and enhances its seismic performance. Seismic performance analysis results show that the building natural period reduced from 0.47 s to 36 s after restoration. This is due to the reduction of the building mass after restoration due to the removal of upper story floors. Reduction of building mass reduces the seismic loads on the building. Separation of the building blocks by expansion joints enhance the seismic performance of the building and guarantee that each block will response alone during earthquake and will not be affected by the other blocks. Furthermore, the proposed parallel steel frames to strength block C was able to carry most the seismic forces that effect block C and as a result reduces the shear stress on the masonry walls. The proposed technique depends on the perfect fitting of the steel frames to the floor slabs and the existing building foundation. Finally, results show that maximum shear stresses in the walls reduced by 40% after the restoration project.

Acknowledgments

The author would like to thank Dr. Omer Ulker for his help during the finite element method stage. Material tests were carried out at ITU University Laboratory, and their contribution is acknowledged.

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