New Generation of Security Road Blocker (SRB) Design and Its Performance Subjected to Commercial Vehicle Crash

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Abstract: Road blockers used in anti-ram traffic barriers are now widely employed in providing both security and positive control of normal traffic. Originally designed and developed for embassies, bullion stores, military bases and other maximum security sites, road blockers are now popular at commercial buildings as they provide the ultimate in access control provision. This paper presents results of a study carried out on the newly designed road blocker that employed the upgraded specification PAS 68:2010. The objectives were to identify main factors influencing the road blocker anti-intrusion performance with respect to commercial vehicle cabin crush collapse mechanisms. A baseline FE model of a K12 road blocker designed by Lace Control Systems was developed and analyzed in LS-DYNA3D. Results show vehicle impact velocity, vehicle strength and its collapse mechanisms to significantly influence the road blocker overall performance.

Keywords: PAS 68:2010; road blocker; crashworthiness; security; anti-ram; truck

1. Introduction

Security Road Blocker (SRB) is an effective means of controlling access to high security areas, stopping heavy laden trucks or commercial vehicles from entering. Originally designed and developed for embassies, bullion stores, military bases and other maximum security sites, road blockers are now popular at commercial buildings as they provide the ultimate in access control provision.

Statistics collected over the past ten years show an increase in the incidents involving terrorist threats. Indeed, during the period from 11 September 2001 to 31 March 2008 in UK, 1471 terrorists were identified under the security risk protocol to have various methodology of carrying out terror threats [1]. One of the methods devised by the terrorists was to drive fully laden trucks with explosives into occupied buildings for maximum loss of life and destruction.

Aiming at addressing these threats and providing organizations with security and safety, the UK Government's Centre for the Protection of National Infrastructure (CPNI) in collaboration with the British Standards Institution (BSI) developed a Public Available Specification (PAS 68:2010) to help barrier manufacturers design secure systems. The Standard PAS 68:2010 is prepared to tackle the requirements of organizations who wish to have assurance that vehicle security barriers will provide the level of impact resistance which is sought [2]. One such barrier that will satisfy PAS is the K12 Road Blocker.

Many such K12 Road Blockers are available and are designed specifically to protect human life and property. For a Road Blocker to acquire the PAS 68:2010 certificate, it should be able to perform well under either the experimental barrier test, which has a fully laden truck impacting the SRB at a minimum speed of 64 kph or a virtual test using finite element technique that is validated by practical test data.

This paper presents a new generation K12 Security Road Blocker designed by Lace Control Systems (LACC). To qualify it, the design method, which includes the use of finite element analysis technique as specified in the PAS 68:2010 was employed. Overall, results show vehicle impact velocity, vehicle strength and its collapse mechanisms to significantly influence the road blocker overall performance.

2. Background to Vehicle Crashworthiness versus SRB Impact Performance

The crashworthiness of trucks has been investigated based on varying purposes for several years. One such study was conducted by DEKRA on the advantages of safety belts in heavy trucks using crash tests and as a result identified the importance of seatbelt to truck passengers [3]. Another study, also conducted by DEKRA in collaboration with the MAN Truck Company of Germany was on collision between a truck and a passenger car [4]. These test results were supplemented with some simulations that assessed the under-riding events and dummy response under varying crash scenarios [4].

In terms of the impact between a truck and a road blocker, only a few experimental tests have been carried out by TRL and MIRA in the UK [5]. The reason Britain is at the fore front of this technology might be because of security that has been publicized especially in the wake after the terrorist attacks in USA and UK. This research on road blockers or anti-rams is conducted in order to meet the objectives stipulated in the PAS 68:2010, which demands that a fully laden truck of 7.5 tons is stopped.

The assessment and performance studies of road blockers, especially those concerned with the K12 types subjected to truck impact have not been widely conducted using numerical simulations. Furthermore, the anti-ram performance of road blockers relating to the impacting velocity, the intruding angle of a truck and the unfolding angle of road blockers need general studying to guide the design methods of road blockers and improve the integrity of the Public Available Specification (PAS) which should be reviewed at intervals.

