DEVELOPMENT OF MOVING DEFORMABLE BARRIER IN JAPAN - PART 2 -

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ABSTRACT

The reduction of occupant injury to side collision is a major subject worldwide.

Extensive research into this subject is now being carried out, mainly in the US, Europe and Japan. As a result, vigorous discussion has come out during various types of international conferences promoting international conformity such as WP29/GRSP, ISO and ESV International Conference.

However, international harmonization of test method has not yet been attained. The US method and European-Japanese methods are different in Moving Deformable Barrier (MDB), the dummy and the injury criteria.

Japanese developed barriers are made mainly of an aluminum honeycomb structure and proved to be of high repeatability in the calibration tests which are the test procedure for Japanese Safety Standard scheduled to be issued on October 1998.

INTRODUCTION

In October 1998 it was decided to be introduced and be put into effect the ECE Reg.95 side impact test procedure in Japan. In this side impact test procedure, the MDB simulating a colliding vehicle strikes the side of a test vehicle. An absorbing material called a deformable barrier is attached to the front of the MDB. The specifications of the deformable barrier, e.g. dimensions, dynamic deflection characteristics, which correspond to those of the typical passenger vehicle, have been set forth. There are, however, no satisfactory dynamic deflection characteristics in the deformable barriers, which have been developed up to the present time, both domestically and outside of the country. If the deformable barrier is left as is, the execution of the testing is likely to be hindered. Therefore, the development of a new deformable barrier is a matter of great urgency.

The deformable barrier used in the past studies for developing side impact test procedure in Japan fails in satisfactorily meeting the performance required for part of the force deflection characteristics. The authors have already reported about this deformable barrier in 15th-ESV International Conference, etc.

Based on the foregoing, a new deformable barrier, which perfectly satisfies the performance required for the calibration test, has been developed. This paper reports on the structure of this recently developed deformable barrier and its calibration test results.

OUTLINE OF THE SIDE IMPACT TEST

Existing methods are the US method (FMVSS 214) and the European method (ECE Reg.95) for the side impact test procedure. Of these methods, Japanese government decided to adopt the ECE Reg.95. The outlines of the test procedure and calibration test for the deformable barrier in ECE Reg.95 are briefly explained here.

Test Configuration

In the ECE Reg.95 test, a MDB, as shown in Figure 1, is applied to collide at an impact velocity of 50 km/h with the side of a standstill test vehicle. The MDB collides laterally at right angles to the test vehicle. The weight of the MDB is designed to be 950 kg including the deformable barrier, measuring instruments, and the like. The collision position is designed so that the centerline of the MDB coincides with the R-point (a hip point when a sheet is set at the rearmost position). The height of the deformable barrier is designed so that the lower end thereof has a ground clearance of 260 mm (300 mm in future). The dummy used for the side impact test is the EUROSID-1, which is mounted on the front seat on the collision side (generally the driver's seat).

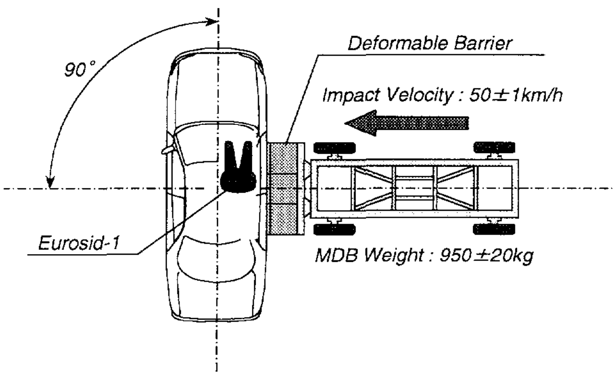


Figure 1. Test configuration of ECE Regulation No.95.

Requirements

Items evaluated for injuries on the dummy, as shown in Table 1, are stipulated by a Head Performance Criterion (HPC, corresponding to a HIC in the frontal impact test), Rib Deflection Criterion (RDC), Abdominal Peak Force (APF), and Pubic Symphysis Peak Force (PSPF). As the criteria for each item, the HPC is 1,000 or less in the same manner as HIC in the frontal impact test, RDC is 42 mm or less, APF is 2.5 kN or less, and PSPF is 6.0 kN or less. In addition to these items, it is expected that in Europe, the Viscous Criterion (V*C) will be adopted in future with the planned criterion being 1.0 m/s or less.

