International Journal of Architectural, Civil and Construction Sciences
ISSN: 2415-1734
Vol:13, No:8, 2019

Application of Seismic Isolators in Kutahya City Hospital Project Utilizing Double Friction Pendulum Type Devices

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Abstract**—**Seismic isolators have been utilized around the world to protect the structures, nonstructural components and contents from the damaging effects of earthquakes. In Structural Engineering, seismic isolation is used for protecting buildings and its vibration-sensitive contents from earthquakes. Seismic isolation is a passive control system that lowers effective earthquake forces by utilizing flexible bearings. One of the most significant isolation systems is seismic isolators. In this paper, double pendulum type Teflon coated seismic isolators utilized in a city hospital project by Guris Construction and Engineering Co. Inc, located in Kutahya, Turkey, have been investigated. Totally, 498 seismic isolators were applied in the project. These isolators are double friction pendulum type seismic isolation devices. The review of current practices is also examined in this study. The focus of this study is related to the application of passive seismic isolation systems for buildings as practiced in Kutahya City Hospital Project. Based on the study, the acceleration at the top floor will be 0.18 g and it will decrease 0.01 g in every floor. Therefore, seismic isolators are very important for buildings located in earthquake zones.

Keywords**—**Maximum considered earthquake, moment resisting frame, seismic isolator, seismic design.

I. Introduction

SEISMIC isolators are utilized to shift the fundamental natural period of a structure to the long period range, e.g., two of four seconds, by pointing horizontally adjustable seismic isolation devices at the base of the construction to physically apply it from the ground. The application translates into reduced floor acceleration and physical possibility demands on the superstructure by comparison to the corresponding non-isolated structure. According to Gordon et al., reduced demands diminish the possibility of damage to displacement acceleration sensitive equipment, nonstructural components and contents [1]. The approach of seismic isolation system was considered more than 100 years and it has only been practiced in the United States for 30 years. The first seismic isolation system with patent file was recorded in San Francisco for a double concave rolling ball bearing called “Earthquake-proof building” in 1870 [2], [3]. There are different isolator types utilized in the sector. Some researchers and scholars have studied these isolator types. Luis Andrade and John Tuxworth compared the lead rubber bearings and friction pendulum bearings for a five-story RC-framed building in 2002. The results of fixed structure and isolated type are compared for dynamic analysis to actual historical records for five important seismic events, namely, the 1940 and 1979 Imperial Valley Earthquake, 1989 Loma Prieta Earthquake, 1994 Northridge Earthquake and 1995 Aigion Earthquake [4]. The effects of two different types of seismic isolators, which are the lead-rubber isolator and friction pendulum isolator, have been studied by Kalantari in 2008. He investigated the decrease of base shear and story shears of a structure. According to his results, lead rubber bearings increase the displacements in low-rise buildings. Moreover, their effects become insignificant while the height of building increases [5]. Torunbalci and Ozpalanlar have studied six story symmetric structure with five seismic protection alternatives such as rubber bearings, friction pendulum bearings, fixed base, additional isolated story and viscous dampers [6]. With using finite element computer program SAP2000, Chandak has compared reinforced concrete building with fixed and isolated base with rubber bearings and friction isolators utilizing response spectrum method [7]. Ashish R. Akhare and Tejas R. Wankhade studied regular G+12 story reinforced concrete hospital building and non-linear time history analyses using SAP2000 in 2014. They also compared the effects of high density rubber bearings and friction pendulum systems. According to them, base shear is effectively reduced in the case of isolated buildings with a friction pendulum system building having the lower value [8]. Donato Cancellara and colleagues investigated high damping rubber bearing (HDRB) and lead rubber bearing (LRB) with friction slider. They also studied the seismic behavior of irregular buildings with two different types of passive base isolation systems with friction slider. According to the results, LRB isolators show a greater dissipative capacity compared to HDRB isolators. Furthermore, LRB isolators have more robustness and stability of their hysteretic cycles when compared to the same cycles of HDRB isolators [9].

In this study, double pendulum type Teflon coated seismic isolators utilized in the Kutahya City Hospital Project have been applied by Guris Construction and Engineering Co Inc., which also built Turkey’s first building with seismic isolator at Kocaeli Hospital Project in 2005. Kutahya City is located in the west part of Turkey, which has the population of 248,000 people. The elevation of the city is around 950 meters above sea level. The Kutahya City Hospital project is the biggest, in terms of the level of investment and floor area in comparison

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with the other hospitals located in the region. Totally, 498 seismic isolators have been applied together with a moment-resisting frame system in Kutahya City Hospital Project. The project consists of three buildings, such as twin L-shaped buildings and third building in the middle, connecting both buildings as shown in Fig 1. Twin buildings T1 and T2 have 150 seismic isolators each, while the MC building has 198 seismic isolators.

