EVALUATION OF BASIC CHARACTERISTICS AND DYNAMIC RESPONSE ON DAMPER SETTLED ON BRIDGE ABUTMENT

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ABSTRACT :

The Currently seismic design of a bridge is in transition to performance based design. Performance based design must evaluate the phenomena precisely and stipulate the conditions of bridge in consideration of performance and safety of bridge system. Under the simulation of a large earthquake, it is essential to define how much damages can be acceptable to each component of bridge and how far its energy sharing can be expected, which enable the seismic design to secure safety throughout the bridge system. Each component of a bridge system such as bridge pier, girder, bearing, abutment of a bridge, in some cases, absorb energy due to a partial damage of materials, concrete cracks and elasto-plastic behavior of steel. While even without damages some can absorb energy repeatedly by installing damping device such as seismic isolation bearing. This study , targeting a bridge system composed of bridge pier, girder，bearing and abutment of a bridge, focused on abutment which can easily secure large reaction force compared with bridge pier generally installed with seismic isolation bearing and can secure sufficient space for installing dampers and others. In this study dynamic response analysis of a bridge with dampers on its abutment has been conducted and dampers performance has been assessed with view to securing rational seismic safety of a bridge system.

KEYWORDS: abutment of a bridge, damper, highway bridge, seismic reliability, simulation

1. INTRODUCTION

Currently seismic design of a bridge is in transition to performance based design. Performance based design aims to realize a reasonable designing by precisely prescribing performances required to structures under real phenomena. As for bridges, the overall components need to be taken as one system and damages need to be prescribed in its whole system. Generally, damages of bridge members are proportional to the level of seismic load. However considering a bridge as one system enables us to see variations in the level of damages according to the material characteristics and the structural characteristics. At worst, its system gets unstable resulting in collapse. In order to avoid this situation, structural stabilization needs to be maintained which can be done by absorbing seismic energy as a whole bridge system in a balanced manner. Therefore performance based design needs to define how much damages can be acceptable to each component and how much its energy sharing can be expected and realize a seismic design securing safety throughout the whole bridge system. On the other hand the present seismic designing of a bridge tries to secure seismic reliability by identifying a part possibly damaged beforehand and concentrating energy absorption to this part. However in reality, complicated nonlinear behavior could be posed due to damages of structural members and expansion joint and a bump of girder along with severity of damages. Although, in some cases, these nonlinear behaviors could absorb energy, it is unable to be taken into consideration in designing as the current evaluation of it is not precise enough for that. One solution to this problem is appropriate location of energy absorbing part by using dampers and others. Various type of dampers such as viscous material, elasto-plastic behavior of steel member and friction mechanism are now practically used for seismic isolation and structural control. However they are still quite limited in application to a bridge system.

2. INVESTIGATION OF BASIC CHARACTERISTICS OF DAMPERS

2.1. Dynamic Response Analysis using Single Degree of Freedom System

In the first step of seismic design of a bridge using dampers, it is necessary to define target displacement permissible to superstructure at the time of an earthquake. Target displacement refers to the maximum of displacement expected in superstructure, and means total of displacement produced in the foundation, the bridge pier and the bearing. Therefore, it is necessary to take performances, such as a displacement absorber, into consideration for a setup of target displacement. Moreover, in order for damper to exhibit the function appropriately, a certain amount of deformation is indispensable. This point is also taken into consideration to set up target displacement. In the second step of design, it is necessary to set up natural period and damping of a whole bridge system which satisfy target displacement. In this research, natural rubber bearings which expect supporting function and period control and elasto-plastic dampers which expect energy absorption are assumed.

Single degree of freedom system was prepared for this basic investigation. The weight of mass point was 1000kN and damping factor was 2%. Elastic spring of the bearings was set up, respectively so that target natural period might be set to 1 sec, 1.5 sec, 2 sec, 2.5 sec, 3 sec, 3.5 sec, 4 sec and 5sec to the mass. Elasto-plastic damper had the elastic stiffness that natural period of mass point at the time of assuming that it supported horizontally only by elasto-plastic damper was set to 1 sec. Target displacement was set from 15cm to 50cm. Acceleration records of Kobe Maritime Metrological Observatory in Hyogo-ken Nanbu Earthquake 1995 and El Centro in Imperial Valley earthquake 1940 were adopted as input motion. Dynamic response analysis was performed using single degree of freedom system. It analyzed by changing yield load of damper parametric so that target displacement might be satisfied. Yield load was increased gradually from zero. It was decided, when the error of displacement obtained from dynamic response analysis to target displacement became less than ±1%. Considering the nonlinearity of damper, the influence of the phase of earthquake motion and etc, it is thought that yield load which satisfies target displacement is not one in this analysis. But, the first satisfied condition was chosen here.

