FAILURE BEHAVIOR OF CONCRETE BARRIERS UNDER IMPACT LOADS

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Abstract- This study examines a new concrete barrier design that is applied in regions where vehicles are disallowed entry. A new model shape that is composed of three parts is constructed in the proposed design. Finite element analysis is conducted with ANSYS computer software to verify the failure effect of parts during impacted load with different velocities. Results show that the new model can efficiently consider the impact load in one part when the total load effect is examined. The other parts remain with no crack or damage. The stresses and strains in the concrete part affected by the applied load gradually change with the increase in load velocity. The findings also indicate that the concrete barrier system protects road users in case of vehicular accidents.

Keywords- Concrete barrier, ANSYS software, Finite element, Failure.

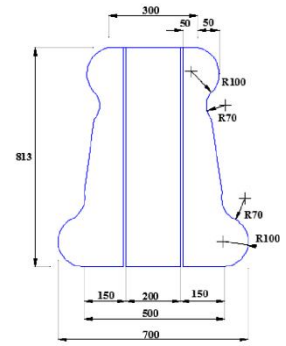
I. INTRODUCTION

Sometimes, vehicle access is not allowed in certain areas, such as roadsides, narrow medians, and bridge barriers. This situation is dangerous because serious accidents may occur; the concrete barriers used in these areas help control errant vehicles. Many types of concrete barriers can meet roadside design criteria. The properties of concrete barriers, such as their shape, height, width, length, and connection design, change from one type to another. In addition, the methods of concrete barriers bonding with floor anchor to reduce concrete barrier installation deflection. A main problem in highways is providing protection for road users in all road types. To keep walkers and vehicle drivers from entering dangerous regions, security devices must be used to promote road security. The design of concrete barriers must be excellent to absorb as much load as possible when vehicles collide with concrete barriers and to ensure the stability of these barriers.

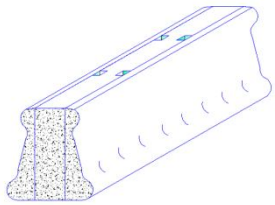
In recent years, the concrete barrier design on Malaysian highways has not been modified. Many vehicles have been destroyed, or drivers have been injured critically during vehicle collision with concrete barriers because of the stiffness of these barriers. The concrete barrier design during construction must be simple. On Malaysia highways, the vehicles involved in accidents are usually totally damaged, with the vehicle drivers either seriously injured or dead. Concrete barriers are broken and lead to interruptions in highway traffic. The reconstruction price for roads is estimated to be millions Ringgit. Substitutes and sections for repair and emergency openings need to be easily installed to address these problems. In this study, a new concrete barrier design is presented. The new design is simulated with the use of ANSYS software to validate its properties and check the failure of parts.

II. DESIGN TECHNIQUE

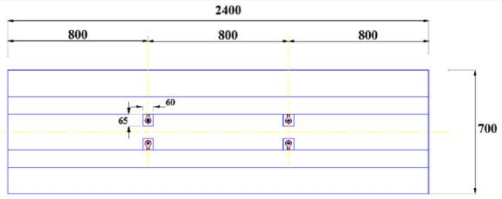
Shape, width, length, the connection of concrete barriers with one another, and the bonding of the concrete barriers with the floor are the main factors that affect the design of concrete barriers. A new design shape is introduced in this study. This design attempts to use a new architectural shape. The model section consists of three parts: the middle part and two outer parts. The outer parts can be made of different concrete materials compared with the inner part. During the impact of a vehicle with the concrete barrier, the barrier will break. Therefore, the new design will help enable easy and low-cost maintenance. Moreover, road traffic is not interrupted during highway-related maintenance works. The new proposed concrete barrier design is shown in Fig. 1.



