STUDY ON THE SAFETY PERFORMANCE OF THE REAR SAFETY GUARD WITH AIR BAG FOR TRUCK

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ABSTRACT

Although the Korea government promotes the movement of safe traffic to reduce deaths in traffic accidents, the number increases every year.

Especially more and more accidents and casualties are reported from the cases of car collision to the back of the vehicles parked for managing car accident on road, cleaning of main roads, side roads and medial strip, and road repair.

Therefore, it has been along that the government should be responsible for taking a protective measure for road users.

71 cases have been reported to occur during highway repair and maintenance. As the result, 8 were dead and 76 were injured, showing the death rate of 11.3%, which is quite high.

So it seems urgent to take some action against it.

America and European countries legislate that vehicles of road repair and maintenance should be mandatorily equipped with shock absorber on car but our country lacks in a legislative measure, which is asked to be done.

Accordingly, this study compares the performance standards of shock absorber for road maintenance vehicle by applying country to establish the criteria.

In addition, it tries to interpret in theory the Rear Safety Guard using Air Bag and compare the safety performance test of a vehicle with the Rear Safety Guard manufactured in accordance with related laws and that using Air Bag.

Based on the result of the safety performance on the 60km/h Rear collision Test, this study proposes improvement in related regulations and laws in an attempt to reduce collision and death by proposing the Traffic Injury Prevention effect of the Rear Safety Guard using Air Bag.

INTRODUCTION

Deaths & casualties by vehicles are getting grow though government provide more developed safety standard in order to reduce them.

Especially, rear-end collisions to the working trucks on the road, which are on cleaning road, treating accident or road maintenance, cause fatal injuries.

That's why social responsibilities for them has been issued since long time ago.

For the last 10 years, 71 cases of rear-end collisions to the working trucks in the highway have incurred, of which 8 persons were dead, 76 persons were injured, which shows remarkable 11.3% of death rate. Accordingly, we need to take urgent measurement against them.

Especially, Under-ride accident, which means rear-end collision car burrow down beneath under working truck, cause fatal influence to the passenger life.

Nowadays, it is compulsory to install Rear Safety Guard in order to prevent such under-ride accident.

It is possible to prevent under-ride accident if Rear Safety Guard is installed as per current installation intensity standard. However, it regulates only shock absorption which may cause fatal shock to the passenger.

This Study issues necessity of regulation amendment to reduce passenger casualties and guides characteristics of shock absorption Rear Safety Guard. In order to provide comparison data, we make use of both Airbag Rear Safety Guard and the Conventional Rear Safety Guard in the performance test of rear collision with 60km/h velocity.

STRUCTURE OF REAR SAFETY GUARDAND THEORETICAL CONSIDERATION

Structure of Rear Safety Guard

Comparing structure of both Rear Safety Guards, the Conventional Rear Safety Guard has cross section of quadrangle beam and Airbag Rear Safety Guard is consist of Control Case and Borer fixed bracket. Control Case prevents rebound of rear-end collision vehicle with air occupied space using TPU (Thermoplastic Polyurethane).

Therefore, difference between the both Rear Safety Guards is, the Conventional Rear Safety Guard has only quadrangle beam to endure loading specified installation intensity by standard, however, Air bag Rear Safety Guard consist of rear Bracket enduring loading specified by standard, at the same time, air in the TPU absorbing 1st shock by TPU Elongation & Control case under low velocity and Borer absorbing 2nd shock by emitting air, simultaneously, minimizing rebound of rear-end collision vehicle.

Air bag Crush Movement Theory

The follows theoretical formula becomes as follows

A body, which has mass m with initial velocity V_0, drops toward an elastic body.

Assume that the deformation of an elastic body is one-dimension and the material is compressible in order to make a formula for describing the moving of a colliding body.

