3．3．5　交通安全施設に関する研究

DEVELOPMENT OF A BUFFER FENCE TO PROTECT CARS FROM DIRECT COLLISIONS WITH SUPPORTS

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ABSTRACT

Accidental collisions with support structures such as utility poles, signposts, and streetlight poles are more likely to be extremely serious than other kinds of accidents. One method of buffering collisions with such structures used in many countries is the breakaway structure that allows a pole to collapse when struck by a vehicle. This method has reduced damage to vehicles and injuries to their occupants caused by these collisions. But this structure is not suitable for narrow roads carrying heavy traffic where a collapsing pole might cause secondary injuries to third parties. This study was undertaken to develop a collision buffer fence (below called a "buffer fence") that prevents a car from directly colliding with a support structure or roadside trees (below called, "support structures") and to reduce injuries to a car's occupants during such a collision for use as a buffer measure for support structures installed beside narrow roads.

The first step in the study was to make the performance requirements of the buffer fence clear to decide the basic structure of a fence that satisfies these performance requirements. Next, the performance of the basic structure was analyzed by a dynamic simulation in order to make changes to resolve the structural problems it revealed and to clarify the structure that would ultimately satisfy all requirements. The structure of the buffer fence that was hypothesized was a small inconspicuous fence with length of 5,000 mm and height of 500 mm considering the need to construct it in limited road space and to protect the urban scenery. The performance of this structure was verified by collision simulation. And to increase the buffering effects of the ends of the fence, four kinds of end buffering structures were studied and analyzed by a simulation. The software used for the simulation analysis was PAM-CRASH from ESI, a company with accomplishments in the field of motor vehicle collision testing and analysis. The results of the simulation analysis revealed that while the deceleration produced at the center of gravity of a passenger car when it strikes a support structure at a speed of 60 km/h is about 650 m/s^2, if it strikes the ends of the buffer fence, the deceleration is reduced to between 170 m/s^2 and 330 m/s^2.

INTRODUCTION

About 950,000 accidents causing death or injury occur in Japan every year. Only about 3% (about 27,000 accidents) of these are collisions with roadside structures that includes utility poles, signposts, streetlight poles and trees. But these accidents account for 16% (about 1,400 accidents) of all fatal accidents (about 8,400 accidents), indicating that collisions with roadside structure tend to be extremely serious [1)]. In many countries, breakaway structures that allow poles to topple over when struck by a vehicle are used as a buffer measure for support structures, and they do contribute to reducing damage and injury caused by collisions. But this type of structure is not suitable for narrow roads carrying heavy traffic where a collapsing support structure might cause secondary injuries to third parties. Traffic barriers are used as a method of preventing collisions with support structures, but because traffic barriers must be long to smoothly redirect a motor vehicle, their use causes many problems: they are expensive and when installed in cities, they spoil the appearance of the roadside.

This research was a study of the structure and performance of buffer fences installed beside support structures standing along narrow roads that carry heavy traffic to prevent serious damage when passenger cars collide with these support structures accounting for conditions such as conserving u· ›an scenery.

OUTLINE OF THE STUDY

Purpose of the study

The purpose was to develop a buffer fence that prevents passenger cars from directly colliding with support structures and mitigates the impact of such collisions.

The study developed a buffer fence with a structure that provides performance that reduces the harmful effects of a collision on occupants of passenger cars: a type of car susceptible to severe damage during collisions and which has been involved in a high percentage of past collisions with support structures [1).

The buffer fence is expected to have the following effects.
[1] Car redirecting performance: Redirects a passenger car when its front has collided with the side surface of the buffer fence (**see Fig. 1A**).
[2] Collision buffering performance: Greatly mitigates impact by preventing the passenger car from directly colliding with the support structure (**see Fig. 1B**).
[3] Side collision safety performance: Reduces the deformation of the passenger car body to guarantee space for the driver to survive by preventing the side surface of a passenger car that has spun from directly colliding with the support structure (**see Fig. 1C**).