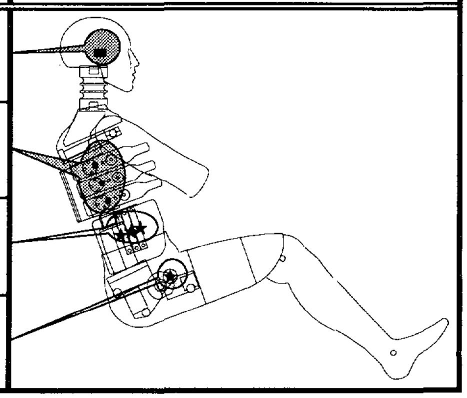
Evaluation items for the body of the vehicle include occurrence of opening of the door during collision, door-opening capability after collision, rescue operability for the dummy, and occurrence of fuel leakage.

Calibration Method for Deformable Barrier

The deformable barrier has a structure of six segments consisting of a matrix of two rows and three columns of blocks. The dimensions of the deformable barrier are width and height 1,500 mm and 500 mm respectively. The depths of the lower blocks and upper blocks are 500 mm and 440 mm respectively. Therefore, a projection corresponding to a bumper is 60

Table 1.

Injury Criteria of ECE Regulation No.95

Body Segment	Name of Injury Criteria	Standard Value	Measuring Point
Head	HPC (Head Performance Criterion)	less than 1000	
Thorax	RDC (Rib Deflection Criterion)	less than 42 mm	
Abdomen	APF (Abdominal Peak Force)	less than 2.5 kN	
Pelvis	PSPF (Pubic Symphysis Peak Force)	less than 6.0 kN	

mm in length. These dimensions were determined based on investigative results from European vehicles using 1976 models. Based on the investigative results, the dynamic force-deflection characteristics were also determined. In addition, the investigation on Japanese vehicles using 1993 models resulted in the same dimensions and force-deflection characteristics.

In ECE Reg.95, a barrier impact test as shown in Figure 2 is defined as a deformable barrier calibration test. In this calibration method, a MDB weighing 950 ±20 kg is collided at an impact velocity of 35±2 km/h with a rigid barrier equipped in six surface segments with load cells. The calibration results are evaluated by the force- deflection characteristics and dissipated energy of the total barrier and each blocks, and the permanent deflection of the middle intersecting surface of the lower blocks (Level B) as shown in Table 2. In this test procedure, discrepancy of the impact point is required to be within ±10 mm in both vertical and lateral directions to obtain the correct characteristics of the blocks.

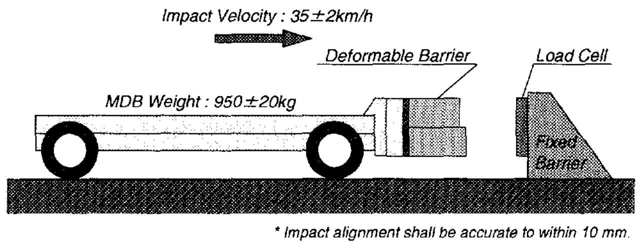
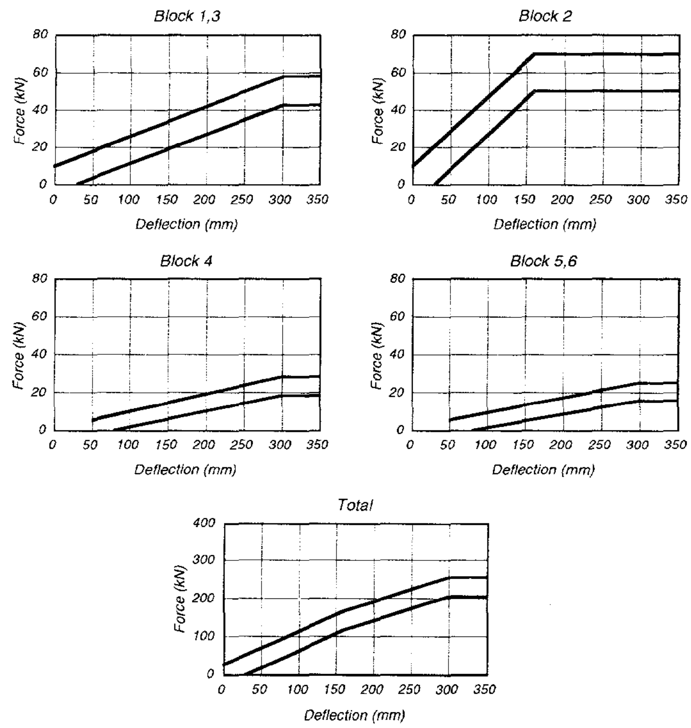


Figure 2. Calibration test configuration of ECE Regulation No.95.

Table 2.
The Requirement Characteristics of Deformable Barrier for ECE Regulation No.95

Dissipated Energy		Force-Deflection Characteristics
Block 1 (kJ)	10±2	
Block 2 (kJ)	14±2	
Block 3 (kJ)	10±2	
Block 4 (kJ)	4±1	
Block 5 (kJ)	3.5±1	
Block 6 (kJ)	3.5±1	
Total (kJ)	45±5	
Deflection of Level B (mm)	330±20	

DEVELOPMENT OF DEFORMABLE BARRIER

The development of the deformable barrier was carried out by JAMA/JARI in collaboration with the Showa Aircraft Industry Co., Ltd. and The Yokohama Rubber Co., Ltd. The deformable barrier with the following characteristics was designed.