As stated earlier, this paper presents a simulation study on the newly designed, by Lace Control Systems, K12 road blocker that employed the upgraded specification PAS 68:2010. A baseline FE model of this road blocker was developed from CAD, meshed in HYPERMESH and analyzed in LS-DYNA3D. The objectives were to identify the main factors influencing the road blocker anti-intrusion performance by relating to a specified impact velocity, unfolding angle of the removable collapsing front radius plates and the general impact properties that are incorporated into integral energy absorbers and main structural components. Although the PAS 68:2010 mainly emphasises the security properties of road blockers, the performances of the intruding truck incorporated in cabin deformations, vehicle accelerations and movements relative to the road blocker are also investigated in this paper.

3. Design Concept and Methodology

3.1. Design of the Road Blocker

The K12 road blocker for this study was designed and developed by Lace Control Systems (LACC) in collaboration with the Bolton Automotive and Aerospace Research Group (BARRG). This anti-ram works on the principle that is designed to prevent an N2 (7.5 tons) truck from intrusion into security areas based on PAS 68:2010. To achieve the PAS objectives, there are some key structural elements needed for success. Some of these are the supporting structures and sacrificial components, which are incorporated into the design so that upon crash loading these help in absorbing the truck crash loading, while maintaining the main body of the road blocker intact.

Figure 1 and Figure 2 show the newly designed road blocker by LACC and comprises of five main structural sub-assemblies: (i) top structures, (ii) chains, (iii) hydraulic cylinder, (iv) radius plates and (v) base. These are assembled to offer two operation conditions while the road blocker is in-situ, namely top structure folding to the ground level so that permission to pass is given to vehicles and unfolding to the maximum angle of α and the maximum height of H so that vehicles are prevented to have access without permission.

The hydraulic cylinder is the lifting mechanism that fulfils the function of changing the positions of the road blocker, while supporting the top structure to be kept unfolding. The chains connect the top structures and the base to guarantee the integrity of the road blocker when subjected to impact. The top structures are composed of two main parts made of steel; the top plate and the top frame as shown in Figure1. The top plate is bolted to the top frame made of square tube sectional beams welded together. There are four short square pins welded perpendicular to the top frame front beam meant to withstand the intrusion of vehicles. These are hidden behind radius plates composed of three parts: top surface, middle surface and lower surface as shown in Figure 2. The base on the other hand is made of four parallel channel sections welded together in an assembly that has provision for bolting to concrete foundation.

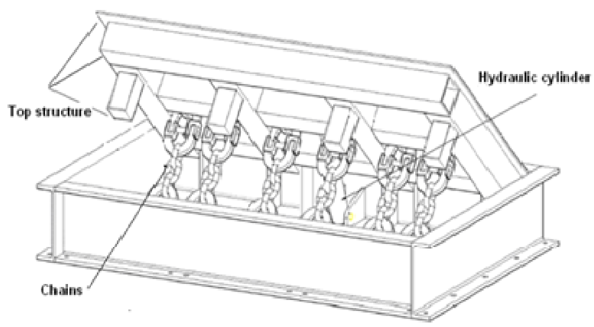

Figure 1. Blocker assembly without radius plates

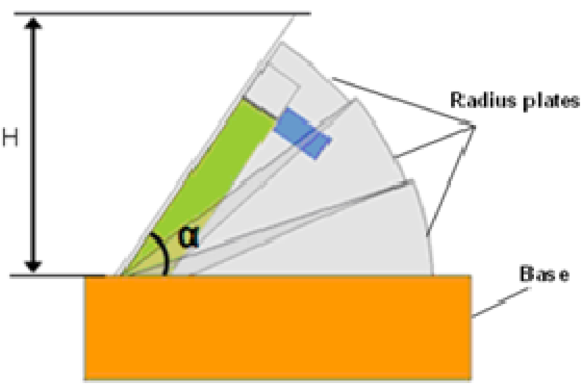

Figure 2. Left transparent view of blocker

The main geometrical parameters of the road blocker are presented in Table 1. These show the unfolding angle of the baseline design to be 55° at maximum opening height of 920 mm, which is defined as the top edge of the top plate when fully unfolded.