The impact conditions established for the study were cases of collisions by a 1-ton passenger car at 60 km/h that is the legal speed limit on ordinary roads and at 80 km/h that exceeds this speed limit: cases set because in Japan the commonest type of vehicles used weighs approximately 1 ton [2) and support structures are installed close to vehicle lanes on almost all ordinary roads.

Study method and procedure

Dynamic simulation analyses were done to clarify the performances of the buffer structure.
The study was performed by first analyzing the state of a collision without a buffer fence, then analyzing the car redirecting performance, side collision safety performance, and collision buffering performance of the basic structure, at a collision speed of 80 km/h. Based on the results of these analyses, the performances necessary for a study at collision speed of 60 km/h were studied at a collision speed of 60 km/h to finally clarify the most appropriate structure.
The study flow chart is shown in **Figure 2,** and the test results are also shown in the figure.

Structure studied

The height of the buffer fence was set at 500 mm as the height that can guide a car bumper and wheels when a car collides with the side of the buffer fence. The length of the buffer fence was set at approximately 5 m: a length that can reduce deformation of the body of a car that has spun so that its side collides with the buffer fence. The basic buffer fence structure that was established is shown in **Figure 3**. The cross-beam of the buffer fence is strong enough to almost completely prevent deformation of a car by a collision, because it is assumed that it will usually be difficult to provide a large gap between the fence and the support structure. The ends of the buffer fence are constructed to prevent large deceleration when a car collides with one of its ends. So in addition to the ends in the basic structure, four other end structures that improved buffering performance were studied (**see Figure 4**). Buffering structures [1] and [2] were, unlike the ends of the standard structure, equipped with 1,000 mm buffers. Of these, buffer structure [1] was equipped with three intermediate props to increase the strength of its buffers, but the props were omitted from buffer structure [2]. Buffer structures [3] and [4] were designed by equipping the ends of the basic structure with 1,500 mm buffers. Of these, buffer structure [3] was equipped with one intermediate support prop to increase the strength of its buffers, but no support props were installed on buffer structure [4].

DESCRIPTION OF THE STUDY

The collision simulation program used to study the structure of the buffer fence was PAM-CRASH from ESI.

Car models

The car models used for the collision simulation were a frontal collision model and a side collision model for a 1-ton domestically manufactured passenger car (**see Figure 5**). The frontal collision model finely divided the front of the car into a mesh in order to more accurately simulate the deformation and deceleration caused by a frontal collision. The side collision model was a model with the side of the car divided into a fine mesh in order to more accurately simulate the state of deformation when the side of the car collides with the fence.

Analytical cases

The deceleration of the car and the deformation of its body when the front or side of the car collided directly with the support structure were analyzed. **Table 1** shows car redirecting performance, collision buffering performance, and side collision safety performance of the buffer fence, and the combinations of structures and collision speeds studied.

Evaluation method and evaluation criteria

The following are the methods and criteria used to evaluate the various types of performance.
The deceleration was evaluated using the 10 ms moving average deceleration in the direction of travel of the car based on the installation standard for traffic barriers [2)] and NCHRP350 [3)], and the sampling of the deceleration was done using an 80 Hz low pass filter at intervals of 0.5 ms.

[1] Car redirecting performance: The buffer fence smoothly redirected the car when its front surface collided at an angle with the side of the buffer fence. The deceleration produced was less than 200 m/s^2 [2)],

[2] Side collision safety performance: The interior of the car was retained when the car collided with the fence from the side

[3] Collision buffering performance: The deceleration when the car collided with the end of the buffer fence or with the buffer structure was less than 200 m/s^2.

STUDY RESULTS

Table 2 shows the results of the simulation analysis.

Without a buffer fence

Figure 6 shows the deformation of the car body based on the frontal collision and the side collision simulation analyses for a collision without a buffer fence.

