DEUISGR23

Full Text Proceedings of

Dokuz Eylül University

INTERNATIONAL SYMPOSIUM SERIES ON GRADUATE RESEARCHES 2023







Editors

Okan Fıstıkoğlu

Sadık Can Girgin

Ayşe Uğurcan Atmaca

March, 2024

www.deuisgr23.org

INCREMENTAL DYNAMIC ANALYSIS OF A SINGLE STOREY PRECAST CONCRETE BUILDING WITH DIFFERENT HEIGHTS

First Author: Cem Göksoy

Dokuz Eylül University, Graduate School of Natural and Applied Sciences, Structural Engineering,

İzmir, Turkey

goksoy.cem@ogr.deu.edu.tr

Second Author: Sadık Can Girgin

Assoc. Prof. Dr., Dokuz Eylül University

İzmir, Turkey

sadik.girgin@deu.edu.tr

Third Author: Vesile Hatun Akansel

Asst. Prof., Muğla Sıtkı Koçman University

Mugla, Turkey

vesileakansel@mu.edu.tr

ABSTRACT: In Turkey precast reinforced concrete structures are widely used as industrial and hangar structures. This type of structure is preferred because architectural types with wide spans and long heights can be built practically and quickly. The building height class (BHC) concept has been stipulated by Turkish Building Earthquake Code (TBEC, 2018) for various types of structural systems. Single-story buildings with pinned beam-column connections cannot be designed higher than 12 m according to TBEC-2018. In structures with beam-column connections, emulative at the top section and welded at the beam plate (MAB3) and Couplers (MAB4), design height restrictions are imposed depending on the earthquake design class of the structure. In a design made according to TBEC-2018, structural stiffness and carrying capacities are determined by drift ratio controls, period lower limit control, and, if the mode combining method is used, earthquake force magnification based on the equivalent earthquake force. In a single-story structure with pinned beam-column connections, the structural design is completed by increasing the earthquake effects directly calculated using these controls.

Keywords: building height class, pinned beam-column connections, precast reinforced concrete structures, TBEC-2018

1. INTRODUCTION

Precast reinforced concrete buildings are in demand because of their advantages in terms of low cost, high quality, and fast production. A large portion of the industrial buildings built in our country since the 90s consist of single-story precast reinforced concrete buildings with intermediate floors. In most prefabricated buildings with partial mezzanine floors, the force flow between the structural elements is provided by beam-column connections articulated at the roof level and moment-transferred at the mezzanine level. Nowadays, multi-story prefabricated reinforced concrete building applications have increased depending on the developed connection and element details that can transfer moment. Considering the development of earthquake regulations in our country over the last 20 years, important regulations have been made within the scope of the conditions regarding the design of precast reinforced concrete buildings. In the earthquake-resistant structural design of precast reinforced concrete buildings, a design based on strength is preferred in terms of engineering practice.

Structural system behavior coefficients, which are important parameters in design according to strength, are semi-empirical parameters that reflect many partial factors. Response coefficients can be calibrated experimentally or analytically but require engineering intuition to reflect construction practices (Fischinger et al., 2014). When the development of earthquake regulations in our country and in Europe (ABYBHY, 1998; DBYBHY, 2007; TBEC, 2018; EuroCode 8) regarding the calculation and design

of prefabricated reinforced concrete buildings is examined, it is seen that the beam-column connections must provide equivalence to the monolithic system in terms of strength and ductility and that their effects on system behavior are quite decisive in terms of different design parameters. ASCE 7-16 (ASCE, 2017) and FEMA P-2082 (BSSC, 2020) regulations in force in the USA also give structural system response coefficient, strength excess coefficient, and building height limits according to different seismicity categories and building carrier system type. In these regulations, carrier systems are specified not according to their connection types, but more generally, as medium-level prefabricated moment transfer systems and normal-level prefabricated moment transfer systems. No height limit is given for the normal-level prefabricated moment transfer system. For medium-level prefabricated moment transfer systems, it is determined to be 40 ft (12.2 m) for the first 3 highest seismicity levels. One of the important innovations in Turkey's Building Earthquake Regulation (TBDY, 2018) is the definition of Building Height Classes (BHC) that can be applied for moment-capable connection types compared with previous earthquake regulations (ABYBHY, 1998; DBYHY, 2007).