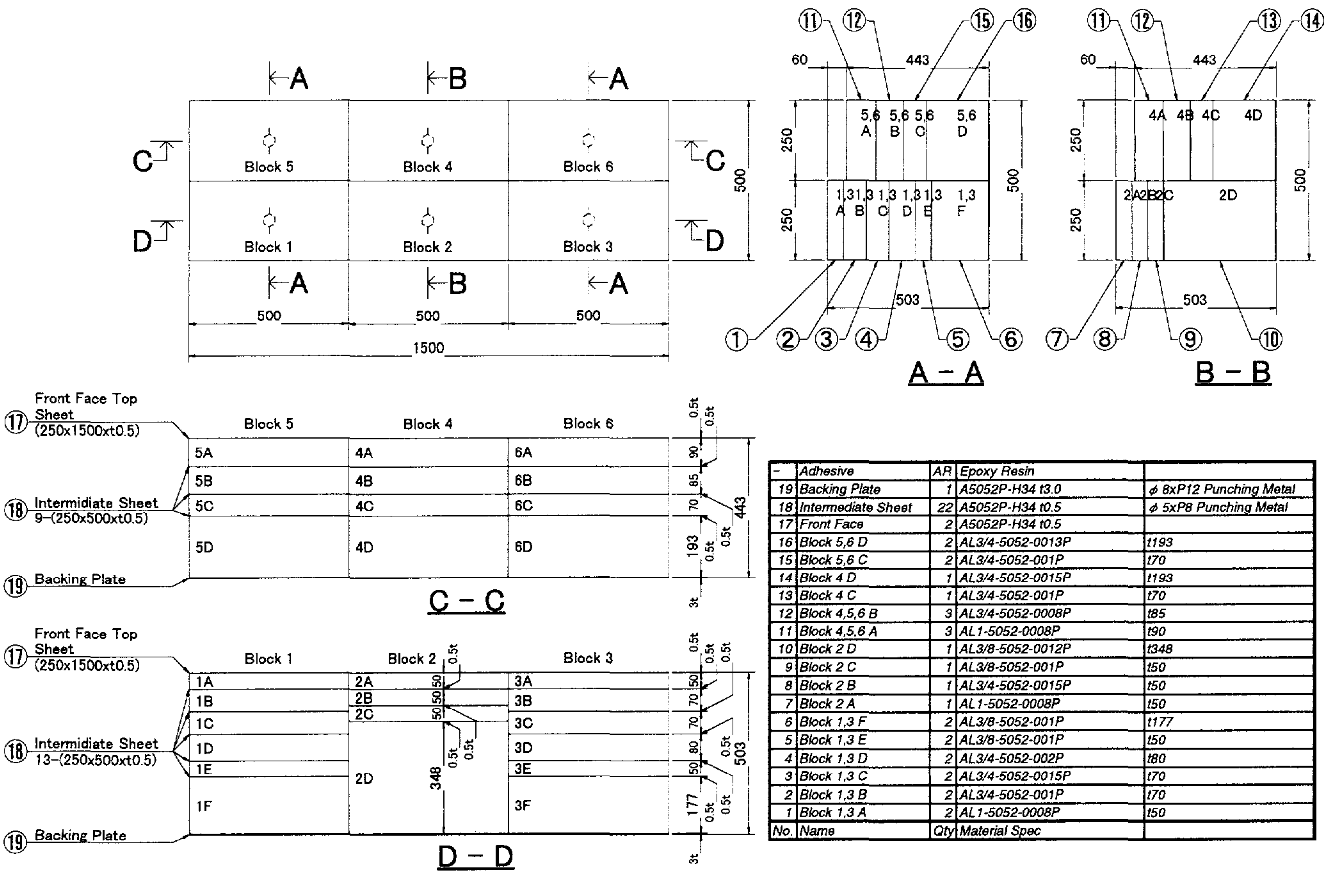
- Superior reproducibility.
- Easiness in observation of deflection mode after collision.
- Stable performances against temperature, humidity, etc.
- Light weight, easily handled.

Structure of Deformable Barrier

The deformable barriers, which have been developed both domestically and outside of the country so far are classified into three types, specifically, a hard formed urethane, pyramid shaped aluminum honeycomb, and multi-layered aluminum honeycomb.