σ is true stress and ε is true strain.

$$\sigma = f(\varepsilon),\ \varepsilon = \ln \frac{l}{l_0}$$

l_0 is the initial thickness of an elastic body, and l is the thickness after deformation.

$$F = \sigma A = f(\varepsilon) A$$

Volume changes after deformation because an elastic body is compressible

$$\alpha A_0 l_0 = A l$$

α is the rate of volume, A_0 is the initial area of deformation, and A is the area after deformation.

If $l_0 - l = x$, then $A = \alpha \frac{l_0}{l_0 - x} A_0$

$$F = \alpha f(\varepsilon) \frac{l_0}{l_0 - x} A_0$$

Therefore, the momentum equation of the colliding body is

$$m \frac{d^2 x}{dt^2} = -\alpha f(\varepsilon) \frac{l_0}{l_0 - x} A_0$$

Considering the effect of gravity, the equation is as follows

$$m \frac{d^2 x}{dt^2} = -\alpha f(\varepsilon) \frac{l_0}{l_0 - x} A_0 + mg \text{ Formula of(1)}$$

Two initial conditions are necessary to solve the above equation. In case of small deformation, we can rewrite equation as

$$\frac{l_0}{l_0 - x} \cong 1$$

$$f(\varepsilon) = E\varepsilon = E\ln(\frac{l_0}{l_0 - x}) \cong E\frac{x}{l_0}$$

If we neglect the effect of gravity

$$m\frac{d^2x}{dt^2} = -\alpha E\frac{x}{l_0}A_0 \text{ Formula}$$

Formula of (2)

If we solve the equation (2) with two initial conditions, $x(0) = 0$ and $\frac{dx}{dt} = V_0$

The formula becomes as follows

$$x(t) = V_0\sqrt{\frac{ml_0}{\alpha EA_0}}\sin\sqrt{\frac{\alpha EA_0}{ml_0}}t$$

And equation (1) becomes

$$F = m\frac{d^2x}{dt^2} = -V_0\sqrt{\frac{\alpha EmA_0}{l_0}}\sin\sqrt{\frac{\alpha EA_0}{ml_0}}t$$

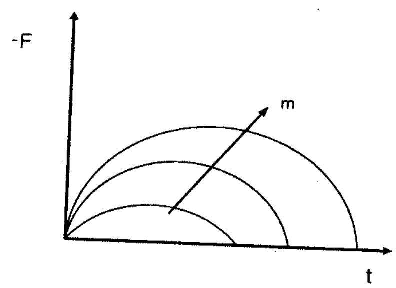
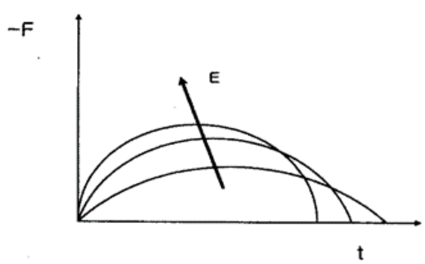


Figure 1. F-t curve in the mass of the colliding body increase



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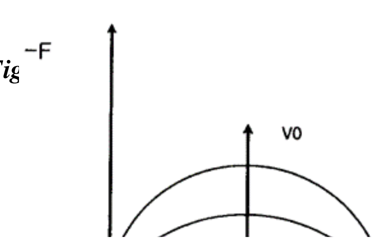

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We can recognize that the relation between force and time is sine curve. Let us consider the effect of several variables.

The more the mass of the colliding body increases, the more the magnitude of the force and the period increase. When the elastic modulus increases, the force increases and the period become shorter.
When the initial velocity increases, the force increases, but the period stays same.

A body, which has mass m with initial velocity V0, drops toward an elastic body. Assume that the deformation of an elastic body is one dimension and the material is compressible in order to make a formula for describing the moving of a colliding body. σ is true stress and ε is true strain drops toward an elastic body. Assume that the deformation of an elastic body is one-dimension and the material is compressible in order to make a formula for describing the moving.