The scope of this study is to investigate the effect of building heights on seismic performance. An archetype was selected (Fig. 1) and designed for 3 different building heights (12m, 14m, 16m) according to regulations in TBEC-2018, except for BHC limitations. For showing seismic performance, incremental dynamic analysis is applied and the Maras earthquake records were selected.

2. SEISMIC DESIGN AND PERFORMANCE OF THE BUILDING

2.1 Force-Based Design

The seismic and vertical load parameters are shown in Table 1 and Table 2. Because the beam-column connections of the buildings are pinned, the R value is taken as 3 and the D value is 2. The response spectrum method was preferred in structural analysis. The subperiod control was made with Equation 1 in TBEC-2018 Section 4.7.3.4. According to the sub-period control, the base shear force of the structure was calculated using the corresponding pseudo-acceleration value in the elastic earthquake spectrum. This base shear force and the calculated by the response spectrum method were calculated using Equation 2 and β coefficient. Earthquake forces were increased by the calculated β coefficient. Relative story drifts were checked according to TBEC-2018 4.9.1.

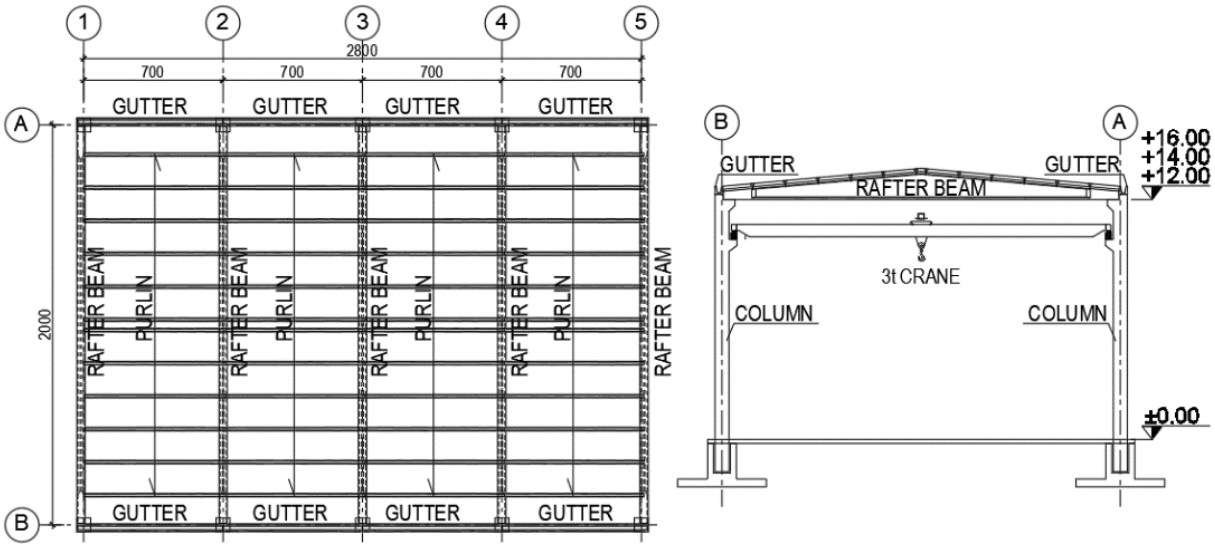


Figure 1. Plan and front view of the archetype

The seismic and vertical load parameters are shown in Table 1 and Table 2. Because the beam-column connections of the buildings are pinned, the R value is taken as 3 and the D value is 2. The response spectrum method was preferred in structural analysis. A period check was made with Equation 1 in TBEC-2018 Section 4.7.3.4. According to the sub-period control, the base shear force of the structure was calculated using the corresponding pseudo-acceleration value in the elastic earthquake spectrum. This base shear force and the calculated by the response spectrum method were calculated using Equation 2 and β coefficient. Earthquake forces were increased by the calculated β coefficient. Relative story drifts were checked according to TBEC-2018 4.9.1.

The three-dimensional SAP2000 (Wilson et. al, 2019) model of the structure is shown in Fig. 4. The diaphragm effect provided by the roof covering material was modeled using the equivalent truss method (Yuksel et. al, 2019). Columns are modeled with fiber-based elements with fibers that each have uniaxial concrete or steel material properties in a plastic hinge length (L_p=0.5h) in TBEC-2018.

