EFFECT OF IMPACT ANGLE TO THE PERFORMANCE OF STEEL CURVED GUARD FENCE SUBJECTED TO TRUCK COLLISION

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1. INTRODUCTION

The curved guard fences are used on curved roads and bridges. Similar to other guard fences, the curved guard fence must meet four performances that are required in the both United State (TRB, 1993) and Japanese (JRA, 1999) design codes as: (1) the leaving of vehicle from road is prevented; (2) the occupant is protected; (3) the vehicle is guide back to the road and (4) to prevent the guard fence separations. The performance of steel guard fence subjected to collision load that is studied from a full-scale test is an important methodology, however, such test need a high cost and much efforts. Miller and Carney (1997) investigated behavior of straight guard fence by simulating collision problem with finite element models. Hirai and Itoh (2005) presented a study on performance of curved guard fence by numerical analysis. Both above papers showed that the numerical analysis is other important method to study on the performance of guard fence. In some cases of curved roads and bridges, depending on the curvature of guard fence, number of lane, movement direction of the truck, the impact angle may be greater than 15 degree. Therefore, the study purposes to verify performance of steel curved guard fence subjected to truck collision with the changes of impact angle.

2. FINITE ELEMENT MODEL

2.1 Classification of guard fence grade

According to Japanese specifications (JRA, 1999), the grades of guard fence are designed following the collision energy that is represented by the impact index. This index is function of the truck weight and velocity and the impact angle, and is determined by following equation in kJ unit.

$$I_s = \frac{1}{2} m \left(\frac{V}{3.6} sin\theta \right)^2 \qquad (1)$$

where I_s is impact index (*kJ*); m is the mass of truck (*t*); V is the vehicle speed (*km/h*); and θ is collision angle (*deg*).

2.2 Guard fence model

The guard fence consists of posts and beams and concrete curb. The fence post is H-Shape of cross section. The post flange is 150 mm of wide and 6 mm of thick, and web is 145 mm of wide and 4.5 mm of thick. The main beam is 139.8 mm of diameter and 6 mm of thickness, and sub-beam is 114.3 mm and 3.5 mm of thickness. Beams and posts are modeled by shell elements (**Fig. 1**). Steel material of fence beam and post are modeled as isotropic elastic plastic material following the von Mises yielding criterion with Young's modulus is 206 GPa, Poisson's ratio is 0.3 and yield stress is 235 MPa. The strain rate effect of steel material on the guard fence displacement is investigated in numerical study. The concrete curb is modeled with solid element, and considered as fix at end.

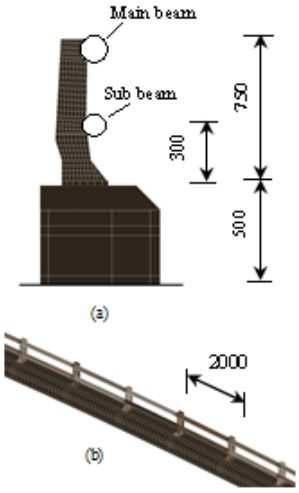

Fig.1 FE models of guard fence (Unit: mm), (a) Cross section and (b) 3D model

2.3 Truck model

The truck frame, driving room, fuel tank and pipelines are modeled by shell elements. Other components as engine and transmission are modeled by solid elements. In the study, the connection of tires and wheels is considered as a rotation joint. The truck steel materials are modeled as isotropic elastic plastic material following the von Mises yielding criterion. The steel Young's modulus is 206 GPa, Possoin's ratios is 0.3 and yield stress is 295 MPa. Aluminum material is used to model for the cargo body, and considered as multi-piece linear stress-strain relationship with Young's modulus is 70 GPa, and Possoin's ratios is 0.34.

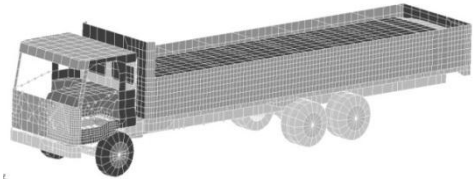

Fig. 2 FE models of the truck

3. NUMERICAL SOLUTION

In the curved guard fence, the angle that is created from rays of the truck movement and tangent of curved fence is impact angle. According to **Eq. (1)**, with the same truck conditions, the impact angle will control the grade level of guard fence. The maximum value of impact angle is mentioned in (JRA, 1999) as 15 degree; however, considering a case of curved road with 100 m of curvature and connecting with straight road. The road has two or three lanes. The truck is assumed to run from straight road and impact to curved fence on the curved road.