The deceleration when the front of the car collided with the support structure not equipped with a buffer fence was 850 m/s^2 at a collision speed of 80 km/h, and it was 650 m/s^2 at collision speed of 60 km/h. These decelerations are highly likely to seriously injure occupants [6)]. And when a car spun so that its side collided with the support structure, the car body was severely damaged, causing conspicuous deformation of the interior so that there wasn't enough space for the occupants to survive.

Structure of the side of the buffer fence

The results of the simulation analysis of a collision with the side of the basic structure buffer fence at 80 km/h revealed that when the car front collided at an angle, it was redirected by the fence and that when the car spun so that its side collided with the fence, the car body was maintained, preventing its deformation. The deceleration as the car was redirected was 160 m/s^2 (impact speed of 80 km/h): a value that satisfied the conditions.

Figure 7 and Figure 8 shows the simulation results.

Structure of the ends of the buffer fence

(1) Basic structure

With the basic structure without buffer structures on its ends, the car stopped after the bottom surface of the car penetrated the end of the buffer fence, generating a deceleration of approximately 710 m/s^2 at collision speed of 80 km/h, and approximately 530 m/s^2 at collision speed of 60 km/h, both large decelerations.

(2) Buffer structure [1]

The results of the simulation of cases where a car collided with buffer structure [1] at collision speeds of 80 km/h and 60 km/h show that although the car did stop after penetrating the end, the deceleration was 510 m/s^2 and 330 m/s^2 respectively, clearly indicating that good buffering effects were obtained. But the deceleration at collision speed of 60 km/h was far above 200 m/s^2.

(3) Buffer structure [2]

The results of the simulation analysis of a case of a collision with buffer structure [2] at 60 km/h show that the deceleration produced is far higher than 200 m/s^2, indicating that the buffer length of 1,000 mm is not sufficient.

(4) Buffer structure [3]

The simulation of buffer structure [3] equipped with a buffer with length of 1,500 mm revealed that the deceleration produced by the collision with the end was 170 m/s^2 that is less than 200 m/s^2. Because the car rode up on the fence (see Figure 9) while traveling at the high speed of 30 km/h, the deceleration when it collided with a support structure was high at 260 m/s^2, revealing that this buffer structure does not satisfy the required buffering performance.

(5) Buffer structure [4]

As in the case of buffer structure [3], the car rode up on the fence, but its speed as it did was lowered to 20 km/h and the deceleration during both a collision with the end and a collision with the support structure was 180 m/s^2 that is less than 200 m/s^2. This structure provides the highest buffering performance of all those tested in this study.

Considerations

The test results reveal that the strength of the side of the buffer fence is sufficient. The study of the buffer structure for the ends revealed that at a buffer length of 1,000 mm, the car stops at the end but its deceleration is high, and when it is lengthened to 1,500 mm, the shape of the end is deformed to form a slope, reducing the deceleration. Because the car stops with reaching a support structure, it does not bounce back into the vehicle lane or run up on the sidewalk after it has collided with the buffer fence, preventing secondary damage.

SUMMARY

The following are the conclusions obtained by the study.

Shape of the buffer fence

It is necessary for the buffer fence to be about 500 mm tall, assuming that a fence of this height will not spoil the appearance of the urban environment, and that it is an appropriate height to buffer and redirect a car that collides with the fence. If a buffer fence with length of about 5 m is constructed, it can redirect a car that has collided with the side of the fence and it can prevent deformation of the body of a car that has spun so that its side collides with the buffer fence.

Collision buffering performance of the buffer fence.

Buffers must be installed on the ends of the buffer fence in order to mitigate the impact of a car colliding with the ends. Of the buffers installed on the buffer fence that were studied, the most effective buffering is obtained at a length of 1,500 mm and height of 500 mm, but at a collision speed of 60 km/h or less, it is technologically possible for this structure to stably stop a vehicle while holding the deceleration down to less than 200 m/s^2. At a collision speed of 80 km/h, it will be technologically difficult to keep the deceleration below 200 m/s^2 using the buffer fence structure that was studied.