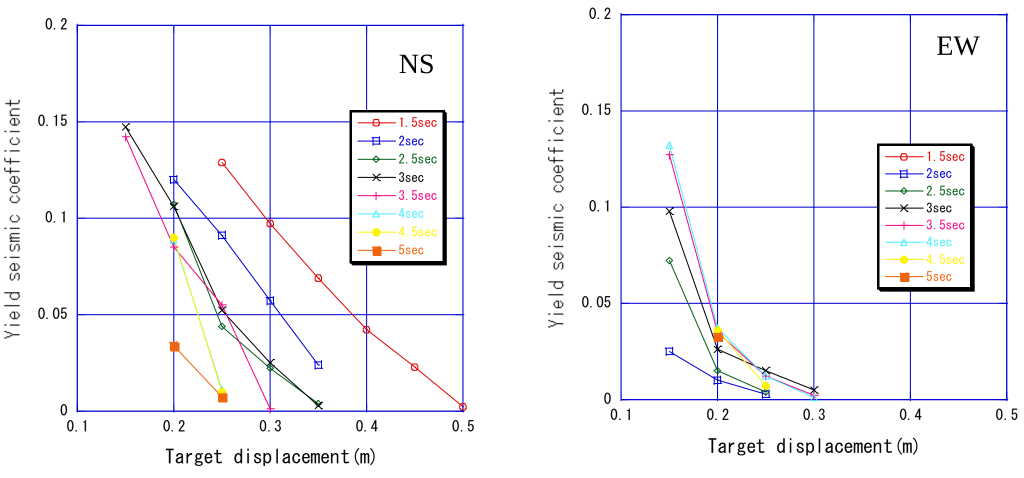

Figure 1 Relationship between Target displacement and Yield seismic coefficient （JMA KOBE）

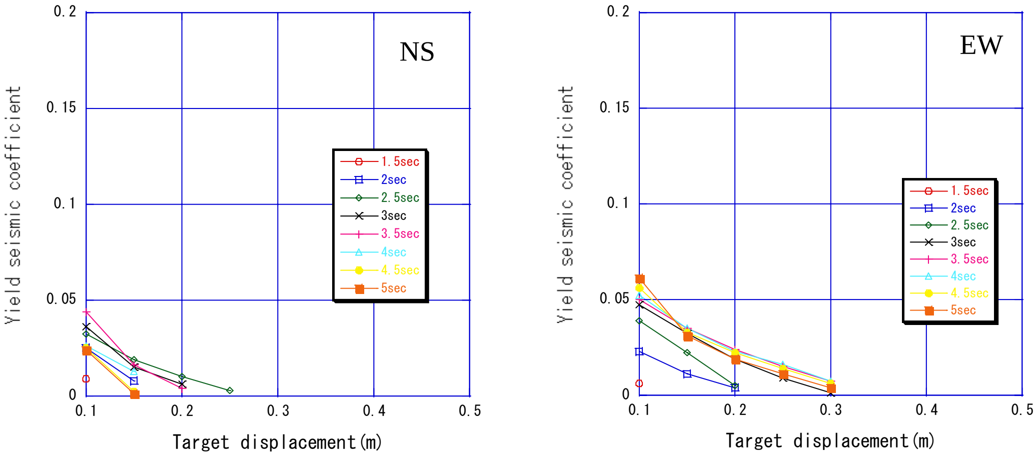

Figure 2　Relationship between Target displacement and Yield seismic coefficient （El Centro）

Figure 1 and Figure 2 show relationship between target displacement and yield seismic coefficient. Yield seismic coefficient means normalized yield load by the weight of mass point. Required seismic coefficient to yield load of damper decreases as target displacement increases in same period. According to the investigation in target displacement 0.15~0.5ｍ, seismic coefficient to yield load were 0.01~0.15 in Hyogo-ken Nanbu Earthquake and 0.01~0.06 in Imperial Valley earthquake.

