STUDY ON FAILURE PROCESS AND ULTIMATE STATE OF STEEL BEARING BY 3D FEM

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1 Introduction

In 2016 Kumamoto earthquake, various damage of bridges was reported. Among the components of the bridge, steel bearings are the most damaged part of the bridge which affects functionality of the entire bridge. Since the 1995 Southern Hyogo Prefecture Earthquake, several studies about the ultimate state of steel bearing during earthquake carried out. However, there are few studies on analyzing the failure processes and ultimate state of steel bearing when various loads assumed at the time of the earthquake. Photo.1 shows the actual damage situation of steel bearing due to Kumamoto earthquake. Therefore, the study investigates the failure process and the ultimate state of pin bearing, pot bearing and pin-roller bearing under combined load using static push-over analysis. Three dimensional finite element method (FEM) used to analyze the bearings.

(a) pin failure (b) pin-roller failure

Photo 1. Damage situation of steel bearing.

2 Research methodology

2.1 Types of bearings

2.1.1 Pin bearing

Pin bearing is a type of fixed bearing that accommodates rotations using a steel pin.

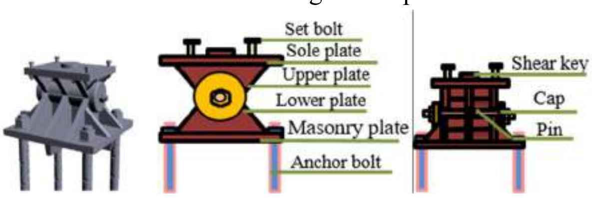


Figure 1． Components of pin bearing.

2.1.2 Pot bearing

Pot bearing is a type of fixed bearing, which consists of a shallow steel cylinder or pot, on a vertical axis with disk, which is slightly thinner than the cylinder fitted tightly inside. The steel piston fits inside the cylinder and the flat brass ring used to seal the rubber between the piston and the pot as shown in Fig 2.

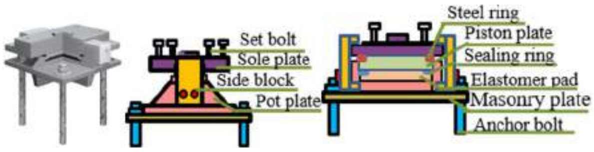


Figure 2． Components of pot bearing.

2.1.3 Pin-roller bearing

Pin-roller bearing is a special form of movable roller bearing in which the pin provided for easy rocking, and bottom parts of the pin placed on a series of rollers.

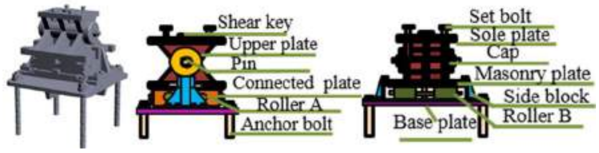


Figure 3． Components of pin-roller bearing.

2.2 Analysis method and modeling

In this study, the numerical model developed for both longitudinal and transverse direction based on Japan Road Association Design Standard. The model and outline of the steel bearings were prepared by MSC.MARC as shown in Fig 5. The analysis adapted von Mises yield criteria and isotropic hardening for all materials. Penalty and shear bilinear methods are considered for solving contact and friction problem of the bearings, respectively. The analysis set six analysis load cases as shown in Table 1, and the boundary condition of the bearings was shown in Fig.4.

Table 1. Analysis load Cases

Case	Loading Condtion
1	Dead load, fixed displacement in bridge axis
2	Dead load, fixed displacement in perpendcular bridge axis
3	Dead load, fixed displacement in 45° dirction
4	Uplift load, fixed displacement in bridge axis
5	Uplift load, fixed displacement in perpendcular bridge axis
6	Only Uplift load

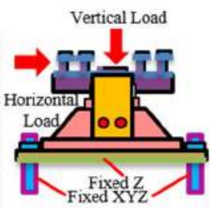
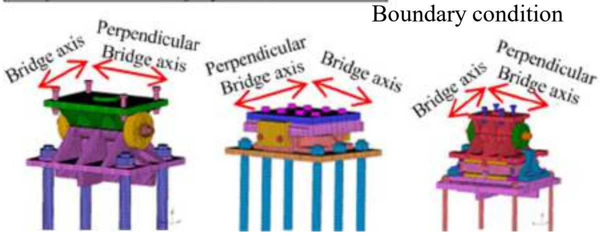


Figure 4.
Boundary condition



(a) Pin bearing (b) Pot bearing (c) Pin-roller bearing

Figure 5. FE mesh 3D model.

Keywords: Failure process, ultimate load capacity, Bridge axis, Perpendicular bridge axis, uplift load, and FEM.
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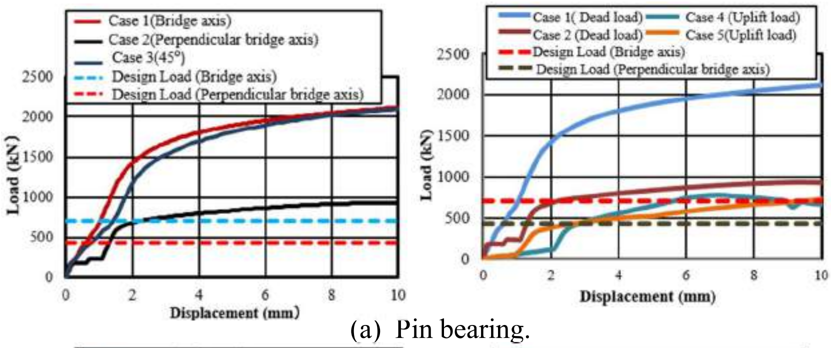
3 Analysis result and discussion