(a) Cross section of concrete barrier



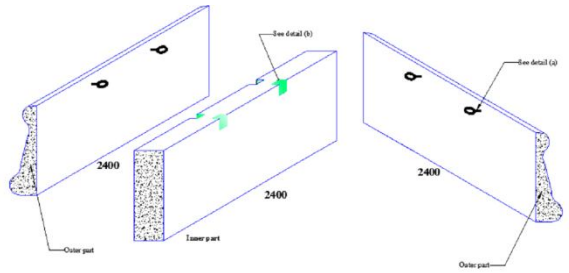
(b) 3D view of concrete barrier



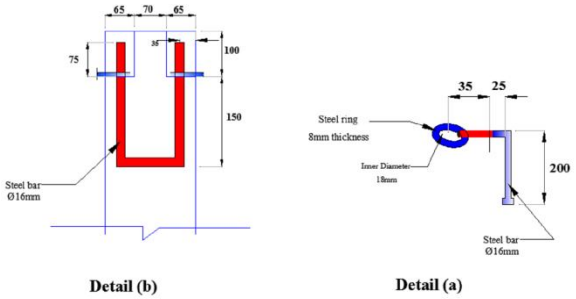
(c) Top view of concrete barrier

Figure 1: Proposed concrete barrier design

The new shape is curved from top to bottom to decrease vehicle tire deflation during vehicle collision with the concrete barrier. The top curve gives the new shape of the design. The three parts of the model are connected with one another by steel bars. The dimensions of the proposed concrete barrier are in limit allowed in the roadside design criteria. In addition, the weight of the concrete barrier segments is on this boundary. Fig. 2 shows the connection. These parts can be easily installed, with the middle part placed in its proper position. Then, the outer parts will lift and hanging with the inner part. This operation is repeated to another segment of the concrete barriers.



(a) 3 parts of concrete barrier



(b) Steel connections of concrete barrier

Figure 2: Connection of the new concrete barrier

III. FINITE ELEMENT MODELING

In finite element software modeling, the analysis of engineering problems could be handled through the use of suitable codes or programs. The non-linear explicit dynamic ANSYS 14 finite element software is used for the numerical simulations conducted in this study. A computer simulation of the impact test is performed for the concrete barrier. The concrete strength is 27.6 MPa, with a 2,300 kg/m3 unit weight for the concrete.

The model meshing of the new concrete barrier design includes solid elements of tetrahedron type, as shown in Fig. 3. The flexible concrete barrier model is used, and concrete failure is shown in the simulation. Impact simulation is utilized to validate the ability of the concrete barrier to absorb the impact load. At this stage, a small element size can be used; a large element size could not give good simulation results. A steel bar is used to apply load to the concrete barrier with the use of rigid elements of structural steel.

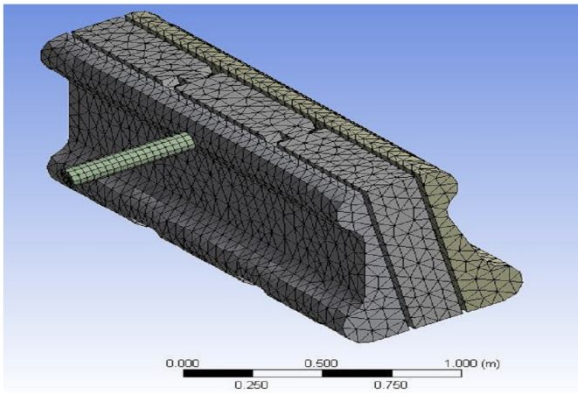
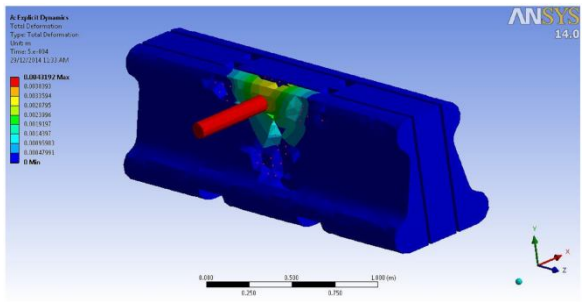


Figure 3: Meshing of the new concrete barrier model

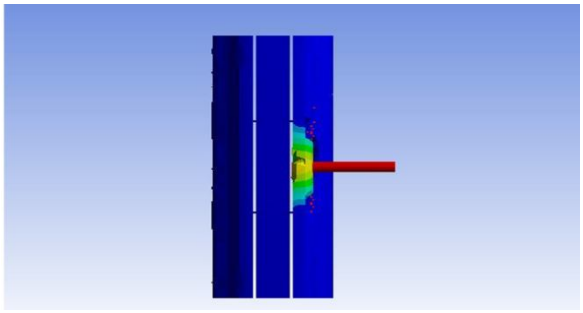
IV. RESULTS AND DISCUSSION

A. Failure Pattern

The failure pattern for a sample of the results, as shown in Fig. 4, indicates that failure occurs only on the outer part that faces the applied load. This arrangement helps keep the other parts of the concrete barrier, safe and not allow the vehicle to pass the opposite lane of the road. The cracking is concentrated at the point load and around it. Furthermore, the connection of the parts does not separately occur. As a result, accident risks are reduced, as well as the cost and time for concrete barrier maintenance.