3. SEISMIC DESIGN OF A BRIDGE USING DAMPERS

3.1. Structural Outline of The Bridge

Four spans continuous steel girder bridge was selected as a structure for this examination. This model was prepared for examination of the seismic reinforcement considering application of dampers. So this bridge was designed according to Specification for Highway Bridges 1980. In this examination, dampers are installed on the abutment of both ends of the bridge and the top of each bridge pier. And natural rubber bearings are installed on the top of piers and the abutments. Figure 3 shows structural outline.

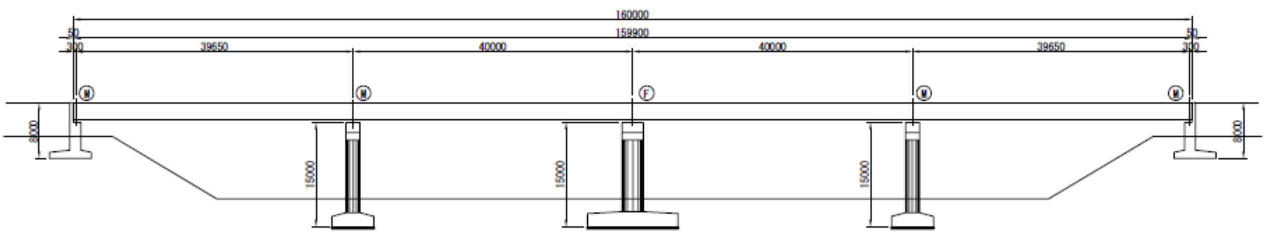

Figure 3　Four spans continuous steel girder bridge

3.2. Analytical model

The whole bridge system was modeled to plane framed model, as shown in Figure 4. Natural rubber bearing was assumed as reaction force distribution bearing. Natural rubber bearing was modeled as elastic spring. The spring constant was set up, respectively so that target natural period might be set from1 to 5sec to mass of a superstructure the same as single degree of freedom system. Elasto-plastic damper had the elastic stiffness that natural period of the superstructure at the time of assuming that it supported horizontally only by elasto-plastic damper to mass of the superstructure was set to 1 sec. Viscous damping was estimated by the equivalent damping matrix created from strain energy proportionality type damping in dynamic response analysis. Horizontal spring and rotational spring were set on the footing bottom.