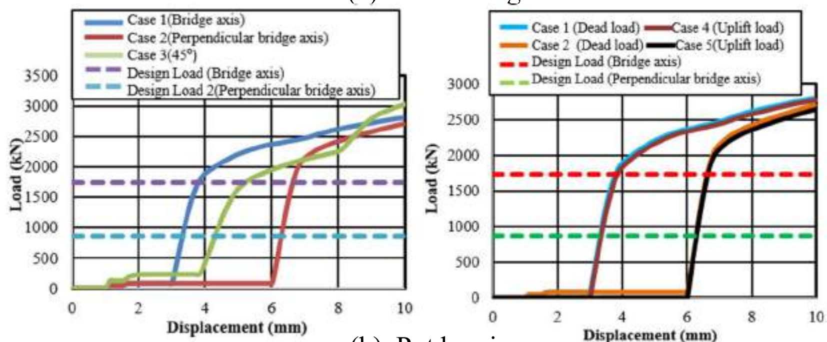
3.1 Load bearing capacity

Fig 6 shows the load-displacement relationship obtained from the analysis. From the curve, it can be observed that the maximum load resistance capacity of case 1, 2 and 3 are higher than the load estimated by Japan Road design standard for all bearings, but pin bearings shows lower load resistance capacity in the direction perpendicular to the bridge axis due to high tensile stress generated on the pin bearing at the early stage of the analysis, while pin-roller bearing also show lower resistance capacity in the bridge axis direction due to high contact stress induced between the masonry plate stopper and side block of the bearing.

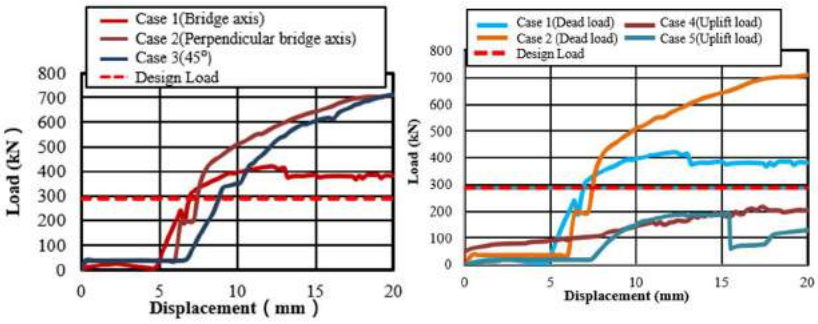
In case 4 and 5, the maximum load resistance capacity of the bearings are higher than expected design load except pin-roller bearing. Case 4 and 5 of Pin-roller bearing capacity is 31% and 33% lower than the design load, respectively due to the contact of masonry and base plate with rollers are completely lost.



(a) Pin bearing.



(b) Pot bearing.

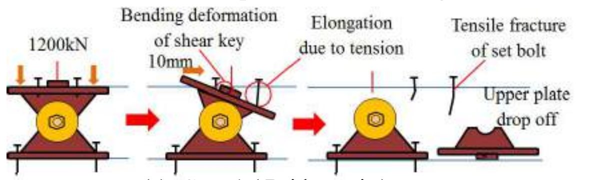


(c) Pin-roller bearing

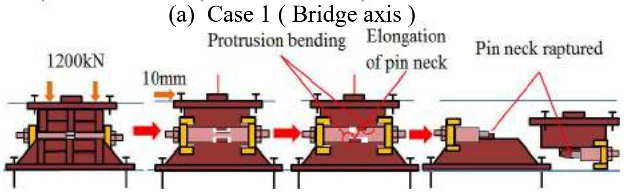
Figure 6. Load – Displacement curve.

3.2 Failure process

The failure process of the bearings are estimate based on the deformation performance and plasticization of the bearing portions. Due to the spaces limitation, pot and pin-roller bearing result is omitted. In pin bearing, when the horizontal load acted in the bridge axis direction the upper seat start to rotated in the perpendicular bridge axis direction, and caused right side set bolt elongation due to tension as shown in Fig 7 (a). As the horizontal load acted in the perpendicular bridge axis direction, the upper seat slide in the direction of the loading, and generated high tensile stress on the pin neck, and the pin neck spilt at the central axis of the pin as shown in Fig 7 (b).



(a) Case 1 (Bridge axis)



(b) Case 2 (Bridge perpendicular axis)

Figure 7. Failure process of pin bearing.

4. Conclusion

The main finding obtained from the analysis result as shown below

1. Plasticization confirmed below expected design load estimated by Japan Road Association Standard. This plays a moderate role in the failure process of the entire bearings

2.Load resistance capacity of all bearings exceeded the design load of the bearing estimated by Japan Road Association Standard except case 4 (Bridge axis with uplift load) and case 5 (Perpendicular bridge axis with uplift load) of pin-roller bearing.

3. In the case of pin bearing, tensile failure of set bolt and pin neck was a probable failure mode of the bearing in bridge axis and perpendicular bridge axis direction, respectively.

4. In the case of pot bearing, side block and side block mounted bolt shear failure, and deformation of pot plate wall was failure mode of the bearing.

5. In the case pin-roller bearing, a unique failure mode was confirmed for each case depending on vertical and horizontal loading direction.