Table 1. Seismic parameters for designing archetypes

Spectrum Parameter	Pseudo-Acceleration
S_{ds} (DD2)	1,179
S_{d1} (DD2)	0,553
S_{ds} (DD3)	0,626
S_{d1} (DD3)	0,249

Table 2. Vertical loads for the design of archetypes.

Load Type	Value
Roof Load	15 kg/m^2
Solar Polar Load	15 kg/m^2
Snow Load	75 kg/m^2
Crene Capacity	3 t

$$T_{pA} = C_t H_N^{3/4} \quad (1)$$

$$\beta_{tE}^{(X)} = \frac{\gamma_E V_{tE}^{(X)}}{V_{tx}^{(X)}} \geq 1 \quad (2)$$

According to these parameters for design, the column sections are shown in figure 2.

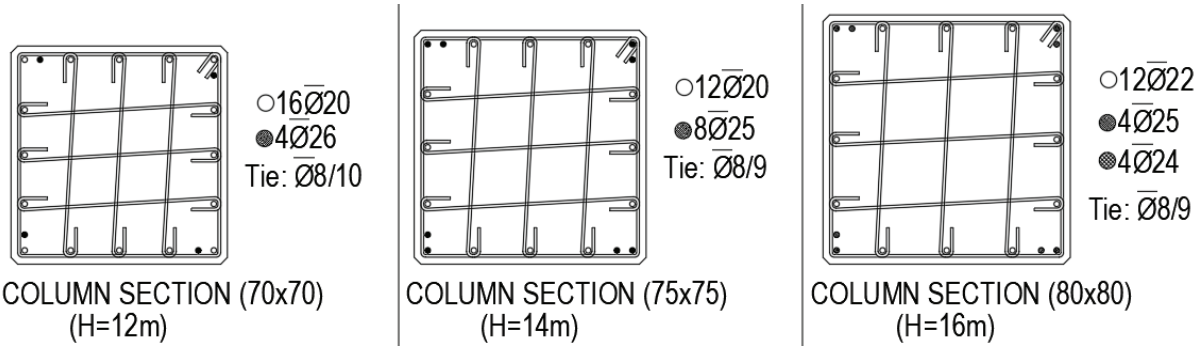


Figure 2. Column sections of the buildings

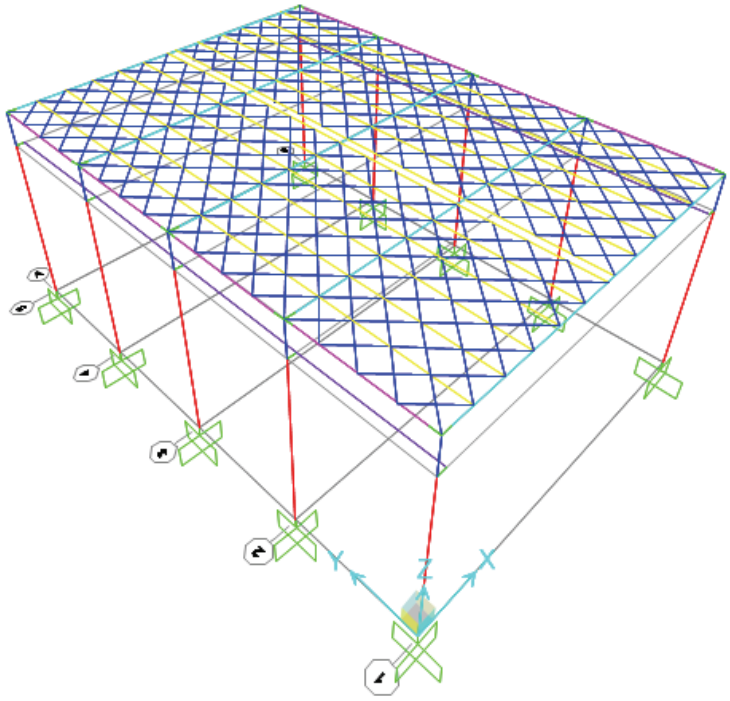


Figure 3. Structural model of the precast building

2.2 Incremental Dynamic Analysis

Spectral acceleration values corresponding to the period of the relevant direction of the structure were determined from the spectrum curves of the two components of the earthquake records on the horizontal axis. These spectral accelerations are scaled by an incrementally positive number in the range of 0.05g and 1.5g (Altınok et. al., 2020). The Maras and Samos earthquake records were used in the analysis for this paper, and their spectrum graphs are shown in figure 5. Due to the calculation method of increment level of IDA, scale factors for each step are calculated.