Table 1. Main parameters of the road blocker

Unfolding angle α (degree)	Width (mm)	Height H (mm)	Total mass (kg)
55	2010	920	800

3.2. Material Data

Table 2 lists three essential types of steel used in the construction of the K12 road blocker by Lace Control System as follows:

Table 2. Parameters of the main road blocker structural materials

Items	Square hollow section	Parallel flange channel	Flat bar
Young's modulus (GPa)	208	208	208
Yielding stress (GPa)	0.355	0.448	0.270
Fracture stress(GPa)	0.55	0.62	0.45
Thickness (mm)	10	9.5	10

4. Modeling of the Road Blocker and the Truck

4.1. The Road Blocker

The FE model of the road blocker was developed by the Bolton Automotive & Aerospace Research group (BAARG) using HYPERMESH and ready to be used in the solver LS-DYNA3D. The model was based on computer aided drawing supplied by Lace Control System. The main characteristics of the complete finite element model can be identified as follows: (i) top structures, radius plates and base assembly were meshed using 20mm sized shell elements; (ii) the hydraulic cylinder was ignored since it only provides the function of lifting the top structures during the lifting phase but can"t contribute much in the crash events; (iii) the steel chains were simulated using rigid body elements on the assumption that they don"t deform at all during the crash; (iv) the main structures were connected using spot weld elements; (v) since the base assembly was embedded underground and fixed with concrete structures, the surroundings of the road blocker were simulated using rigid wall, while the bottom of the base was also constrained by fixing nodes at bolts positions; (vi) the total number of element in the barrier came to 44008; (vii) the fracture of the structure and failure of the material were ignored in this research since it is a reasonable assumption for evaluating rigid structures. The major debris and their dispersion in the simulation were also not considered in this study and as a result the main criterion was to evaluate whether the road blocker is capable of preventing vehicles from intruding into the defined secure zones.

4.2. The Truck

In combination with the stipulated requirements in PAS68: 2010 and the design objectives by LACC, the configuration for the N2 truck was specified as shown in Table 3. According to the specification, a truck impacts the road blocker perpendicular at the speed of 64km/h with their central line coinciding.

Table 3. Main parameters of the truck model (N2)

Mass (kg)	Width (mm)	Overall length (mm)	Wheel base (mm)	Unladen mass (kg)	Impact speed (km/h)	Overlap percentage (%)	Impact angle (degree)
7500	2220	7350	4200	3900	64	100	90

In the current study, an N2 truck which satisfies the requirements was employed. The modelled truck was a MAN 2000 model developed by BAARG [6] and The Technical University Graz (TUG) in the EU project known as APROSYS [7]. For this specific study, BAARG further improved the model to incorporate the necessary design features including the additional mass.

The front-end of the truck was meshed using more refined shell elements, especially with regards to the side members and the bumper that contribute the bulk of the energy absorbed and force resistance. The loading platform was meshed coarsely because its deformation is not significant during the crash events. The ballast and cargo were replaced with solid elements and fixed to the truck loading platform. For measurement, some accelerometer elements were fixed in the cabin so as to measure the impulse which the passengers may suffer during the crash. The full FE truck model comprised of a total of 217,532 shell elements.

5. Simulation of the Road Blocker Truck Model

5.1. Critical Condition for Intrusion

In order to evaluate whether the road blocker prevents vehicles from intruding, a critical condition for intrusion was established based on the movement of the truck relative to the road blocker. Figure 3 illustrates the critical condition for intrusion, where the truck front wheels reach the critical position on top of road blocker and stop there. If the front wheels stride over that critical position, the truck will be rendered as intruding into the security zone and the road blocker not performing its intended function. This is assumed as the most stringent impact condition, although the PAS 68:2010 allows the

N2 truck to over-ride the road blocker for up to a distance of 4 m. Therefore, the critical condition used to judge the suitability of the road blocker and truck intrusion is defined as:

$$S1 > D,\ S2 > H \quad (1)$$

Where, S1 - the upward displacement of the front wheel

S2 - the forward displacement of the front wheel

D - the upward distance between the front wheel centre at initial contact condition and the top edge of peak point