As is confirmed from the experience of conducting side impact tests so far, the hard forming urethane deformable barrier breaks into pieces during collision so that the deflection mode cannot be analyzed and the characteristics greatly change with changes in environmental conditions. The pyramid shaped honeycomb deformable barrier produces differences in the results of injuries in the dummy, depending on the position of collision. Based on these results, the aluminum honeycomb was selected as the material and a multi-layered structure was designed to develop a deformable barrier.

Deformable Barrier Developed by Showa Aircraft Industry Co., Ltd. – The structure of a deformable barrier developed by the Showa Aircraft Industry Co., Ltd. is shown in Figure 3. This

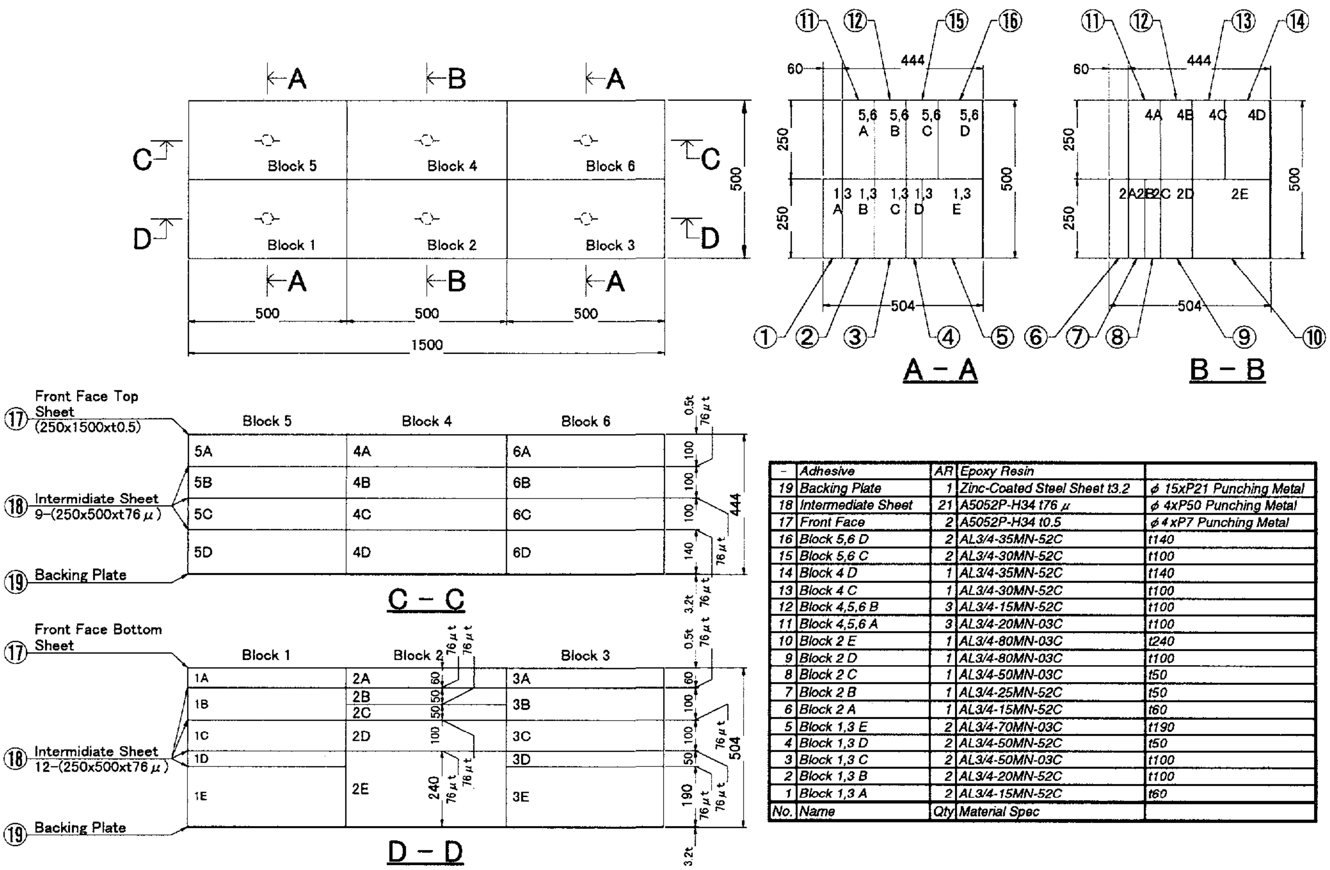


-	Adhesive	AR	Epoxy Resin	
19	Backing Plate	1	A5052P-H34 t3.0	ϕ 8xP12 Punching Metal
18	Intermediate Sheet	22	A5052P-H34 t0.5	ϕ 5xP8 Punching Metal
17	Front Face	2	A5052P-H34 t0.5	
16	Block 5,6 D	2	AL3/4-5052-0013P	t193
15	Block 5,6 C	2	AL3/4-5052-001P	t70
14	Block 4 D	1	AL3/4-5052-0015P	t193
13	Block 4 C	1	AL3/4-5052-001P	t70
12	Block 4,5,6 B	3	AL3/4-5052-0008P	t85
11	Block 4,5,6 A	3	AL1-5052-0008P	t90
10	Block 2 D	1	AL3/8-5052-0012P	t348
9	Block 2 C	1	AL3/8-5052-001P	t50
8	Block 2 B	1	AL3/4-5052-0015P	t50
7	Block 2 A	1	AL1-5052-0008P	t50
6	Block 1,3 F	2	AL3/8-5052-001P	t177
5	Block 1,3 E	2	AL3/8-5052-001P	t50
4	Block 1,3 D	2	AL3/4-5052-002P	t80
3	Block 1,3 C	2	AL3/4-5052-0015P	t70
2	Block 1,3 B	2	AL3/4-5052-001P	t70
1	Block 1,3 A	2	AL1-5052-0008P	t50
No.	Name	Qty	Material Spec	

Figure 3. The structure and the configuration of the deformable barrier developed by Showa Aircraft Industry Co., Ltd.

deformable barrier is a modification of the deformable barrier which was reported at the 15th-ESV International Conference. As shown in Figure 3, the deformable barrier incorporates 4 to 6 layers of a honeycomb block of different cell size and foil thickness. The aluminum honeycomb is stretched in the lateral direction when the deformable barrier is fabricated. The aluminum honeycomb material is AL5052, which is commonly used in Japan. Each honeycomb block is pre-crashed by 5 mm so that the initial peak of the aluminum honeycomb in a collision is eliminated. The honeycomb blocks are attached to each other using an epoxy resin based adhesive through an aluminum punching sheet with a length of 250 mm, width of 500 mm, and thickness of 0.5 mm with 5mm diameter holes as the intermediate sheet. Also used are an aluminum punching plate with a length of 500 mm, width of 1,500 mm, and thickness of 3 mm with 8 mm diameter holes, as the back plate. And two aluminum plates with a length of 250 mm, with of 1,500 mm, and thickness of 0.5 mm as the front plate. The weight of this deformable barrier is as low as about 17 kg because all materials forming the deformable barrier are aluminum.