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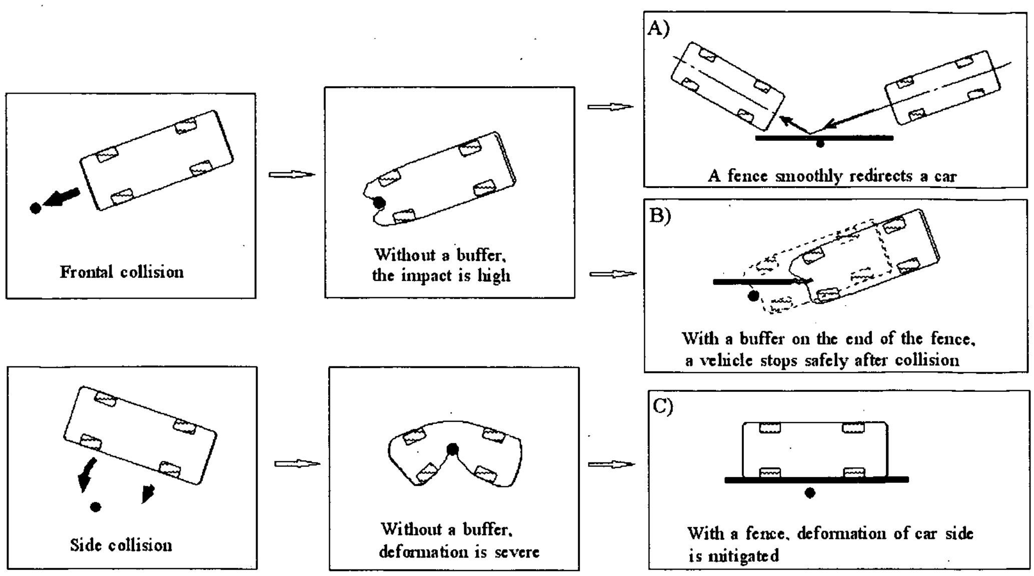