H - the height of the peak point on the road blocker during an impact event

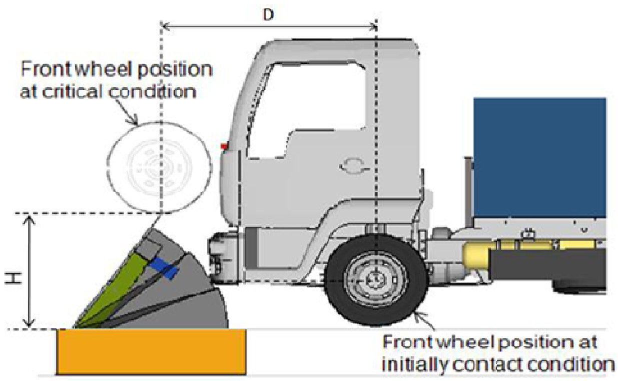

Figure 3. The critical condition for intrusion

5.2. Simulation Scenario

As a baseline condition, the truck impacted the road blocker perpendicularly head-on at a speed of 64km/h as stipulated in PAS 68:2010. A series of simulations were carried out under this condition in order to identify sensitive factors influencing the road blocker anti-intrusion performance.

6. Results and Discussions

6.1. Anti-Intrusion Performance Analysis of the Baseline Model

The road blocker experiences a crash event which lasts 120ms. Figure 4 clearly shows the sequences of the crash events between the truck and the road blocker, the truck initially contacts the road blocker at 0ms, with the resistance of the road blocker, the forward velocity of the truck gradually decreases. Meanwhile, its upward velocity goes up and as a result moves vertically, while the forward velocity drops to 0m/s at about 105ms. Soon after, the truck start to move backwards, while upward velocity drops and finally ending up at 0m/s by the time when the crash event reaches 120ms. The maximum vertical displacement is recorded therewith and soon separation is observed. At the PAS 68:2010 conditions, the K12 road blocker designed by LACC in conjunction BAARG has succeeded in preventing the truck from intrusion. The road blocker collapse mechanism is depicted in Figure 5.

Furthermore, Figure 5 illustrates the plastic deformation contours on the road blocker with the maximum indentation being 246 mm, which is located at the top edge of the middle plate. Figure 6 on the other hand shows the displacement characteristic of the maximum deformation point. It is important to note that by the time of 40ms, the displacement of the deepest point has reached 225mm which is fairly close to the maximum displacement. However, the maximum displacement is achieved at 105ms as the deformation continues before the separation of the truck from the road blocker is observed.