The tensile strength of the thermoplastic polyurethane is 440 kgf/cm² and the tensile stress(at 300% elongation) is 260 kgf/cm².

TEST AND CONSIDERATION

Test Facility

Collision test facility strictly follows clause No. 102 evaluation on passenger protection at the time of collision of Vehicle safety standard.

Towing collision test facility was made to test 60km/h velocity of collision.

Figure1, Figure2 shows collision test facility and test method respectively.

Test standard is Head-on center impact of Figure.2 (a).

Figure 4-(a). Cable Draw Type collision Test Equipment

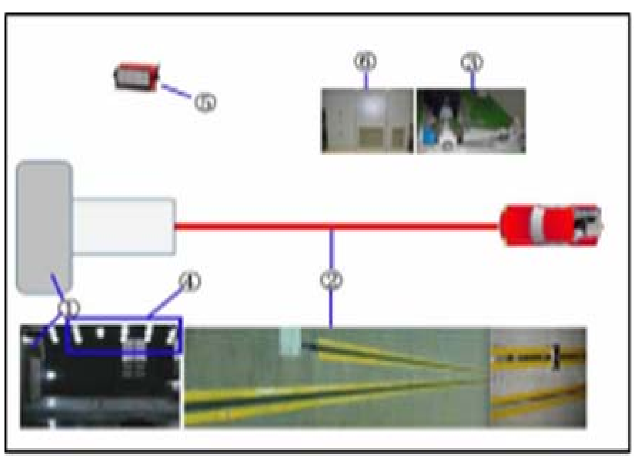
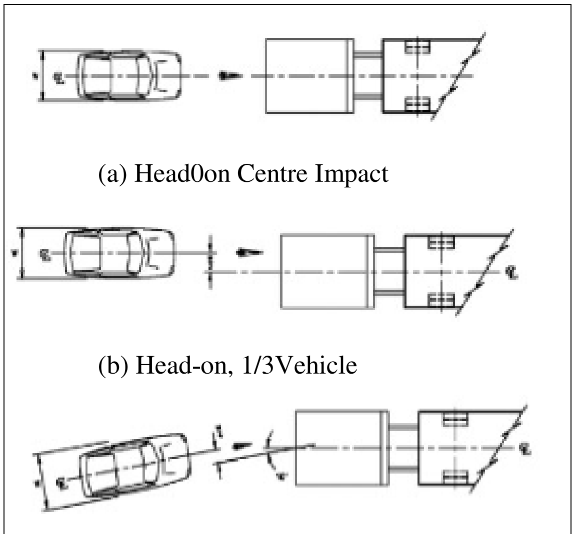


Figure4-(b).System diagram.

(Note)
①Collision test facility for this Study consists of fixed collision wall
② Driving road
③ Driving motor
④ Lighting facility
⑤ Data accumulator
⑥ Control unit



(a) Head0on Centre Impact

(b) Head-on, 1/3Vehicle

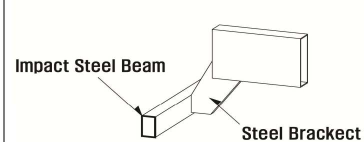
(c) Nose1/4 Offset, at 10°

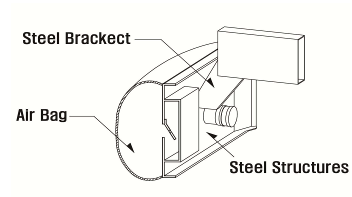
Figure5. Test standard for crash absorption facilities

Testing

<u>Collision testing</u> This is to find shock absorption performance of the Conventional Rear Safety Guard and mobility of rear-end collision vehicle at right after collision. We designed both types of Rear Safety Guard to meet the conditions of rear-end collision vehicle. Table.1 shows types of test specimens for trial impact tests.

