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A SEISMIC DESIGN OF NUCLEAR REACTOR BUILDING STRUCTURES APPLYING SEISMIC ISOLATION SYSTEM IN A HIGH SEISMICITY REGION –A FEASIBILITY CASE STUDY IN JAPAN-

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A feasibility study on the seismic design of nuclear reactor buildings with application of a seismic isolation system is introduced. After the Hyogo-ken Nanbu earthquake in Japan of 1995, seismic isolation technologies have been widely employed for commercial buildings. Having become a mature technology, seismic isolation systems can be applied to NPP facilities in areas of high seismicity. Two reactor buildings are discussed, representing the PWR and BWR buildings in Japan, and the application of seismic isolation systems is discussed. The isolation system employing rubber bearings with a lead plug positioned (LRB) is examined. Through a series of seismic response analyses using the so-named standard design earthquake motions covering the design basis earthquake motions obtained for NPP sites in Japan, the responses of the seismic isolated reactor buildings are evaluated. It is revealed that for the building structures examined herein: (1) the responses of both isolated buildings and isolating LRBs fulfill the specified design criteria; (2) the responses obtained for the isolating LRBs first reach the ultimate condition when intensity of motion is 2.0 to 2.5 times as large as that of the design-basis; and (3) the responses of isolated reactor building fall below the range of the prescribed criteria.

KEYWORDS : Seismic Design, Seismic Safety, Nuclear Reactor Building, Seismic Isolation, Base Isolation, Lead Rubber Bearing, High Seismicity

1. INTRODUCTION

The seismic isolation technologies have been widely developed in the world and in Japan as well. In Japan, during the 1995 Hyogo-ken Nanbu earthquake hitting the city of Kobe, Hyogo-ken, the seismic isolation technology has been recognized as effective in obtaining seismic safety during strong ground excitation. A large number of commercial buildings have been designed and constructed utilizing seismic isolation systems. A wide variety of isolating systems have been developed. Application of seismic isolation systems was extended to nuclear power plant facilities after the 2007 Chuetsu-oki earthquake hitting the Kashiwazaki-Kariwa Nuclear Power Plant.

With the maturation of seismic isolation technology, a research program was initiated in Japan to develop the evaluation method for seismic isolation systems for nuclear power plant facilities. Within the national program entitled “Safety Enhancement for LWRs” supported by the Japanese Government, a research and development program on development for evaluation methods for seismic isolation systems has been carried out between the years from 2010 to 2012 for the first phase, and for the year of 2013 to 2014 for the second phase of the program. Within the R&D program, a feasibility study has been carried out upon the seismic design for nuclear reactor buildings with the application of seismic isolation systems [1, 2]. Two types of reactor buildings, PWR and BWR buildings, innovated for the application of seismic isolation systems, are taken into consideration. With this application of seismic isolation systems to nuclear power plant facilities, we can plan, design and construct safer nuclear power plant facilities on sites with high seismic activity, as in Japan, and higher cost-effective nuclear power plant facilities as well through standardization of design, determined independently based on variations in either seismic conditions or site conditions. Applying seismic isolation systems for nuclear power plant facilities on sites with high seismicity, significant reduction of seismic responses is expected during an intense ground motion, which leads to the standardization of design on nuclear power plant facilities possible and practical.

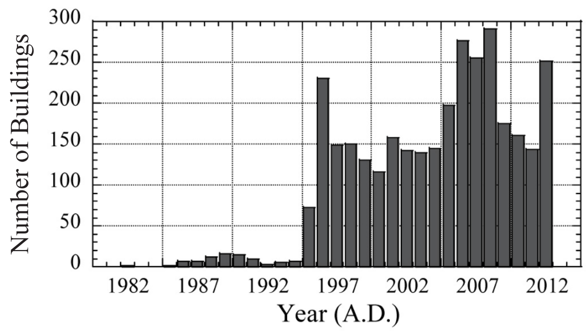

Fig. 1. The number of seismic isolated buildings constructed between years from 1982 to 2012. The first seismic isolated building in Japan was constructed in 1982. Note that the number of seismic isolated buildings increased after the year of 1995 when the Hyogo-ken Nanbu earthquake hit the city area of Kobe, Hyogo-ken, Japan.

2. DEVELOPMENT AND DIFFUSION OF SEISMIC ISOLATION TECHNOLOGY IN JAPAN

2.1 Seismic Isolation Technologies for Commercial Buildings

It was our first experience that seismic isolated buildings were subjected to real strong ground motions when the Hyogo-ken Nanbu earthquake hit Kobe on January 17, 1995 in Japan. The reported magnitude of the quake is 7.3, and the peak ground acceleration and ground velocity observed at the Kobe Meteorological Observatory Station were 0.85G and 1.1 m/s, respectively. Two buildings were located in northern Kobe to the heavily damaged area, one of which is a six-storied computer center building, and the other, a four-storied research center building. During the earthquake both seismic isolated buildings revealed good structural response behaviors. Within both buildings, accelerometers have been installed. The peak accelerations of the seismic isolated building on the horizontal components are significantly yielded less being around 1/5 to 1/2.5 times as large as those obtained in the non-isolated buildings closely located to the isolated buildings, while no response reduction was observed on the vertical components.

The evidence obtained during the 1995 Hyogo-ken Nanbu earthquake can be recognized that the innovated seismic isolation technologies have been found efficient, making seismic responses significantly less, producing no structural damage on building structures during an intense seismic action. It has been promoting the application of seismic isolated systems for buildings, for hospitals, for central and local government office buildings, for disaster emergency responses, high-rise buildings of high quality for either offices or condominiums. Figure 1 illustrates the number of seismic isolated buildings constructed in Japan between the years from 1982 to 2012 [3].

2.2 Seismic Isolation Technologies for Nuclear Power Plant Facilities

The M6.8 Niigata-ken Chuetsu-oki earthquake occurred on July 16, 2007 and hit the Kashiwazaki-Kariwa (KK) nuclear power plant station, Tokyo Electric Power Co. Ltd. (TEPCO). No serious structural damage for the reactor buildings was observed. It was reported that the two-storied administration office building, construction of which was a ductile steel frame, suffered damage in the non-structural components. The typical damage observed was the falling of ceiling panels in the building and tuning over of office cabinets, leading to the loss of essential functions which should have enabled it to be used as an emergency response center, as was intended.

With maturation of seismic isolation technologies developed for commercial buildings since the 1995 Hyogo-ken Nanbu earthquake, seismic isolation technologies have been applied to building structures on nuclear power plant sites as well as those used for new administration office buildings, auxiliary buildings for emergency response centers and others [4-6].

The efficiency of the seismic isolation technology was realized again during the 2011 Off the Pacific Coast of Tohoku Earthquake of March 11, 2011. A two-storied building was constructed with the application of seismic isolation technology in the year of 2010 on the site for the purpose of emergency responses from the lesson learned from the KK NPP station during the 2007 Niigata-ken Chuetsu-oki earthquake. The general configuration of the isolated building on the site is as follows [7]: (1) two-storied; (2) steel-reinforced concrete composite structure, (3) structural plan of 52.6 m by 40.6 m. The isolation system is composed of four types of device as follows: (1) natural rubber bearings (NRB) [10 units]; (2) lead-plug rubber bearings (LRB) [four units]; (3) sliding bearings [31 units]; and (4) oil dampers [16 units].