(a) 3D view of concrete barrier failure pattern



(b) Top view of concrete barrier failure pattern

Figure 4: Failure pattern of the new concrete barrier model

B. Stresses and Strains

A parametric study was conducted with the use of different speeds of the same loads. The goal is to demonstrate the effect of the differences in speed in the new design of the concrete barriers. The speeds used were 45, 64, 90, and 135 km/hr. These speeds are low, medium, and high in different types of roads. Fig. 5 shows the findings on the concrete stresses on the outer part because of the impact load, which is depicted in Fig. 4. The stress increases as the impact time progresses, and it reaches the maximum value during the middle part of the impact, which is approximately 0.2 msec to 0.3 msec. Then, the stress decreases until the final time. This phenomenon occurs because the concrete on the outer part reaches failure, receives the stresses, and absorbs the impact load. Therefore, the stress magnitude is reduced by this energy dissipation exerted from the impacted load.

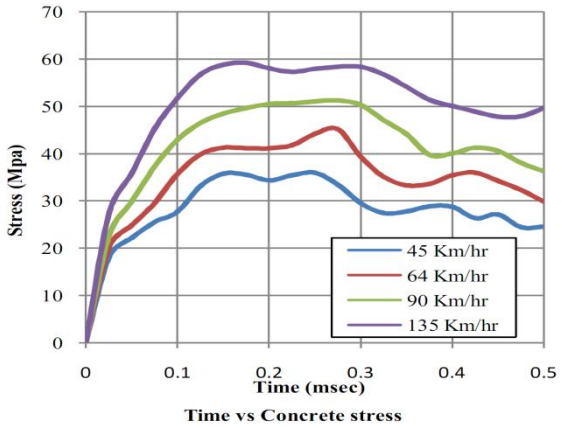


Figure 5: Relationship between the impact time and concrete stress

The concrete strain on the outer part increases as the impact time progresses, as shown in Figure 6, for the different speeds of the loads. The maximum concrete strain occurs during the final impact time, and this finding is logical. However, at the speed of 90 km/hr, the behavior changes differently from that at the other speeds. This speed is therefore sensitive during impact.

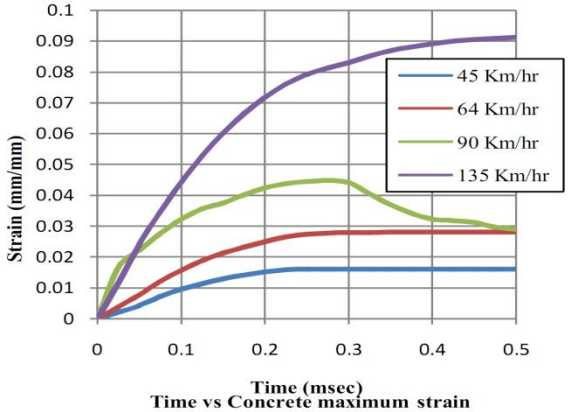


Figure 6: Relationship between the impact time and the concrete stain

CONCLUSIONS

A new design for concrete barriers is presented in this study. This design presents a new idea on the installation of concrete barriers. The results of finite element analysis indicate that failure occurs on the outer part. However, other parts (middle and another outer part) are not damaged during the applied impacted loads, as shown in Fig. 4. Therefore, the model enables resisting the impacted loads, that exerted from vehicle collision in the roads, with damage in part and other parts could keep at work to prohibit the vehicle from passing to the opposite lane and progressing the traffic accident. Moreover, the concrete barrier system could work to protect road users even if it is damaged. Other conclusions of this study are as follows: crack breakdown emerges near the applied load and continues around it. With different impacted speeds against the concrete barrier, the stresses and strains in the concrete part affected by the applied load change increase with the vehicle velocity. The 90 km/hr vehicle speed is more sensitive than the other speeds. Future studies can further focus on this case. Our model meets roadside design specifications.

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