Table1
A kind of test specimens for trial impact test

Specimens		Section(size)
Conventional Rear Safety Guard	NO.1	

Air Bag Rear Safety Guard	NO.2	

(Note) NO.1 : Steel impact beam + steel structure bracket
NO.2 : Air Bag impact cushion + Steelimpact structure + Steel structure bracket

The characteristics of respective tests are that fundamental structures of the both types of Rear Safety Guard are same.

However, Airbag Rear Safety Guard is assembled by air injected airbag. Those airbag's material, size, pressure, part price and weight are being studied through structure analysis and accurate testing.

Once it is accomplished, various types of products will be produced, which are able to meet each types of test.

Collision test Test performance of high speed rear-end collision tests follows American NCHRP Report 350 standard Shock Absorption Facility Test and U.K Design Manual for Roads and Bridges(TD49/07,Volume8 Section4, Part7), Requirements for Mounted collision Cushions standard. And 60km/h rear-end collision performance test was done in order to find collision performance of the both types of Rear Safety Guard.

Ten (10) tons of truck manufactured in 2003 for test installed both types of Rear Safety Guards with its total weight of 10,340kgs and midsized sedan of its weight of 10,340kgs was also used for rear-end collision vehicle.

The testing started that midsized sedan collided truck with Conventional Rear Safety Guard. After collision, its Conventional Rear Safety Guard was replaced with Airbag Rear Safety Guard for retesting. Same collision test method was applied to the Airbag Rear Safety Guard truck.

The test vehicle was installed with data accumulator inside test vehicle, acceleration meters at X,Y,Z axis and yaw sensor.

Tape switch for lighting was installed to sense impact at collision point.

500f/s high speed digital camera and video camera installed at left, right and upper right in order to record collision. Fig.3 shows collision test.

Figure6. The scene of the car collision test ofRear Safety Guard for 10ton Truck.

ANALYSIS AND CONSIDERATION

As follows Fig 7, Fig 8, Fig 9 Fig 10 showed that the 60km/h rear-end collision performance test results for both types of Conventional Rear Safety Guard and Air Bag Rear Safety Guard.

This study practical use evaluation standards is THIV 44km//h, PHD 20g, ASI 1.9G

The analysis for passenger protection performance index data by 60km/h collision performance test shows, at first, according to the test of Conventional Rear Safety Guard equipped truck, Yaw sensor detected data was maximum of +112.5˚ at 0.23 second and minimum of -51˚ at 0.24 second, and, acceleration index (ASI) was 50msec at composition of x,y,z axis direction, it was maximum 1.3(G'S) at 0.1890 ~ 0.239 second according to analysis result.

Theoretical Head Impact Velocity (THIV) shows 35.1km/h at 0.2149 second, which is synthesized value of x, y axis, and Post-Impact Head Deceleration (PHD) shows 17.1(G'S) at 0.2269~0.2369second, which is 10m second average synthesized value of x,y direction.

At second, in case Airbag Rear Safety Guard was installed, Yaw sensor detected data was maximum of -50° at 0.16 second and minimum of +19° at 0.45 second, and, Acceleration Severity Index (ASI) was 50msec at composition of x, y, z axis direction, it was maximum 0.9(G'S) at 0.0199~0.0609 second according to analysis result.

Theoretical Head Impact Velocity (THIV) shows 28.9km/h at 0.1269 second and Post-Impact Head Deceleration (PHD) shows 8.4(G'S) at 0.1269~0.1369second.

As follow in brief for above mentioned test data.

The results of data analysis, in case of Conventional Rear Safety Guard, shows Yaw effect based on z axis sharply rotate around 100~150° to the + direction at 0.15~ 0.25 second, however, in case of Airbag Rear Safety Guard, it shows 11~50° to the - direction at 0.15~ 0.25 second.

Especially, in case of Conventional Rear Safety Guard, it absorb collision force 0.10~ 0.20 second after collision, however, in case of Airbag Rear Safety Guard, it absorb whole collision force at the same time of collision.