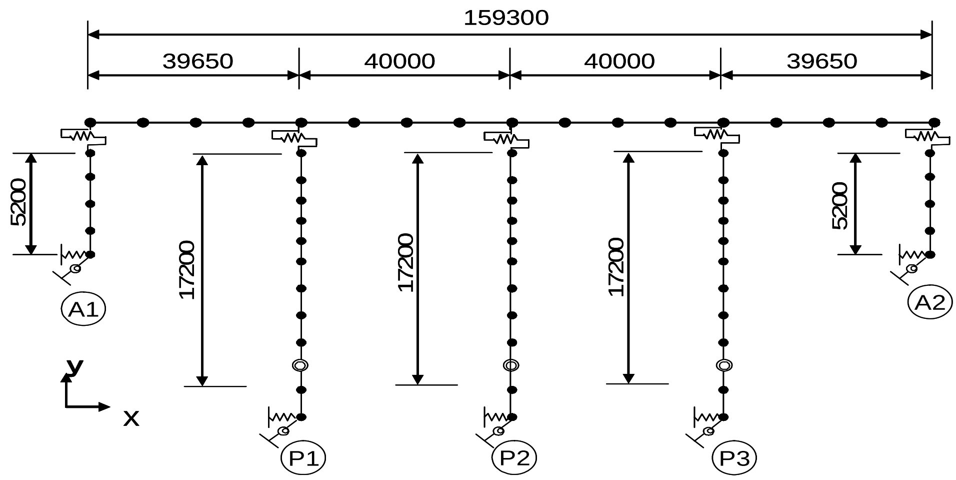

Figure 4 Plane framed model

3.3. Evaluation of The Characteristics of The Damper Based on Dynamic Response Analysis

Dynamic response analysis was performed using this model which installed damper. Based on yield seismic coefficient obtained from dynamic response analysis using single degree of freedom system, initial yield load of elasto-plastic damper was set up so that target displacement might be satisfied. It was decided, when the error of displacement obtained from dynamic response analysis to target displacement became less than ±5%. Based on dynamic response analysis, Figure 5 and Figure 6 show relationship between target displacement and yield seismic coefficient. Yield seismic coefficient means normalized yield load by the weight of a superstructure. Required seismic coefficient to yield load of damper decreases as target displacement increases in same period. According to the investigation in target displacement 0.15~0.5m, seismic coefficient to yield load were 0.01~0.15 in Hyogo-ken Nanbu Earthquake and 0.01~0.05 in Imperial Valley earthquake. Relationship between target displacement and the rate of reaction force shows in Figure 7 and Figure8. The rate of reaction force means the reaction force of the damper normalized by the reaction force of the bearing on the abutment. The rate of reaction force decreases as target displacement increases in same period. The rate of reaction force decreases as the period decreases in same target displacement. It became clear that about a maximum of 2~3 times of reaction force acts on the abutments of a bridge. Relationship between period and response magnification factor shows in Figure 9 and Figure 10. The response magnification factor decreases as period increases in same target displacement. And, the response magnification factor increases as target displacement increases in same period. The reduction effect of response acceleration is expected in 3 seconds or more of the period.

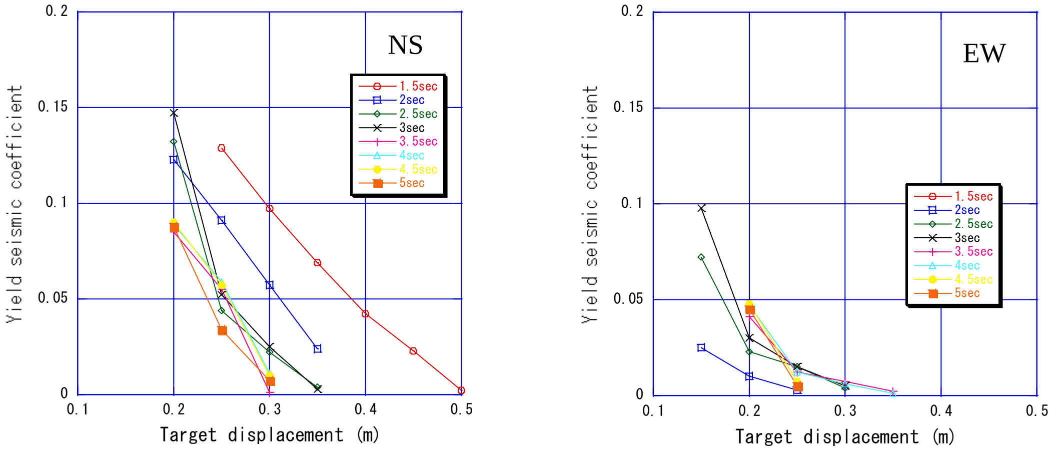

Figure 5 Relation between target displacement and yield seismic coefficient (JMA KOBE)

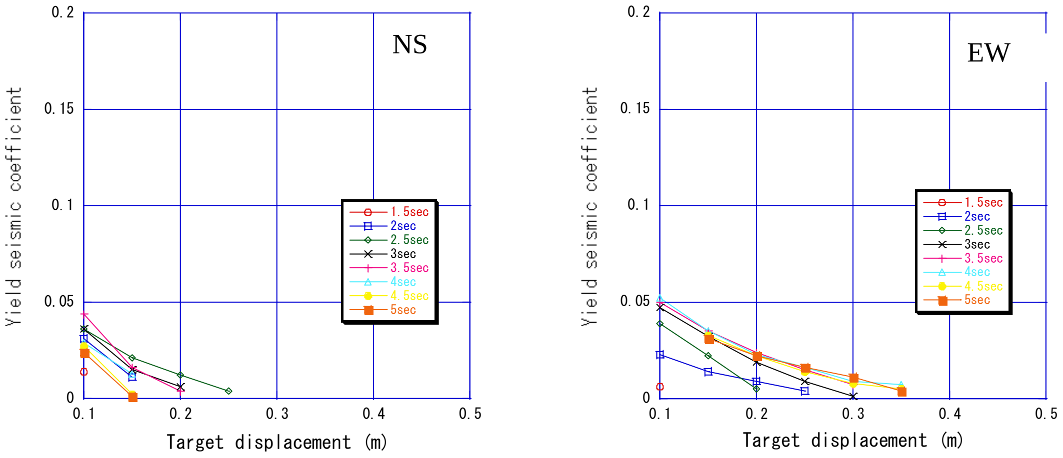

Figure 6 Relation between target displacement and yield seismic coefficient (El Centro)