Deformable Barrier Developed by The Yokohama Rubber Co., Ltd. – A deformable barrier developed by The Yokohama Rubber Co., Ltd. is shown in Figure 4. The deformable barrier is basically the same as that developed by the Showa Aircraft Industry Co., Ltd. However, each honeycomb, which differs from that manufactured by the Showa Aircraft Industry Co., Ltd., has the same cell size. Changing the foil thickness and aluminum materials controls the characteristics. The aluminum honeycomb is stretched in the vertical direction when the deformable barrier is fabricated. Two types of aluminum materials, specifically, AL5052 and AL3003 are used as the aluminum honeycomb material. Each honeycomb



–	Adhesive	AR	Epoxy Resin	
19	Backing Plate	1	Zinc-Coated Steel Sheet t3.2	ϕ 15xP21 Punching Metal
18	Intermediate Sheet	21	A5052P-H34 t76 μ	ϕ 4xP50 Punching Metal
17	Front Face	2	A5052P-H34 t0.5	ϕ 4xP7 Punching Metal
16	Block 5,6 D	2	AL3/4-35MN-52C	t140
15	Block 5,6 C	2	AL3/4-30MN-52C	t100
14	Block 4 D	1	AL3/4-35MN-52C	t140
13	Block 4 C	1	AL3/4-30MN-52C	t100
12	Block 4,5,6 B	3	AL3/4-15MN-52C	t100
11	Block 4,5,6 A	3	AL3/4-20MN-03C	t100
10	Block 2 E	1	AL3/4-80MN-03C	t240
9	Block 2 D	1	AL3/4-80MN-03C	t100
8	Block 2 C	1	AL3/4-50MN-03C	t50
7	Block 2 B	1	AL3/4-25MN-52C	t50
6	Block 2 A	1	AL3/4-15MN-52C	t60
5	Block 1,3 E	2	AL3/4-70MN-03C	t190
4	Block 1,3 D	2	AL3/4-50MN-52C	t50
3	Block 1,3 C	2	AL3/4-50MN-03C	t100
2	Block 1,3 B	2	AL3/4-20MN-52C	t100
1	Block 1,3 A	2	AL3/4-15MN-52C	t60
No.	Name	Qty	Material Spec	

Figure 4. The structure and the configuration of the deformable barrier developed by The Yokohama Rubber Co., Ltd.

block is also pre-crashed. The honeycomb blocks are attached using an epoxy resin based adhesive through an aluminum punching sheet with a length of 250 mm, width of 500 mm, and thickness of 76 μ m and with 4 mm diameter holes as the intermediate sheet. Also used are a steel punching plate which is zinc-plated and has a length of 500 mm, width of 1,500 mm, and thickness of 3.2 mm and with 15 mm diameter holes as the back plate. And two aluminum punching plates with a length of 250 mm, width of 1,500 mm, and thickness of 0.5 mm and with 4 mm diameter holes as the front plate. The weight of this deformable barrier is as low as about 22 kg, although it is heavier than that manufactured by the Showa Aircraft Industry Co., Ltd. because the steel plate is used as the back plate.

