ON THE SEISMIC UPGRADING OF EXISTING BUILDING BY SEISMIC ISOLATION SYSTEM

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SUMMARY

Authors discussed the seismic upgrading of the TEKKEN Co's headquarters building in an urban area by a seismic isolation system. The ultimate horizontal resistant force of the building before upgrading was about 60% of the value required in the current building codes (the 1981 building standard low of Japan). For seismic upgrading and maintaining the functions of building against the recorded strong earthquakes, we studied the reduction of input seismic motions by an isolation system at the 1st basement. It was impossible to provide a sufficient horizontal clearance around this site. Therefore, the horizontal displacement of the isolated basement is limited to 400mm using Viscous Dampers in addition to High Damping Rubber Bearings and Natural Rubber Bearings. As the analytical results, we found that, by using also Viscous Dampers, a sufficient effect of the basement isolation can be achieved by limiting the displacement of the isolated basement.

INTRODUCTION

After the 1995 Hyogo-ken Nanbu earthquake, aseismic retrofit of the existing building which does not satisfy a quakeproof standard on the basis of current building standard codes (the 1981 building standard low of Japan) becomes an important social problem. As for aseismic retrofit of a building, methods of construction due to additional shear walls or braces, and vibration control techniques, but the application is limited to structures under construction.

Recently, in various aseismic retrofit methods, the basement seismic isolation system attracts the attention and has been applied to existing building. The proposed the TEEKEN Co's headquarters building was designed by old earthquake proofing standard and was completed in 1979. After calculation of the horizontal load-carrying capacity due to a current building code, it was almost about 60% of ultimate horizontal load-carrying capacity in all the stories. Therefor some aseismic retrofit to this building is required. In this paper we show the base isolation retrofitting method for seismic upgrading of existing building.

OUTLINE OF THE EXSITING BUILDING

As shown in Fig.1, the TEEKEN Co's headquarters building of ninth stories with one basement floor, three penthouse floors of steel frame and reinforced concrete composite floor with shear walls built in the moment resisting frames. The diagram also shows the vertical view and the building scale of height of 31.01m, a maximum height of 41.18m. As the plane view in Fig.2,

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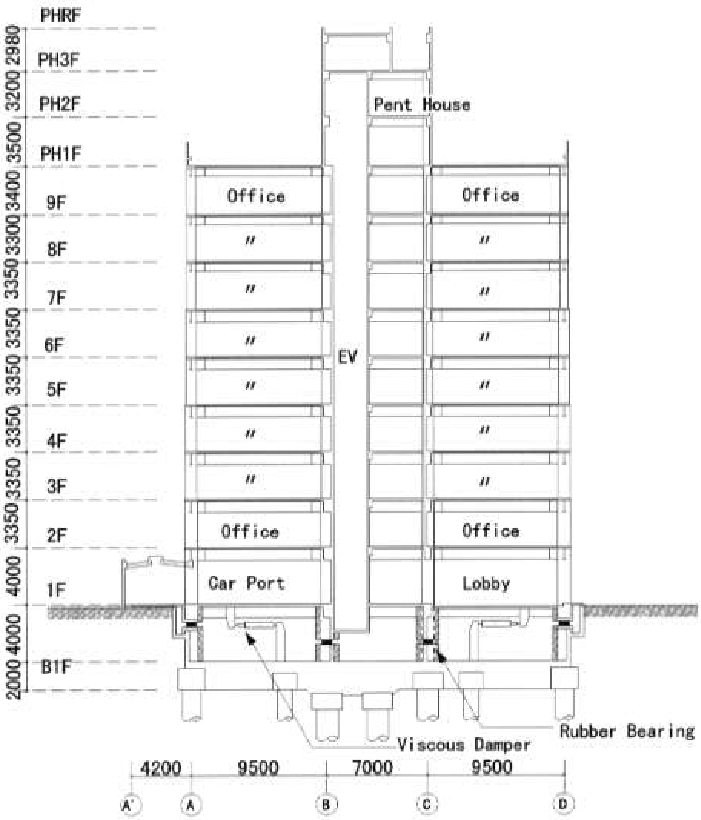
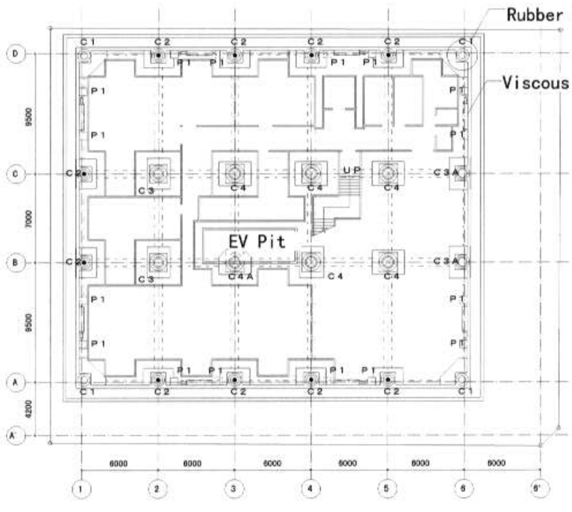