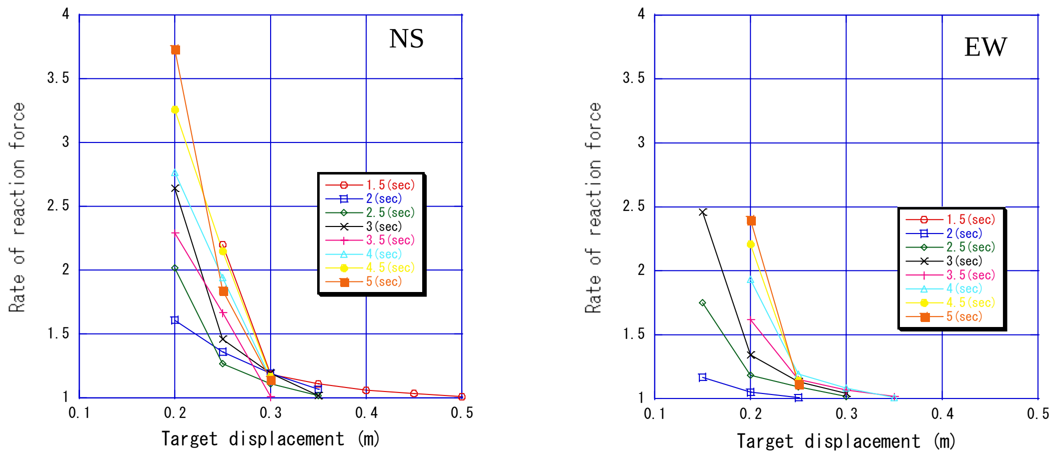

Figure 7 Relationship between target displacement and rate of reaction force (JMA KOBE)

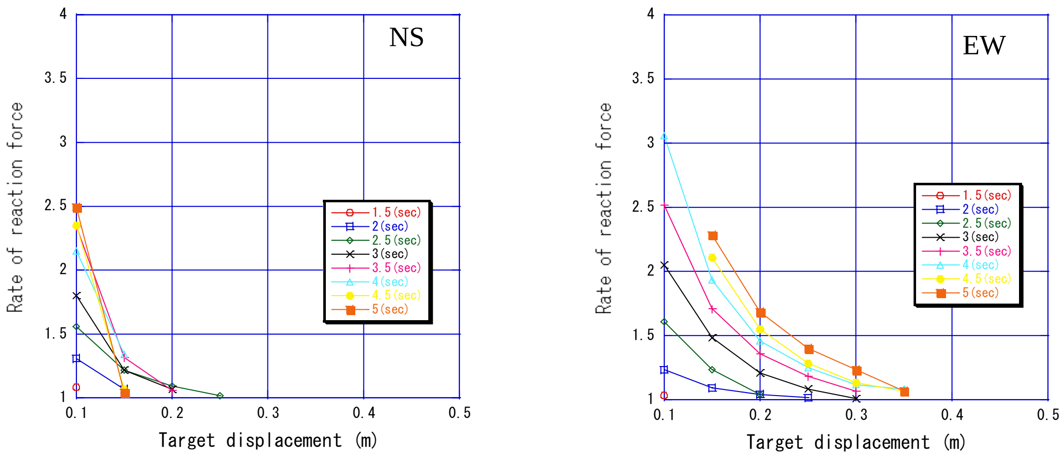

Figure 8 Relationship between target displacement and rate of reaction force (El Centro)