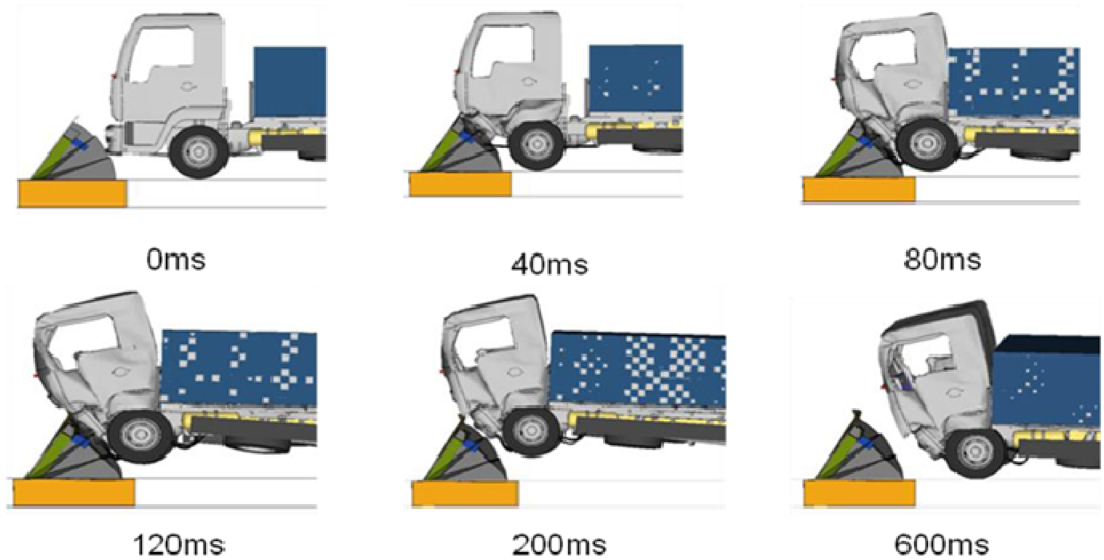

Figure 4. sequences of the truck-road blocker impact simulation

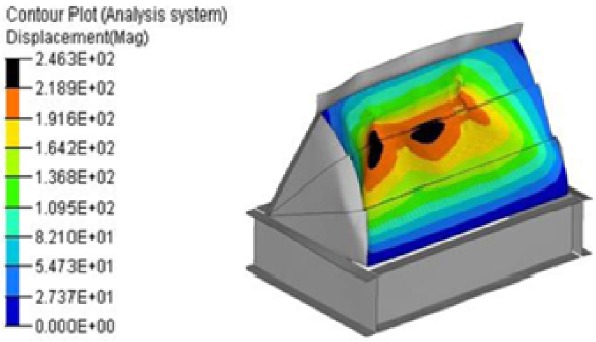

Figure 5. Deformation contour of road blocker

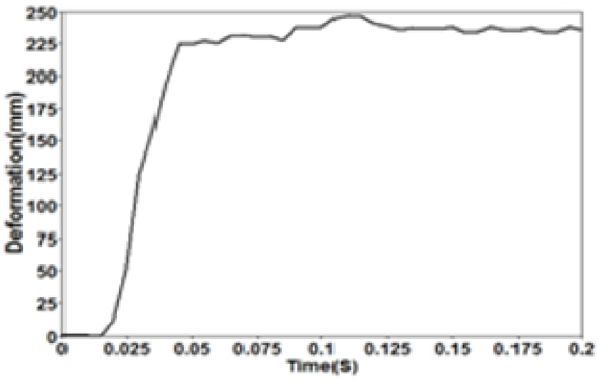

Figure 6. Displacement of the maximum deformation point

The energy absorbed characteristics of the road blocker are shown in Figures 7 and 8, while the performance of each part is quantified in Table 4. The total energy absorbed by the road blocker is 206 kJ, the top frame and the radius plates are the main energy absorbing parts, especially for the top frame which absorbs 60.7kJ and contributes about 29.5% of total energy.

Analysis can also be made of the absorbed energy curve in Figures 7 and 8 of the road blocker by assessing the main parts as shown. The energy absorbing events can be clearly divided into 4 phases, which are presented below as:

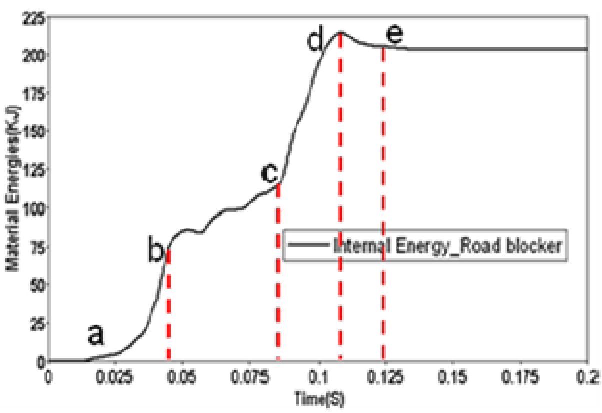

Figure 7. Total energy absorbed by road blocker

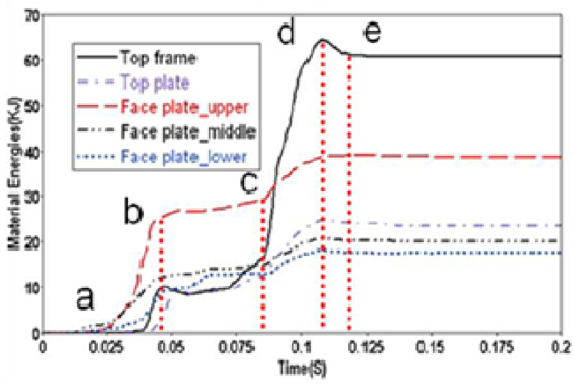

Figure 8. Energy absorbed by parts of road blocker

Table 4. The energy absorption for the road blocker

Items	Internal energy (kJ)	Percentage (%)
Top frame	60.7	29.5
Face plate upper	38.8	18.8
Top plate	23.5	11.4
Face plate middle	20.2	9.8
Face plate lower	17.8	8.6
Other components (base assembly, side plates, roadway, etc)	45	21.8
Road blocker	206	100