Figure 1: Vertical view of the TEKKEN Co's headquarters building



Sign	Diameter of Basement	Types	Number
C4, C4A	1400φ	◎Natural Rubber 1000φ	6
C3	1300φ	○Natural Rubber 900φ	2
C3A	1300φ	○High Damping Rubber 900φ	2
C2	1200φ	◉High Damping Rubber 800φ	10
C1	1100φ	□High Damping Rubber 700φ	4
		Total Number	24

Figure 2: Plan view of the TEKKEN Co's headquarters building

the shape of cross section is the rectangular of the longer side of 30.55m in 5 spans and the shorter of 26.55m in 3 spans. The first floor has the entrance of a colonnade to the second floor and parking space, and other space is for an office. The seismic isolator is set up at the first basement floor with a most little influence for use of a current building.

Table 1: performance of rubber bearing

Types		High Damping Rubber Bearing			Natural Rubber Bearing	
Diameter(mm)		700ϕ	800ϕ	900ϕ	900ϕ	1000ϕ
Horizontal Stiffness (kN/mm)	δ =100mm	190.25	245.17	312.83	152.00	184.37
	δ =200mm	129.45	167.69	212.80		
	δ =300mm	107.87	140.24	178.48		
Equivalent Damping Coefficient	δ =100mm	0.17	0.17	0.17	————	————
	δ =200mm	0.17	0.17	0.17		
	δ =300mm	0.15	0.15	0.17		
Vertical Stiffness(kN/mm)		209862.31	237320.93	334406.77	289296.18	368724.40

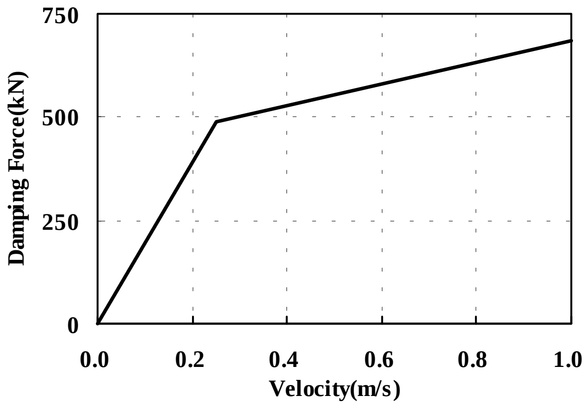


Figure 3: the characteristics of a viscous damper

SEISMIC ISOLATON PLAN OF EXISTING BUILDING

For the seismic isolation, every column and wall between the first and basement floors of the existing building are cut off and built in the base isolation system of various type passive dampers. In this case, the separation between a retaining wall and the building wall is limited to 500mm.

The selection of seismic isolator is very restricted, because the building is located in a urban area, the construction site is narrow, and movable allowance of equipment pipes is limited with 400mm. Therefore as the basement isolation system, we selected 24 High Damping Rubber Bearings and Natural Rubber Bearings of the low elasticity type (the diameter is 700mm to 1000 mm), and in addition 8 Viscous Dampers. The layout of the seismic isolator is shown in Fig. 2 and the performance is shown in Table 1. The characteristics of the Viscous Damper is proportional to the relative velocity where performance changes to 490kN(50tonf) for the relative velocity of 0.25m/s and maximally 686kN(70tonf) for 1.0m/s as shown in Fig. 3.

GROUND CONDITON AND INPUT EARTHQUAKE MOTION FOR DESIGN

The TEKKEN Co's headquarters building is located in Misaki-cho, Chiyoda-ku, Tokyo, Japan. The topography of the retrofitting site is low land of an alluvial deposits. The geological structure is backfill, clay, silt, fine sand, sandy gravel and fine sand layer downward from the ground level in which the geological columnar section and result of PS logging is shown in Fig.4.