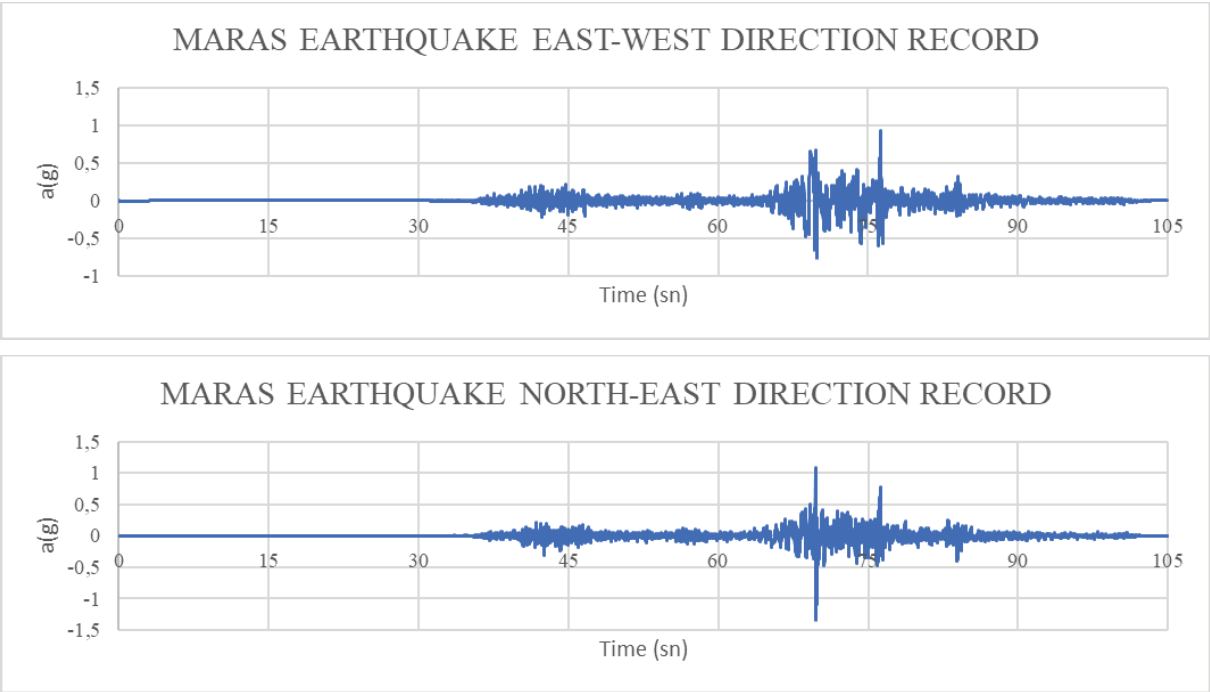


Figure 4. Maras earthquake records

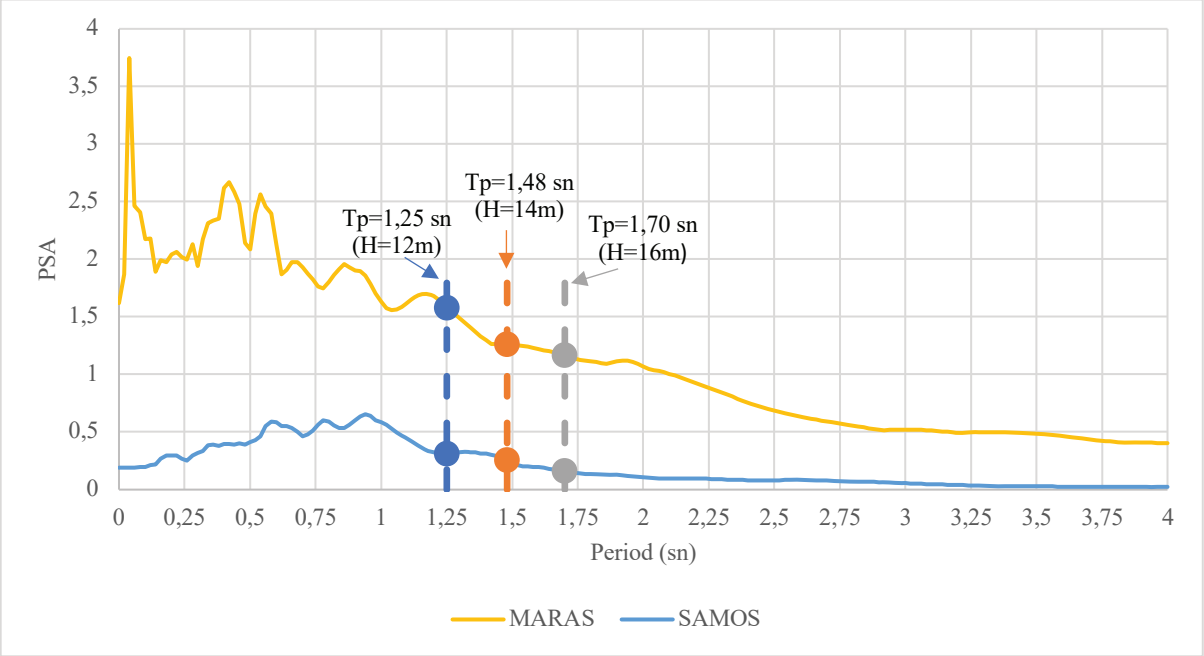


Figure 5. PSA spectrum of earthquakes and the PSA corresponding building periods.

3. RESULTS AND CONCLUSIONS

In this study, we investigated the cyclic performance of single-storey precast concrete buildings with pinned beam–column connections. The Turkish Earthquake Code (TBEC, 2018) stipulates building height limits for precast concrete buildings with pinned connections with 12m height. For this purpose, various heights, such as 12 m, 14 m, and 16 m, were designed, and numerical analysis models were constructed in the SAP 2000 program. The IDA analysis shown in the figure was performed for the records of the Maraş earthquake. IDA graphs performed on 3 buildings with heights of 12, 14, and 16m are shown in Figures 6 and 7 and 8.