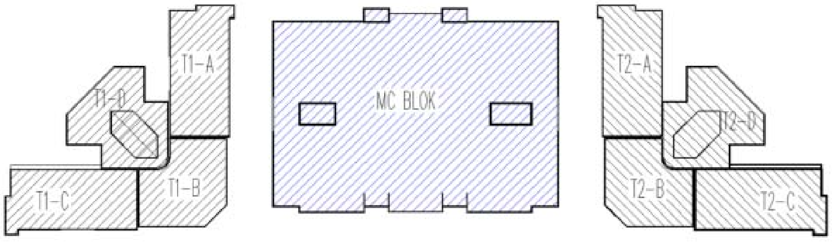


Fig. 1 Plan view of Kutahya City Hospital Project

II. Benefits of Seismic Isolators

Seismic isolators have proven benefits for buildings. Seismic isolators reduce the deflection and acceleration of the floors. While comparing the buildings without seismic isolators, buildings with seismic isolators will have less deflection starting above the isolator level through the top floor. This allows buildings to safely react to earthquake. Seismic isolators are necessary for buildings located in earthquake zones and especially for high-rise buildings, museums and hospitals.

Kutahya City Hospital Project has seismic isolator requirement, for two main reasons; first it is located in a 2nd degree earthquake zone and secondly, operation rooms in the hospital are required to remain in service during an earthquake. For that reason, the seismic isolators are located at the garage level. The acceleration and displacement of the hospital buildings are calculated to have minimum effect on the top floor during an earthquake.

The feasibility study showed that on the top floor, there would be 0.80 g acceleration if it was a building without seismic isolators in the case of maximum considered earthquake (MCE). MCE occurs once every 2,475 years and the possibility of its happening in the next 50 years is 2%. The feasibility showed in the case of MCE lower bound of the displacement would be 558 mm.

TABLE I
Lower And upper Limit Analysis Results

MCE Lower Bound	Value	Unit
Friction Coefficient, μ:	0.038	_
Isolator Radius, R:	5000	mm
Isolator Displacement, D:	558	mm
Equivalent Damping Ratio, ξ:	16.20%	_
Spectrum Mod. Fac., B:	1.34	(Close Field)
Effective Period, T_{eff}:	3.87	Sec
0.8*Effective Period, $0.8T_{eff}$:	3.10	Sec

The chosen seismic isolator for this project has maximum displacement of 560 mm. According to the feasibility study, the acceleration at the top floor will be 0.18 g and it will decrease 0.01 g in every floor. Previous studies showed that the magnitude and distance of an earthquake will affect the effectiveness of the isolator. Fig. 2 shows the seismic isolators utilizing in Kutahya City Hospital project. In Fig. 2, the image on the left shows the seismic isolator from the top view with six wedges, while the image on the right reveals the bedding place of the isolator, in which the device is assembled in the bearing.

(a)

(b)

Fig. 2 Double friction pendulum type seismic isolator (a) and the bedding of the device (b) used in the project

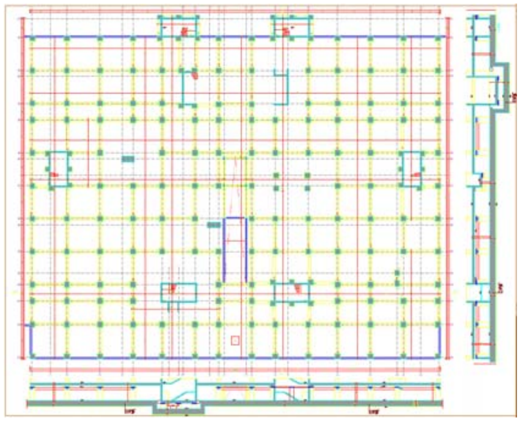
III. Application of Seismic Isolators in the Project

Seismic isolation systems are convenient methods for protecting buildings during the earthquakes. Seismic isolation technique is also an innovative and well-developed performance-increase strategy to reduce earthquake deformation on structures. When compared with Japan, the US and Italy, Turkey has limited experience in seismic isolation technology in terms of human resources. Guris Construction and Engineering Co. Inc. is the first company to use seismic isolators in a building as part of the Kocaeli City Hospital Project in Turkey. In the Kutahya City Hospital Project, the same seismic isolation technique is applied in the basement floor using a moment-resisting frame system.