Figure.1 Anticipated Effects of the Buffer Fence

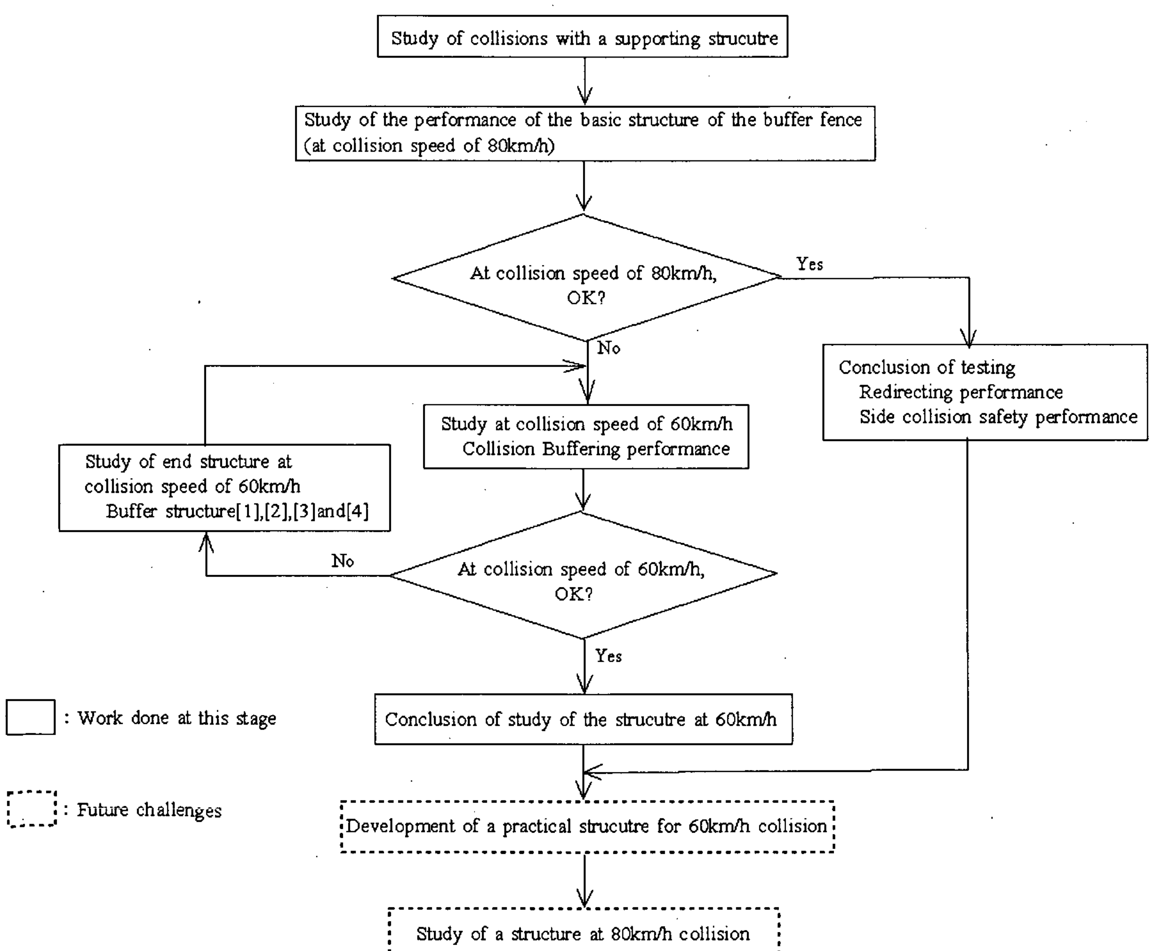


Figure.2 Study Flow Chart

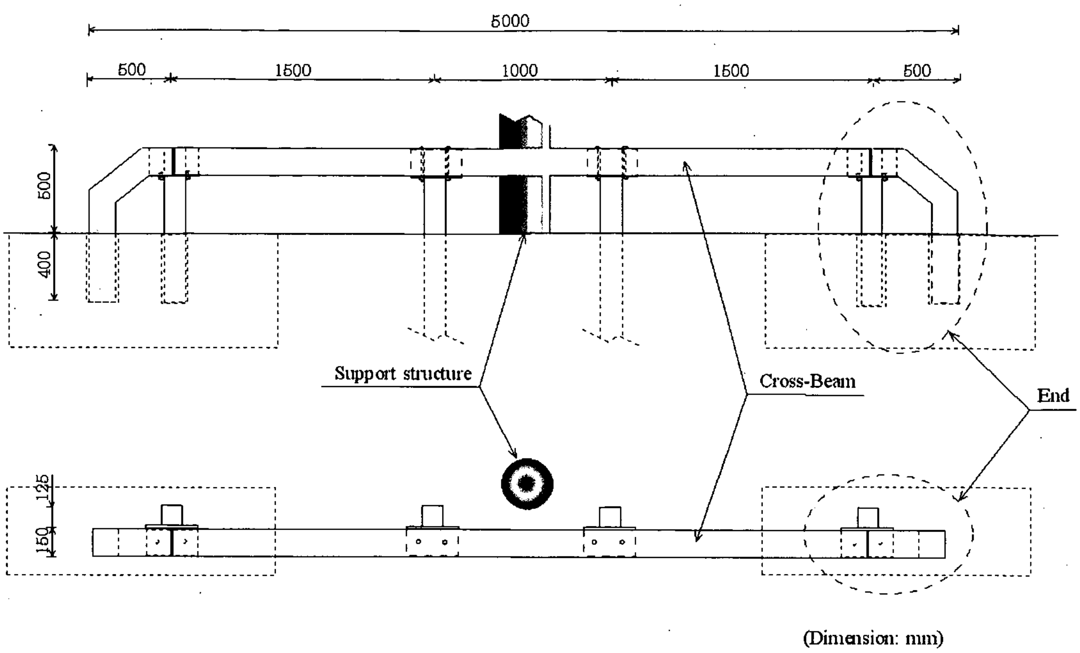