According to the analysis results, the collapse performance point of the 12m-high structure was calculated as 1.20g, the 14m-high structure was 0.85g, and the 16 m-high structure was 1.05g (Fig. 8). Also, moment/yield moment ratio–rotation relationships are shown in Figure 7, and it is obvious that as the height increases, the plastic rotation capacity does not exhibit degradation. 16m height building has the most displacement capacity. Behavior of 12m and 14m buildings be

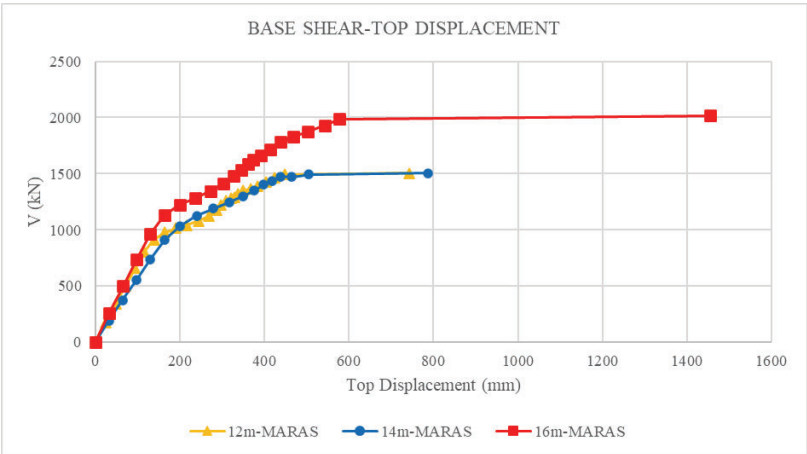


Figure 6. Base shear-top displacement relationship according to IDA results using the Maras earthquake

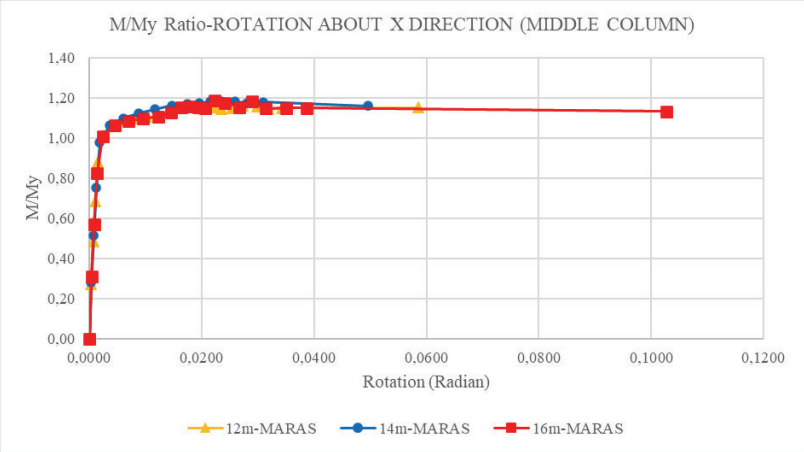


Figure 7. Moment– rotation relationship of the middle column according to IDA results using Maras earthquake