Test Results

The calibration tests were carried out twice for every deformable barrier and four times in total to

Table 3.
The Accuracy of the Calibration Test, the Dissipated Energy and the Deflection at the Level B

		Showa Aircraft Industry Co., Ltd.		The Yokohama Rubber Co., Ltd.		Requirement Value
Test No.		S1	S2	Y1	Y2	
MDB Weight (kg)		949	948	956	956	950±20
Impact Velocity (km/h)		35.1	34.9	35.1	35.0	35±2
Discrepacy of Impact Point (mm) *	Vertical	0	3	7	5	±10
	Lateral	-5	-2	0	3	±10
Disipated Energy (kJ)	Block 1	10.0	9.1	10.8	10.5	10±2
	Block 2	15.5	15.6	15.1	14.8	14±2
	Block 3	9.7	9.6	10.8	10.4	10±2
	Block 4	4.3	4.1	4.1	4.0	4±1
	Block 5	3.4	3.3	4.0	3.9	3.5±1
	Block 6	3.6	3.5	4.0	4.0	3.5±1
	Total	46.5	45.1	48.8	47.6	45±5
Diflection of Level B (mm)		325	320	328	328	330±20

* ; The vertical direction is positive to upper, and the lateral direction is positive to right.

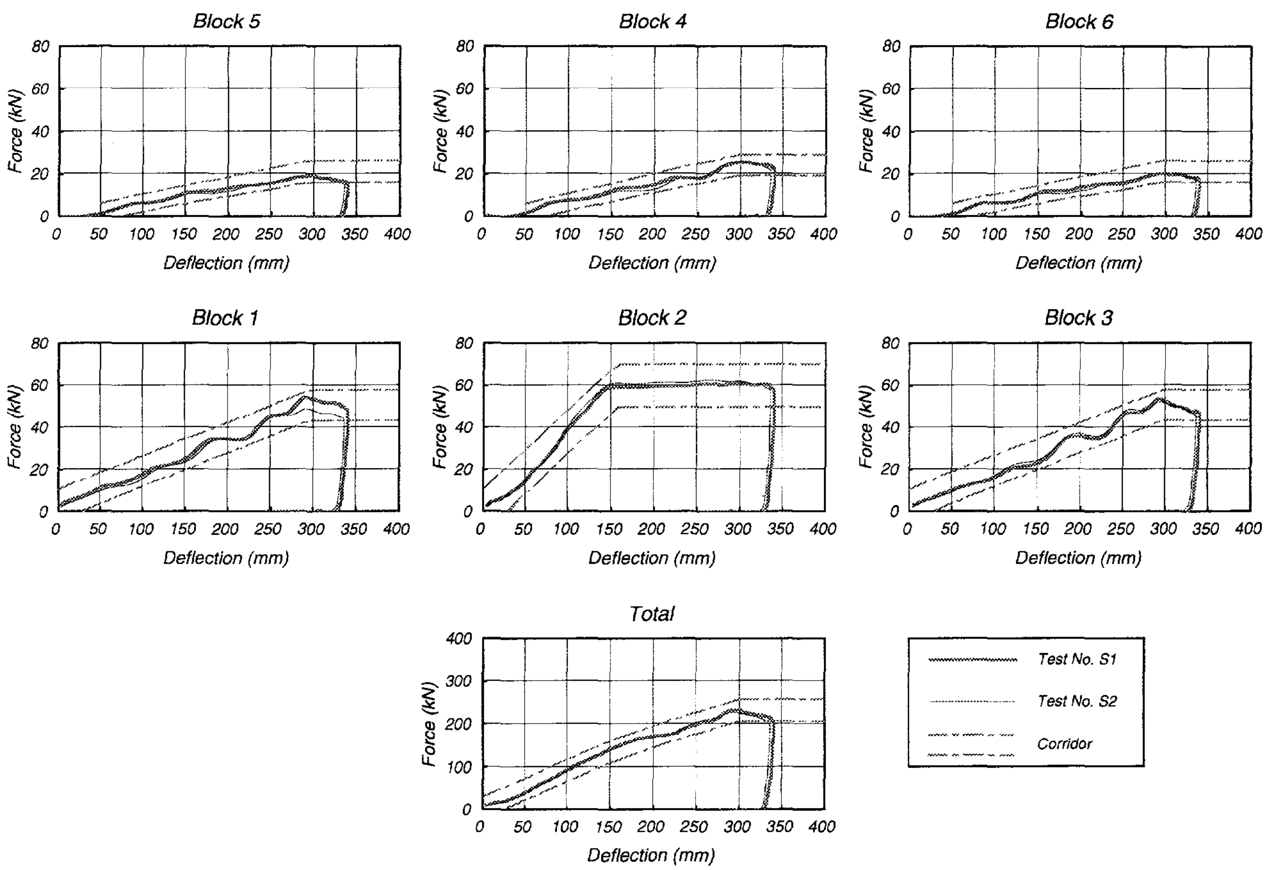


Figure 5. The force-deflection characteristics of the deformable barrier developed by Showa Aircraft Industry Co., Ild.

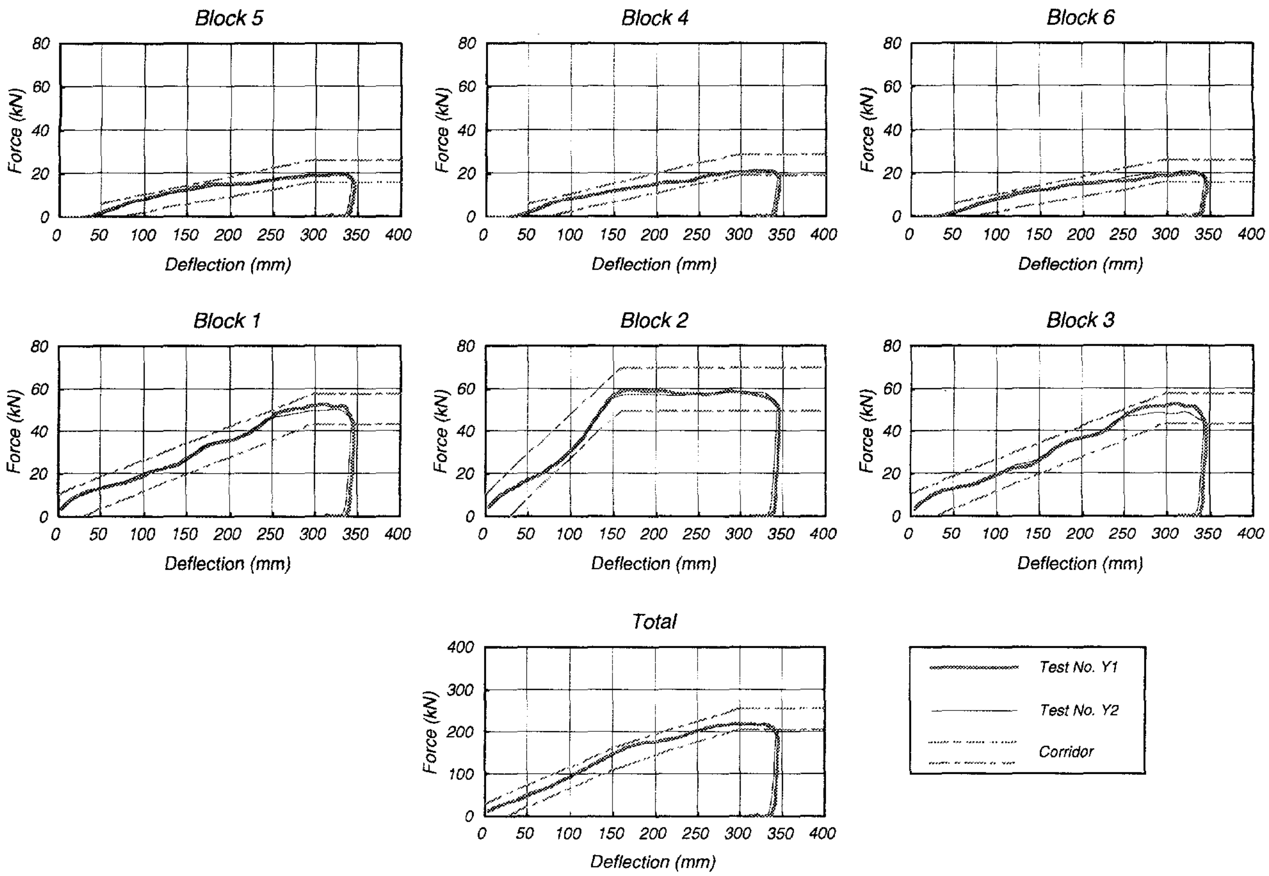


Figure 6. The force-deflection characteristics of the deformable barrier developed by The Yokohama Rubber Co., Ltd.

confirm the reproducibility. The accuracy of the calibration test, the amount of dissipated energy and the deflection at the level B are shown in Table 3. The force-deflection characteristics of the deformable barriers developed by the Showa Aircraft Industry Co., Ltd. and The Yokohama Rubber Co., Ltd. are shown in Figures 5 and 6 respectively.