The artificial earthquake for design, as the input earthquake motion, is considered of standard earthquakes (e.g., El Centro 1940 NS, Taft 1952 EW and Hachinohe 1968) satisfying the site conditions. Two of the artificial earthquakes are selected as the most destructive ones among the historical and hypothetical earthquakes at the site, that is, the 1923 Kanto earthquake of M_{JMA}=7.9 in JMA scale which we call here after the hypothetical Kanto earthquake and the 1885 Ansei-Edo earthquake which is considered from the fault model and magnitude of M_{JMA} =7.2 in JMA scale on the basis of the earthquake damage assumption report in Tokyo which we call here after the hypothetical Ansei-Edo earthquake [Tokyo metoroporitan,1997]. The other artificial earthquakes are BCJ-L1 and BCJ-L2 [The Building Center of Japan, 1992] as the incident waves from the engineering bedrock of the shear wave velocity Vs=400m/s, and generated as the wave from the earthquake response analysis of the surface layer using the program "SHAKE" [Schnable *et al.*, 1972], which we call here after the Misaki-Site-L1 and Misaki-Site-L2. The specifications of these proposed earthquakes are shown in Table 2.

DYNAMIC ANALYSIS

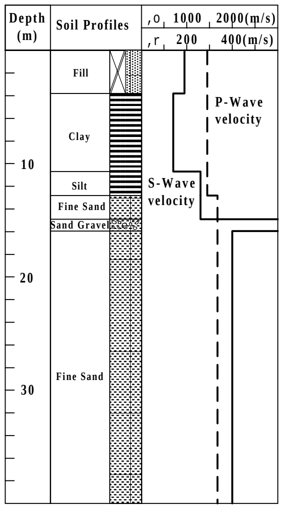


Figure 4: The geological columnar section and PS logging at the building site

Table 2: the input earthquake motions for design

Level	Level 1			Level 2		
	Amax(m/s/s)	Vmax(m/s)	Dmax(m)	Amax(m/s/s)	Vmax(m/s)	Dmax(m)
El Centro 1940 NS	2.55	0.25	0.07	5.11	0.50	0.13
Taft 1952 EW	2.49	0.25	0.06	4.76	0.50	0.12
Hachinohe 1968 NS	1.65	0.25	0.05	3.30	0.50	0.10
Hachinohe 1968 EW	1.28	0.25	0.06	2.55	0.50	0.12
Misaki-Site L1	3.40	0.36	0.15	------	------	------
Hypothetical Ansei-Edo earthquake	------	------	------	3.95	0.33	0.12
Hypothetical Kanto earthquake	------	------	------	5.03	0.41	0.17
Misaki-Site L2	------	------	------	6.19	0.71	0.30

The dynamic analysis of the building was executed for a nonlinear multiple mass model using the equivalent shear springs based on the result of static elasto-plastic analysis. The hysteresis characteristics of superstructure is of the degrading tri-linear model for each stories based on the results of the static elasto-plastic 2-dimensional frame analysis. The hysteresis characteristics of seismic isolators of the High Damping Rubber Bearings were modified into the bi-linear model to simulated the rubber deformation and the Natural Rubber Bearings are modeled linear model.

The damping characteristics of the superstructure is of elastic stiffness proportion type of the damping factor h=0.02 for the fundamental natural mode of the superstructure. Seismic isolators ignores the internal damping and considers hysteresis damping, in which the Viscous Damper is of the relative velocity proportion type (see Fig. 3) ; analytical additional damping due to Maxwell model.

Natural Period

First three Natural modes of the current building fixed at ground level are shown in Fig. 5 and the natural periods in Table 3. The fundamental natural periods are 0.41 second in X-direction (the longer direction) and 0.73

Table 3: natural periods and participation factors
(Ground level fixed model)

Direction		1st	2nd	3rd
X	Natural period (second)	0.409	0.161	0.097
	Participation factor	1.358	-0.499	-0.306
Y	Natural period (second)	0.730	0.272	0.163
	Participation factor	1.324	0.504	-0.332

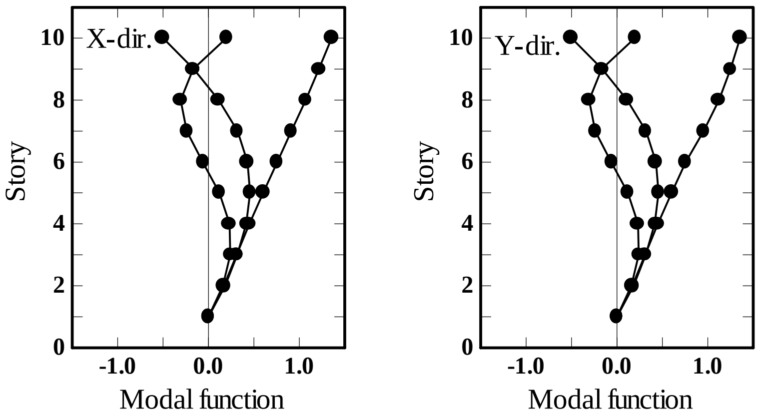


Figure 5: Modal function (ground fixed model)