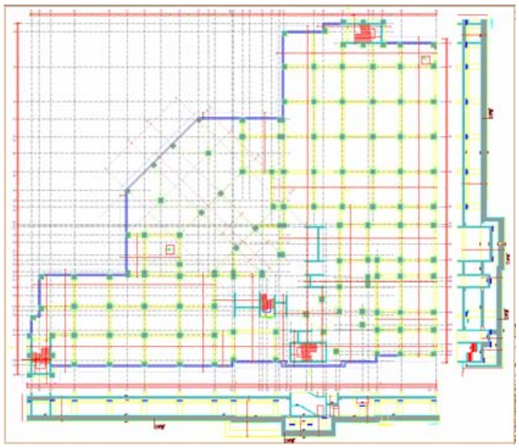
As can be seen in Table I, the friction coefficient μ is 0.038 and the isolator radius is 5 m. For safety reasons, the nominal dynamic friction coefficient μ is applied as 0.04. According to the calculations, the maximum isolator displacement value was found as 558 mm. The isolator displacement capacity was decided as 560 mm for the project. Environmental temperature is applied as 10°C in the calculation of specification changes due to the isolators' placement in the building. For the double pendulum type isolators, the λmax, for the upper limit is applied as 1.58, and for the lower limit is applied as 0.95 in the project. Moreover, the equivalent damping ratio is 16.20%, as seen in Table 1. Calculating these parameters based on the construction specifications is very significant in order to carry out the best application techniques in situ.

Fig. 3 Field application of the project

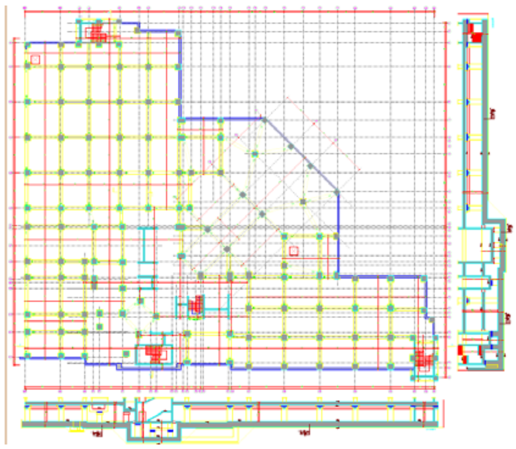
Fig. 3 shows the field application image of the Kutahya City Hospital Project. As it can be seen in the figure, the seismic isolators are applied on each column, which are required. The operation of the isolation technique should be advanced carefully, otherwise there can be no more chance to disassemble the devices from the columns after completing the Project. On the other hand, Fig. 4 shows the plan view of Kutahya City Hospital Project including the seismic isolator locations in the buildings. In addition to this plan view, Fig. 4(a) shows the plan view of MC building and Fig. 4(b) and Fig. 4(c) show the plan view of the T1 and T2 twin buildings in detail.



(a)



(b)



(c)

Fig. 4 Plan view of MC Building (a) and Twin Buildings T1 (b) and T2 (c) in the Kutahya City Hospital Project

Double friction pendulum type seismic isolators are heavyweight devices. Transportation of these isolators is also important during the applications. For that reason, tower cranes are utilized to carry these isolators as part of this hospital project. To summarize, utilization of seismic isolators in enormous projects needs to be well experienced because of the health and safety factors involved. Moreover, the initial cost of these devices is quite high. More importantly, there is limited opportunity to make adjustments or conduct maintenance once the devices are in place.

IV. Conclusion

Seismic isolation is an innovative technique used in buildings in the case of earthquakes, including maximum considered earthquake. Since, the seismic isolators reduce the acceleration and the deflection at every floor, it is necessary to use these devices for structures in earthquake zones. It is significant to use the correct seismic isolators depending on the specification of the building and location. In Kutahya City Hospital Project, due to the requirements, double pendulum type Teflon coated seismic isolators were applied. According to the feasibility study, acceleration at the top floor will be 0.18 g and it will decrease 0.01 g in every floor. The applied seismic isolator has a maximum deflection capacity of 560 mm. This study concludes that seismic isolators are important for inclusion in buildings located in earthquake zones.

Acknowledgment

The study was supported by the Guris Construction and Engineering Co. Inc., Turkey. The support is greatly acknowledged.

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