As shown in Table 3, the results of the amount of dissipated energy and deflection at the level B also sufficiently satisfied the performance requirements. As for the reproducibility, the block 1 of the deformable barrier developed by the Showa Aircraft Industry Co., Ltd. showed some differences in the amount of dissipated energy but this will be no problem on a practical level.

As shown in Figure 5, the force-deflection characteristics of the deformable barrier of the Showa Aircraft Industry Co., Ltd. satisfies the performance requirements in all blocks. There were some differences in reproducibility when the deflection of the block 1 was above 275 mm but this was no problem on a practical level. Other blocks showed excellent results. Some segments of the deformable barrier which was reported at the 15th-ESV International Conference had characteristics which did not fall in the corridor above 320 mm. This improvement ensures that the characteristics of such segments also fall in the corridor.

As shown in Figure 6, the force-deflection characteristics of all blocks of the deformable barrier of The Yokohama Rubber Co., Ltd. satisfied the performance requirements. Although the characteristics of the upper blocks was near the upper limit of the corridor when the deflection was in a range from about 75 mm to 175 mm. Slight differences in reproducibility were observed in the blocks 1 and 2 when the deflection was in the vicinity of 300 mm. Excellent results were obtained as a whole.

SUMMARY

This time we developed a deformable barrier for a side impact test in collaboration with two domestic corporations to obtain the deformable barriers, which satisfied the performance requirements for the test procedure. This deformable barrier can also satisfy the design concept. The developed deformable barrier had sufficient reproducibility and the deflection mode after collision could be analyzed because of the use of aluminum honeycomb. Also, the deformable barrier had stable performance against temperature, humidity, etc., and had a weight as low as around 20 kg.

CONCLUSION

As mentioned at the beginning, a deformable barrier, which satisfies the performance required for the ECE Reg.95 has not yet been developed. Despite continued similar efforts to develop a deformable barrier in many foreign countries including Europe, there has been no report of success in the development of a deformable barrier which meets these requirements. The deformable barrier deficiently meeting the requirements which was developed through these studies in Japan could be applied in the fields of type approval tests or developments tests for new-model cars which will be implemented in the future.

There are signs that EEVC/WG13 in Europe will stipulate the structural requirements of the deformable barrier used in the ECE Reg.95. The ECE Reg.95 is a test procedure with almost the same content as the method which Japanese government will introduce. So Japanese government and JAMA will participate in this project with the consent of the EC commission. It is expected that the studies in Japan could advance after ascertaining the trend in Europe to develop a new deformable barrier as needed.

Finally, special thanks are also due to the Showa Aircraft Industry Co., Ltd. and The Yokohama Rubber Co., Ltd. for their valuable cooperation in the development of the deformable barrier.

REFERENCES

ECE Regulation 95, "Uniform Provisions Concerning the Approval of Vehicles with Regard to the Protection of the Occupants in the Event of a Lateral Collision".

NHTSA, "Final Regulatory Impact Analysis New Requirements for Passenger Cars to Meet a Dynamic Side Impact FMVSS 214".

EEVC Working Group, "Structure Improved Side Impact Protection in Europe", 9th ESV Conference, November 1982.

E.Chapoux, J.C.Jolys, R.Dargaud, "An Approach for the Design of a Deformable Mobile Barrier to Evaluate the Protection Afforded to Occupants of a Passenger Car Involved in a Side Collision", 9th ESV Conference, November 1982.

D.R.Gebbels, "The CCMC Mobile Deformable Barrier for Lateral Collision Testing", 10th ESV Conference, July 1985.

H.Ohmae, M.Sakurai, Y.Nakamura, K.Watanabe, "A Study on Energy-Absorbing Units of MDB for Side Impact Test", 11th ESV Conference, May 1987.

M.Ueno, H.Ohmae, T.Harigae, K.Satake, T.Yamaguchi, E.Fujiwara, "Development of Moving Deformable Barrier in Japan", 15th ESV Conference, No.96-S6-O-06, May 1996.

N.Esumi, K.Satake, H.Ohmae, T.harigae, M.Ueno, "Research Concerning Vehicle Occupant Protection for Lateral Collision – Accident Analysis of Lateral Collision and Vehicle Characteristics in the Japanese Market –", 15th ESV Conference, No.96-S6-O-02, May 1996.