Table 4: natural periods and participation factors

Direction		1st	2nd	3rd
X	Natural period (second)	3.316	0.266	0.135
	Participation factor	1.010	-0.012	-0.002
Y	Natural period (second)	3.349	0.483	0.233
	Participation factor	1.032	-0.037	-0.007

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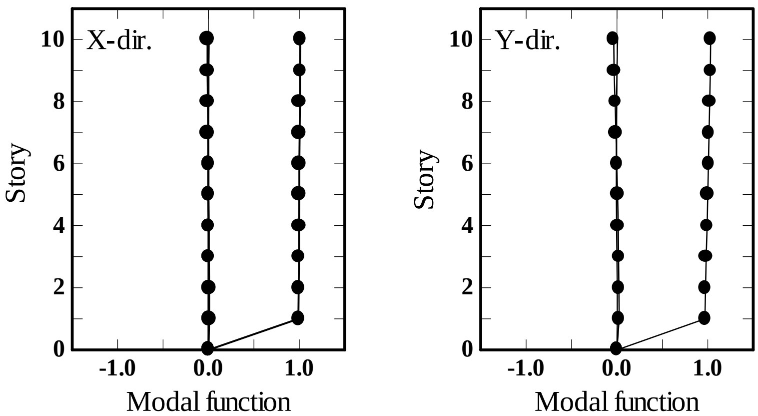

Figure 6: Modal function (base isolation model)

second in Y-direction (the shorter direction). It is understood that low-pass filter characteristics will appear strongly in Y-direction than in X-direction since the stiffness of Y-direction is fairly lower than X-direction.

Natural modes for the base isolated model in which the total thickness of rubbers of 320 mm allows strain of 200% is shown in Fig. 6 and the natural periods in Table 4. The fundamental natural periods for the base isolated model are about 3.3 second in each direction. The natural periods for the base isolated model is considerably larger than these of the ground level fixed model. From the modal functions of the base isolated model, the superstructure under consideration is idealized as a rigid block.

Time History Analysis

The followings are the investigations about the dynamic behaviors of the building as a seismic isolation system subjected to the most severe input motion for Misaki-Site-L2. The dynamic time history analyses is carried out for three cases; the ground level fixed model, the hybrid isolation model (High Damping Rubber Bearings + Natural Rubber Bearings + Viscous Dampers) and the single isolation model of High Damping Rubber Bearings.

Fig. 7 shows the distributions of maximum response acceleration for three analytical models. The ground level fixed model responds up to about 700 gal for each direction, but two isolation models remarkably reduces the acceleration response for each direction. The Y-direction of isolation models increases response from middle to top stories compared with X-direction. It is estimated that the higher modes would appear strongly in Y-direction than X-direction because the difference of the stiffness.

Fig. 8 shows the distributions of maximum relative story displacement for the ground level fixed model and the two base isolation models . It is noted that except for the first story, the relative story displacement of the ground level fixed model is about 50 mm (the story deformation angle is bout 1/160), and ones of isolated models are not recognized. However, for the first story, the displacement of the single isolation model of High Damping Rubber Bearings is over 400mm, which exceeds the design criterion for deformation. However, displacement of the proposed hybrid isolation system of about 350mm, is under the design criterion.