Figure.3 Basic Strucutre of the Buffer Fence

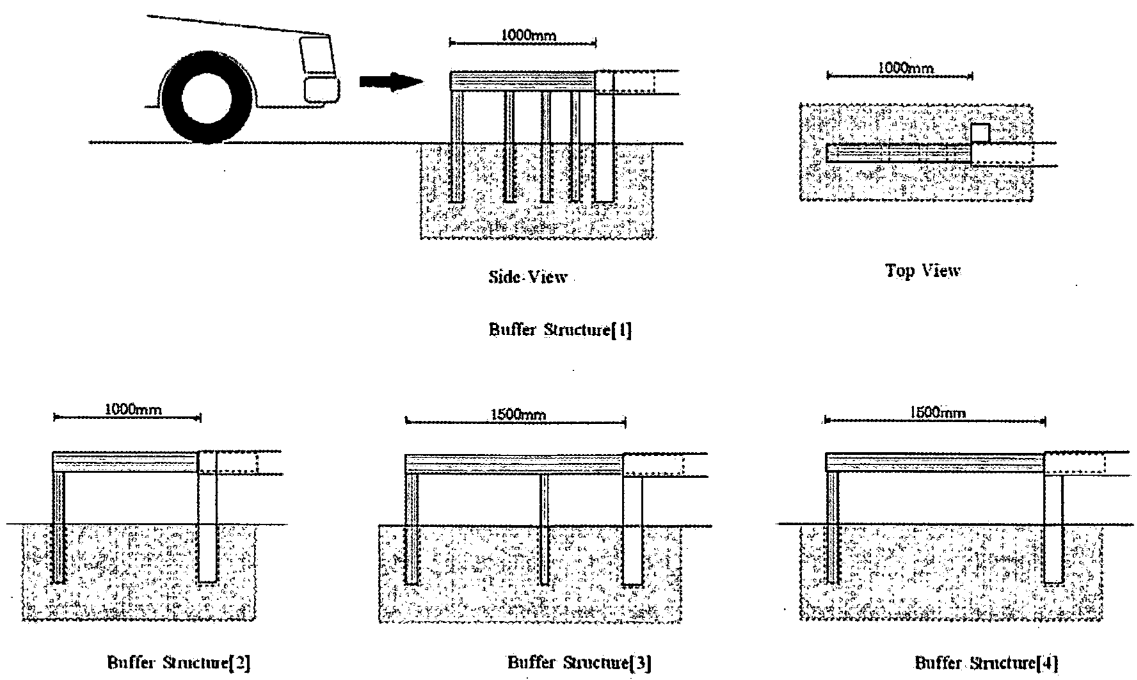
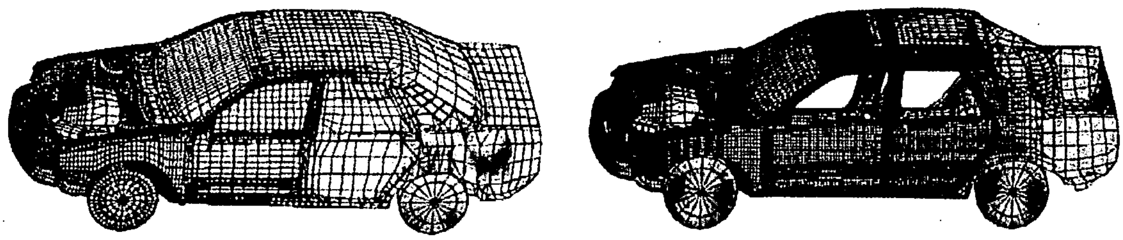