From the under-ride's view, in case of Conventional Rear Safety Guard, passenger may have severe casualty because rear-end colliding car burrow down beneath under working truck, however, in case of Airbag Rear Safety Guard, passenger may have much less casualty because collision absorption occurs at the early time of collision.

The current regulation on Rear Safety Guard specifies to certify structure rigidity through only component test, which is revealed to be lack of prevention for the passenger casualties.

So, it is necessary to amend regulations on structure and test evaluation method of Rear Safety Guard because Rear Safety Guard bracket structure rigidity should be improved to prevent submarine effect by under-rider at collision.

Furthermore, there is no collision absorption performance standard.

So,we recognized that not only evaluation standards for injury THIV,PHD, ASI but also under ride situation level is should be provision of safety regulation.

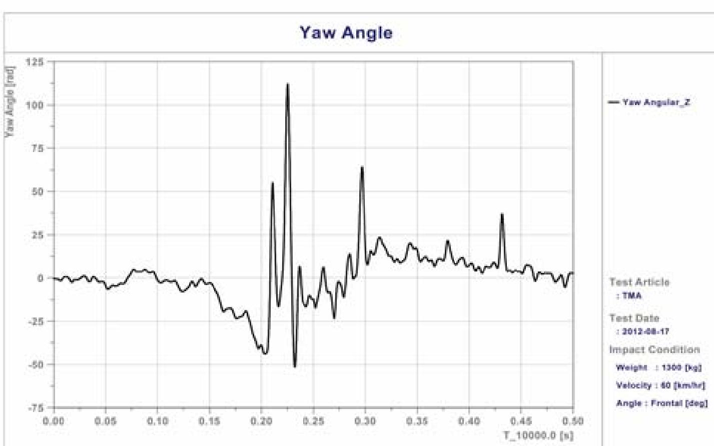


Figure7-(a). YAW data-Conventional type installed

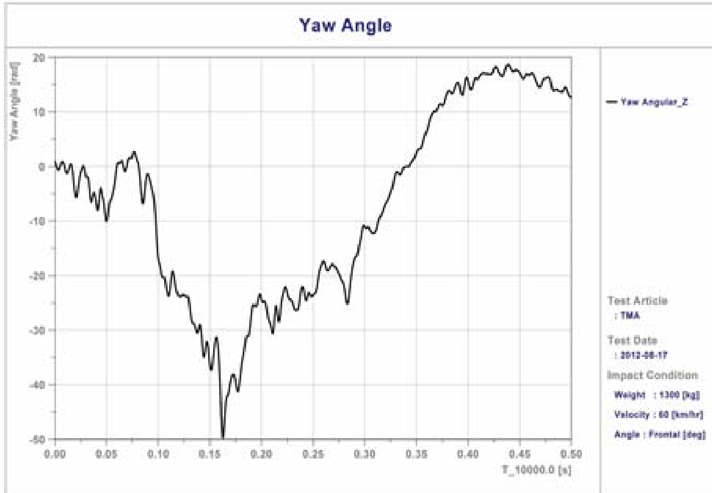


Figure7-(b). YAW data-Air bag type installed

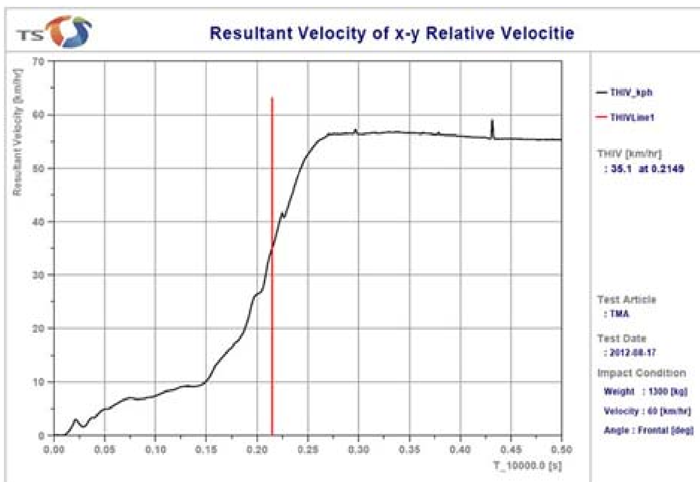


Figure8-(a). THIV data- Conventional type installed