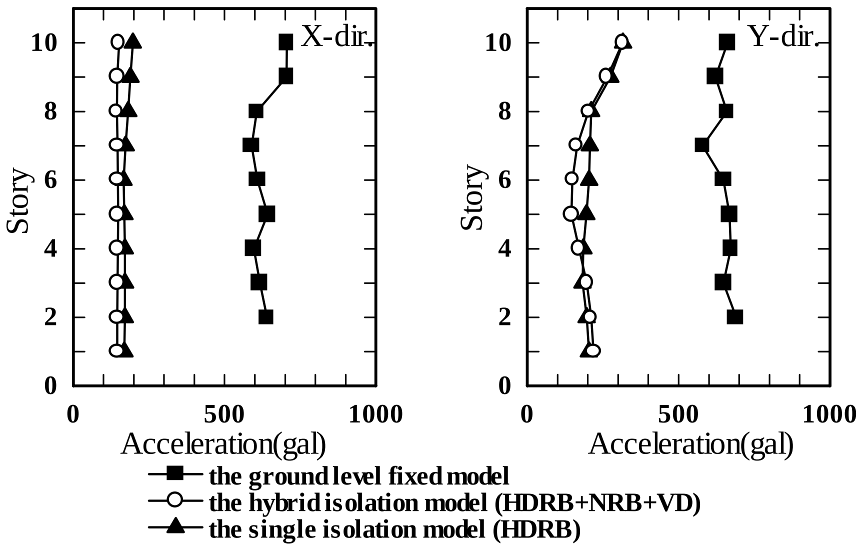

Figure 7: Distributions of maximum response

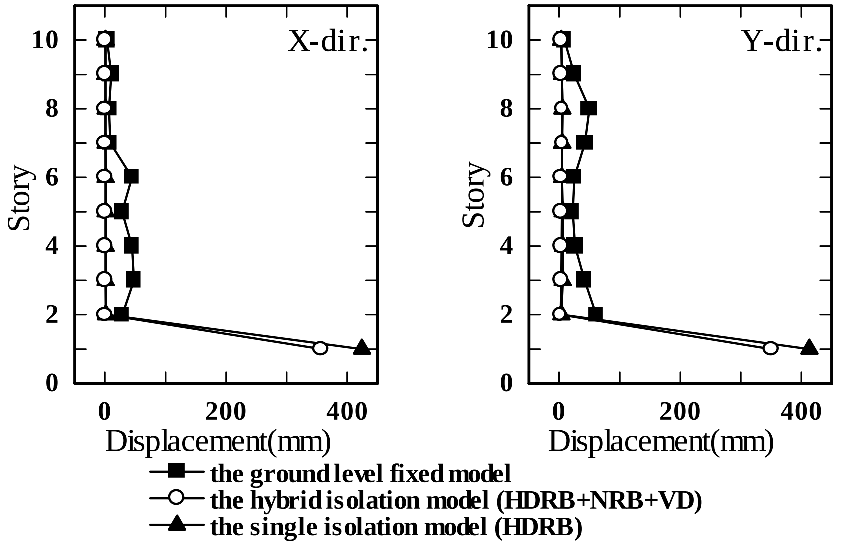

Figure 8: Distributions of relative story displacement

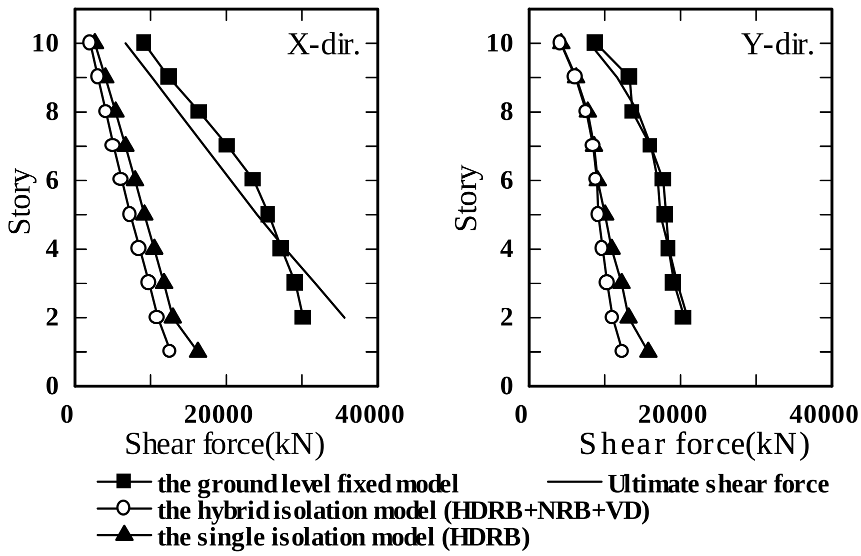

Figure 9: Distributions of maximum story shear force

Fig. 9 shows the distributions of maximum story shear force. The base isolation systems reduce the maximum response of shear force. From these analytical results of the building, it can be noted that base isolation system is an effective aseismic retrofit method of the existing building. Especially, in applications of the base isolation system for existing building in urban area of narrow space, the hybrid isolation including the Viscous Damper is an effective method for reducing the response of superstructure and deformation within the design criterion.

CONCLUSIONS

This paper presented the seismic upgrading of existing building by the base isolation system, which is located in a urban area with narrow space. Although it is not easy to establish retrofit methods to completely satisfy various site conditions, the base isolation system including the Viscous Damper satisfies the design criterion and makes the aseismic retrofit of low-rise buildings possible.

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