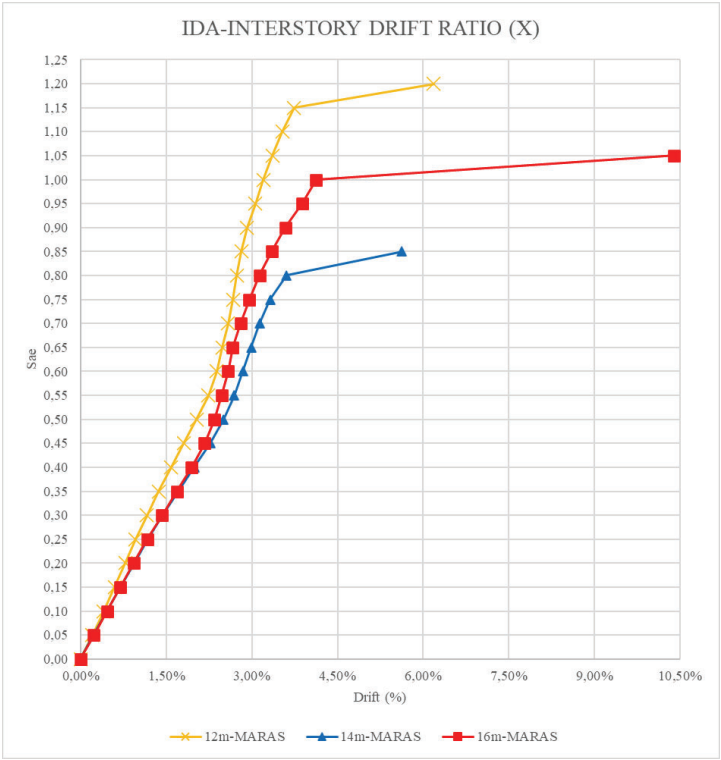


Figure 8. Drift ratio/S_{ae} relationship according to IDA results

According to the incremental dynamic analysis results, building height limits do not have a significant effect on the seismic behavior of the precast building with pinned connections. However, further numerical studies will also be conducted to account for different spans, beam–column connection types, and reinforcing bar ratios for structural elements.

REFERENCES

Altınok, M. A, (2020). Use of fragility curves for evaluation of different seismic retrofitting techniques applicable to substandard structures

ASCE7-16. (2017). Minimum Design Loads and Associated Criteria for Buildings and Other Structures in Seismic Design Requirements for Building Structures: Structural Engineering Institute (pp. 89-121). Retrieved from https://ascelibrary.org/doi/book/10.1061/9780784414248

Building Seismic Safety Council (BSSC) (2020) NEHRP Recommended Seismic Provisions for New Buildings and Other Structures, Volume I: Part 1 Provisions, Part 2 Commentary. FEMA P-2082- 1. Washington, DC: Federal Emergency Management Agency

CEN, European Committee for Standardisation TC250/SC8/ [2003] Eurocode 8: Design Provisions for Earthquake Resistance of Structures, Part 1.1: General rules, seismic actions and rules for buildings, PrEN1998-1

Fischinger, M., Zoubek, B., & Isaković, T. (2014). Seismic response of precast industrial buildings. Perspectives on European Earthquake Engineering and Seismology: Volume 1, 131-177.

TBEC 2018: Turkish Building Earthquake Code. (2018). T.C. Resmi Gazete. Ankara, Türkiye.

Wilson EL, Habibullah A (2019) SAP 2000 Software, Version V20.2.0. Computer and Structures, Inc. (CSI), Berkeley.

Yüksel E, Özkaynak H, Soydan C, Güllü A (2019) In-plane behavior of sandwich panels and their contribution to roof diaphragm stiffness, Precast Concrete Journal, Turkish Precast Concrete Association 129:5-13 (in Turkish).