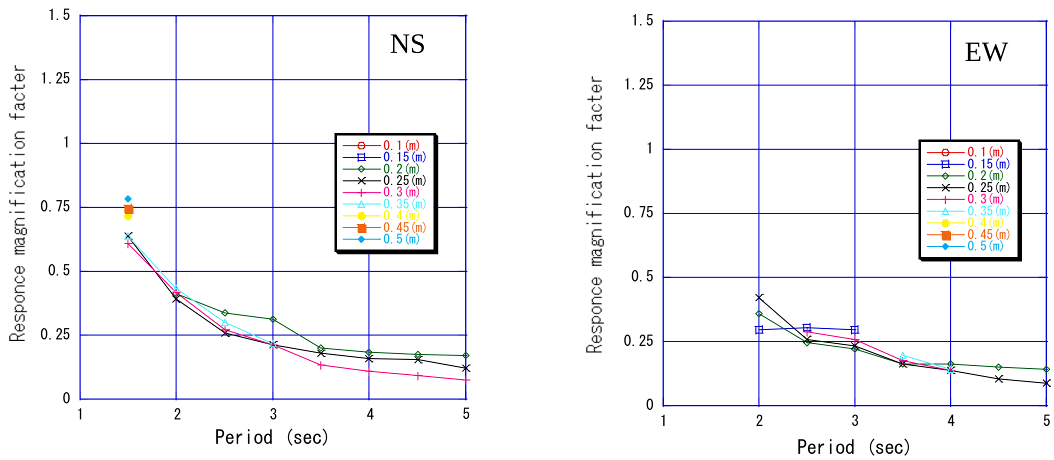

Figure 9 Relationship between period and response magnification factor (JMA KOBE)

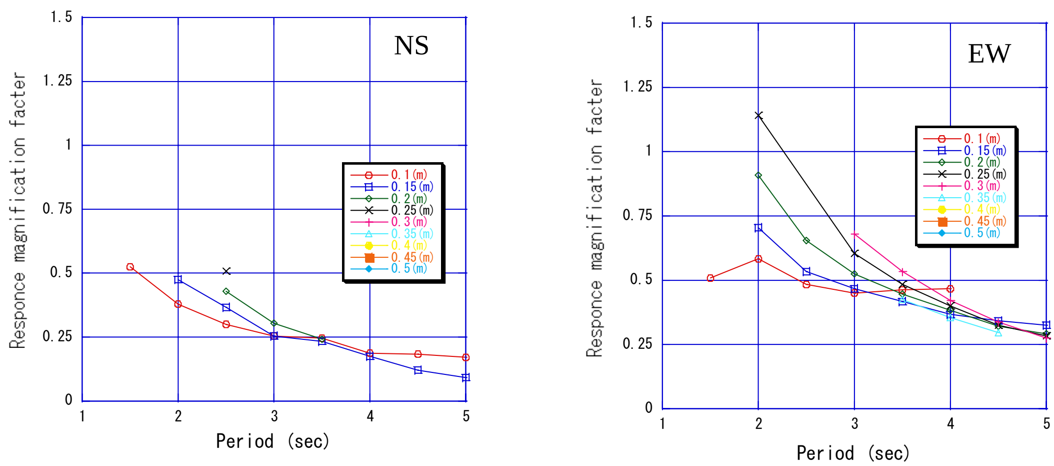

Figure 10 Relationship between period and response magnification factor (El Centro)

4. CONCLUSION

Evaluation of basic characteristics of a damper settled on the bridge abutment. Seismic coefficient to the yield load of a damper, the maximum acceleration of the superstructure and the reaction force induced at the bridge abutment were confirmed as characteristics of a damper. The following conclusions may be deduced from the results presented.

(1) From the dynamic response analysis using single degree of freedom system, seismic coefficient to yield load of damper decreases as target displacement increases in same period. According to the investigation in target displacement 0.15~0.5ｍ, seismic coefficient to yield load were 0.01~0.15 in Hyogo-ken Nanbu Earthquake and 0.01~0.06 in Imperial Valley earthquake.

(2) From the dynamic response analysis using plane framed model of a bridge, Required seismic coefficient to yield load of damper decreases as target displacement increases in same period. According to the investigation in target displacement 0.15~0.5ｍ, seismic coefficient to yield load were 0.01~0.15 in Hyogo-ken Nanbu Earthquake and 0.01~0.05 in Imperial Valley earthquake. Various dependencies of yield seismic coefficient were similar between single degree of freedom system and plane framed model.

(3) The rate of reaction force decreases as target displacement increases in same period. The rate of reaction force decreases as the period decreases in same target displacement. It became clear that about a maximum of 2~3 times of reaction force acts on the abutments of a bridge.

(4) The response magnification factor decreases as period increases in same target displacement. And, the response magnification factor increases as target displacement increases in same period. The reduction effect of response acceleration is expected in 3 seconds or more of the period.

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