Phase I: a ~ b, the face plates are the main energy absorbing parts of the road blocker;

Phase II: b ~ c, the road blocker doesn't absorb energy significantly as the front end of the truck absorbs most of the energy during this period;

Phase III: c ~ d, the road blocker absorbs energy significantly with the deformation of the top frame;

Phase IV: d ~ e, uniform maintenance of the crash energy of the truck front during rebound stage,

Figure 9 on the other hand shows the contact force characteristic between the truck and the road blocker. The peak force in the events is 2520 kN at 98 ms. Accelerations of the left and right side of the truck cabin

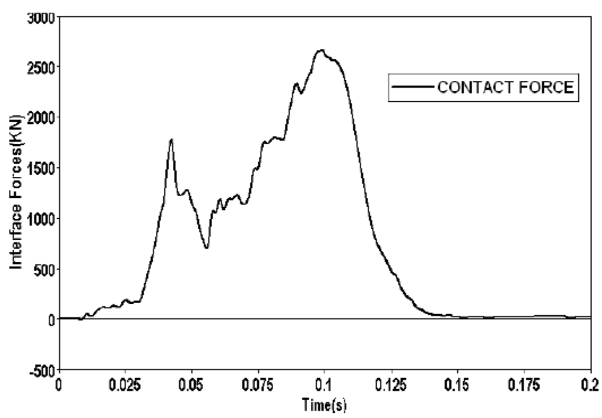

Figure 9. Contact force between truck and road blocker

are shown in Figure 10. The maximum acceleration of about 90g being at about 80 ms. During this crash period the engine contacts the top frame of the road blocker for a period from about 70 ms to 100 ms. This is during the time when the highest force and highest acceleration are recorded in the crash event.

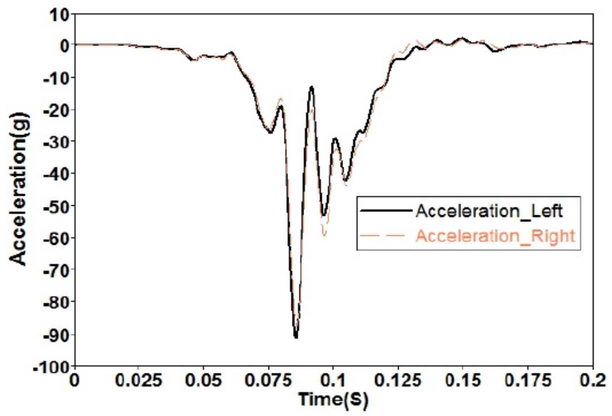

Figure10. Accelerations of cabin in baseline model

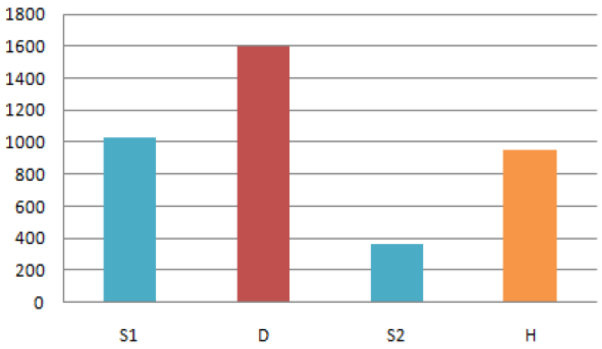

Figure 11. Comparisons of the movements and critical condition under baseline condition

The upward and forward displacements from the wheel centre reached 365 mm and 1030 mm respectively as shown in Figure 11. From these result it is obviously seem that the critical condition for intrusion have not been compromised. Therefore, the road blocker has performed successfully preventing the truck intrusion according to the requirement of PAS 68:2010.

7. Conclusions

A numerical study on the anti-ram performance of a K12 road blocker subjected to an N2 truck was successfully performed according to PAS 68:2010. The main factors influencing the road blocker anti-intrusion performance were determined based on specified impact velocity of 64 km/h. The general crash behaviour related to absorbed energy, structural deformation, acceleration and truck movement have been analysed so as to guide the design of a road blocker.

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