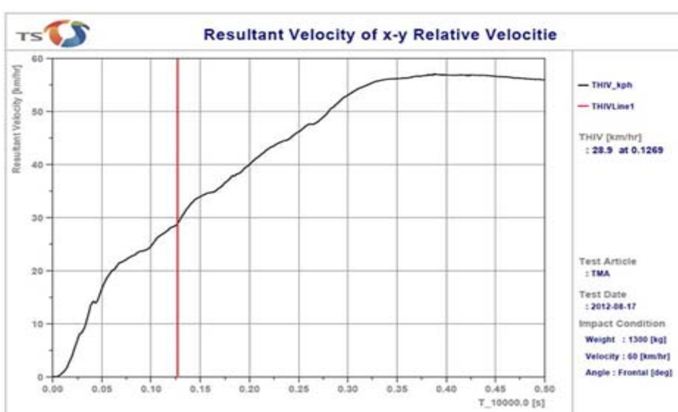


Figure8-(b). THIV data-Air bag type installed

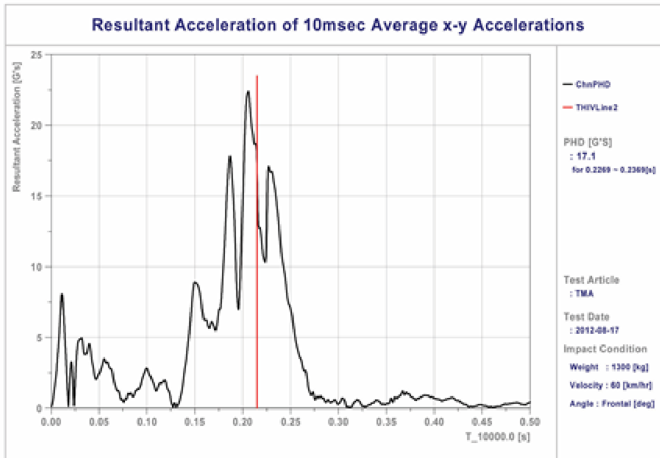


Figure9-(a). PHD data- Conventional type installed

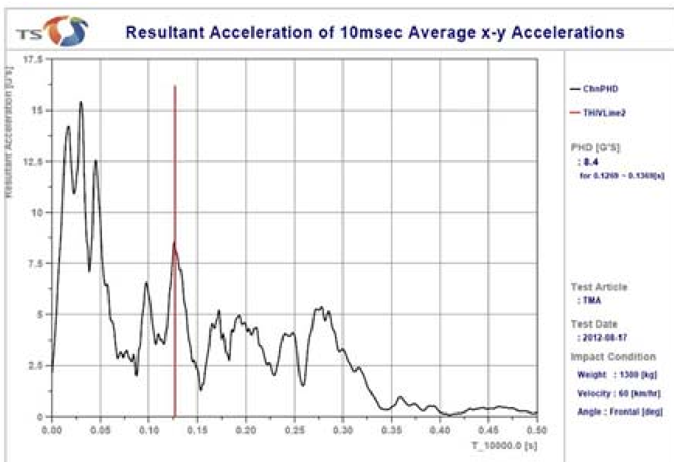


Figure9-(b). PHD data-Air bag type installed

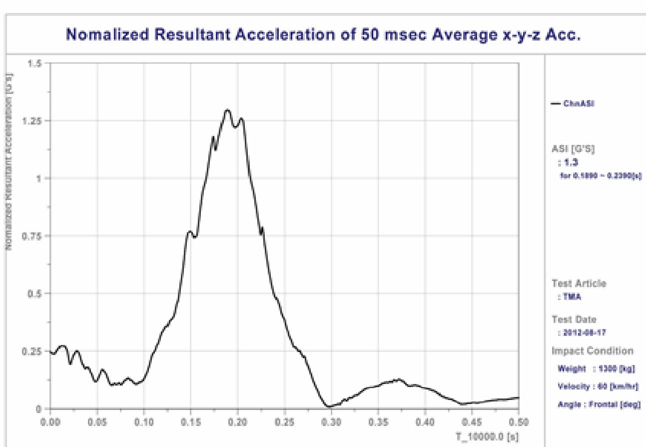


Figure10-(a). ASI data- Conventional type installed

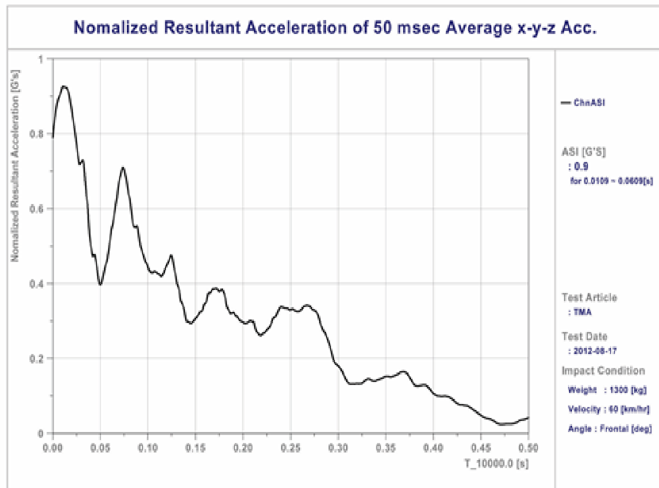


Figure10-(b). ASI data-Air bag type installed

CONCLUSIONS

We have considered the related regulation to improve Rear Safety Guard. And, the analysis results of 60km/h rear-end collision performance test by installing both types of Rear Safety Guard are as follows.

1) Rear-end collision performance test of both types of Rear Safety Guard shows that Airbag Rear Safety Guard inferior 12% of THIV, 49% of PHD and 69% of ASI to them of Conventional Rear Safety Guard.

2) Mobility of rear-end collision vehicle at collision shows that Airbag type of Rear Safety Guard equipped vehicle less burrowed down beneath truck due to less Under-ride effect. Accordingly, airbag Rear Safety Guard with polyurethane revealed to much reduce passenger casualty.

3) Rear-end collision vehicle equipped with Conventional Rear Safety Guard burrowed down beneath the truck up to front window of rear-end collision vehicle because Conventional Rear Safety Guard couldn't absorb collision force.

It means that it is difficult for Conventional Rear Safety Guard to prevent passenger casualty. Therefore, structure rigidity and evaluation method for passenger casualty such as THIV, PHD and ASI should be improved by adopting Truck Mounted Attenuator (TMA) evaluation method.

4) Need to provision that the under ride situation levels on Rear-end collision vehicle because of cause to reduce deaths in traffic accidents,

5) We can recognize that Air Bag Truck Mounted Attenuator (TMA) is superiority absorbing performance on collision base on the showed similar trend for the Air Bag Theoretical Formula and 60km/h rear-end collision test result of complete vehicle attached Air Bag Truck Mounted Attenuator (TMA).

Hence, it is possible that reduce deaths traffic accidents on rear and the other dictions collision, in case of the much more study to commercialize and improvement of quality for Air Bag Truck Mounted Attenuator (TMA).

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DefinitionS/AbbreviationS

ATMA Air Bag Truck Mounted Attenuator
THIV Theoretical Head Impact Velocity
PHD Post-Impact Head Deceleration
ASI Acceleration Severity Index