Keyword: Curved guard fence, Impact collision, LS-DYNA 3D, Numerical analysis
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In this case, the impact angle of the curved guard fence and truck may be greater and reach to 20 and 25 degree. Therefore, study analysis is carried out by following progress; (1) guard fence is subjected to 15 degree of impact angle that meet specifications requirements; (2) the 20 and 25 degree of impact angle is applied to verify the state of guard fence and (3) impact angle is increased more to investigate the limitation of impact angle, in which guard fence cannot meet required performances. The numerical solution includes the displacements and absorbed energy of fence components, truck behavior is studied to understand on curved guard fence behavior.

3.1 Displacement response

The comparison of largest displacement at post between three cases of impact angle is presented in **Fig. 3**. This can be shown that the maximum displacement occurs when the head of truck collides to the fence. After impact moment, the truck leaves the guard fence and comes back the road. This is shown by displacement track that is quite stable value after impact moment. The displacement of 25 degree impact angle case is greater than others, and is around twice than displacement in 15 degree of impact angle case.

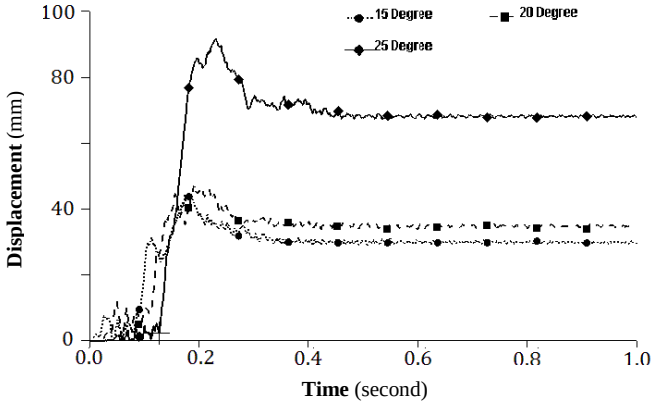


Fig. 3 Displacement response of guard fence post

3.2 Energy response

In the impact collision, the kinetic energy of truck will be absorbed a portion by guard fence. When this shifted energy is large, the breakaway may occur in guard fence component (beam or post). The comparison of absorbed energy of guard fence simulations is presented in **Fig.4.** The energy absorbed of fence in case 25 degree of impact angle is around twice than case of 15 degree.

Figs.3 and **4** can be seen that the kinetic energy of truck is stable in all simulation; however, the absorbed energy capacity of guard fence is rising with the increasing of impact angle. As the result, displacements of guard fence component of large impact angle case are much than other cases.

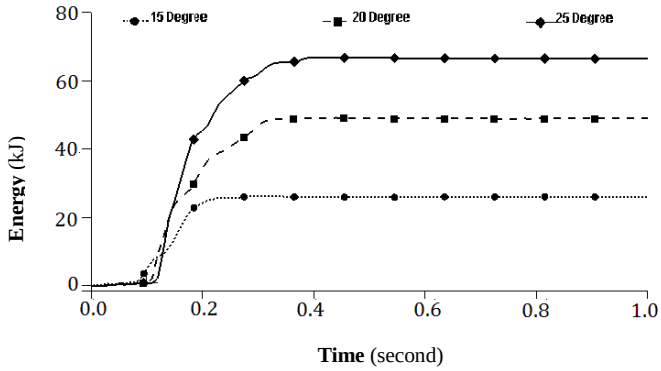
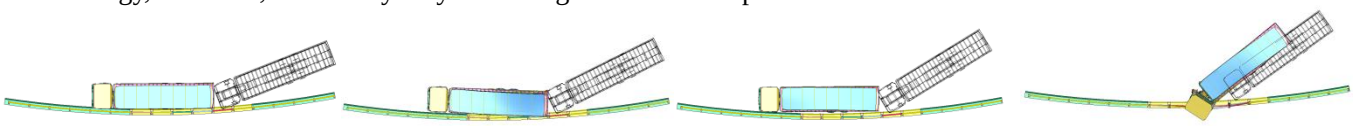


Fig. 4 Absorbed energy of guard fence

3.3 Truck movement

The truck movements are presented in **Fig. 5**. It can be seen that, when guard fence still meet required performance, truck will be leaded by guard fence and come back to the road. However, study analysis found that when impact angle is 30 degree, the guard fence cannot guide the truck (**Fig. 5** (d)). As above discussion, this cause by guard fence absorbs much energy, therefore, breakaway may occur in guard fence components.



(a) 15 degree (b) 20 degree (c) 25 degree (d) 30 degree

Fig. 5 Truck movement in considering with effect of impact angle

4. SUMMARY AND CONCLUSIONS

The research used the numerical analysis to study on the performance of curved guard fence subjected to truck collision when considering effect of impact angle. The study conclusion is summarized as in same truck conditions, the impact angle affect to the absorbed energy capacity of guard fence. The guard fence can absorb much energy with rising of impact angle.

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