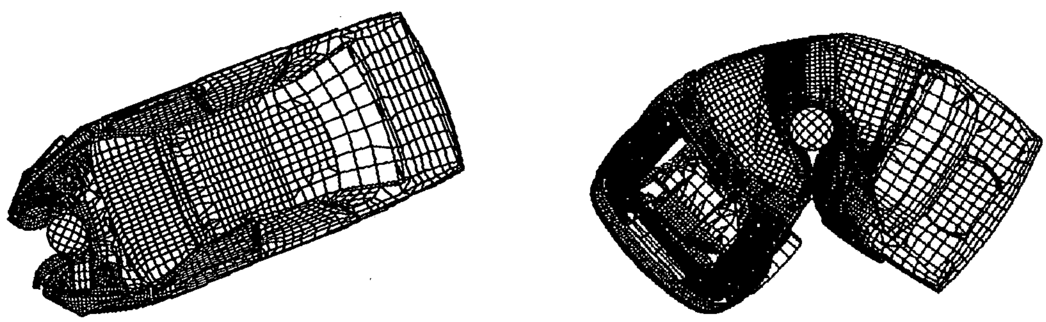
Figure.4 End Structure of the Buffers Studied



a) Frontal Collision Model
(Front of the car body divided into a fine mesh)

b) Side collision model
(Side of the car body divided into a fine mesh)

Figure.5 Car Body Models



Frontal Collision

Side Collision

Figure.6 Car Body Deformation Without a Buffer Fence (Collision Speed 80 km/h)

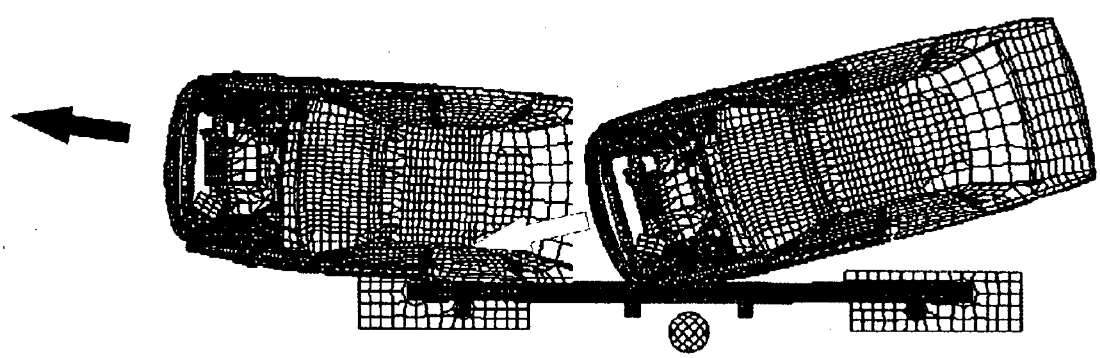


Figure.7 Car Redirection of Car Collision with the Side of the Buffer Fence

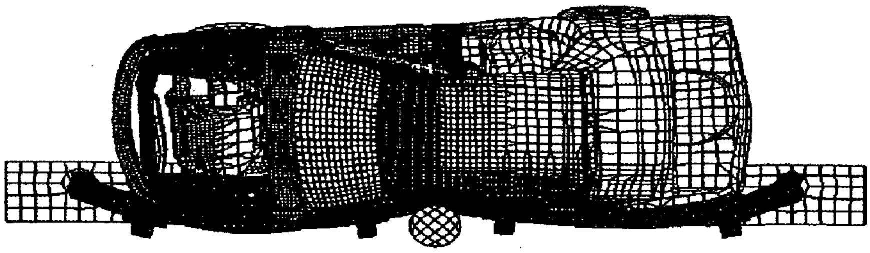


Figure.8 Car Body Deformation After Side Collision

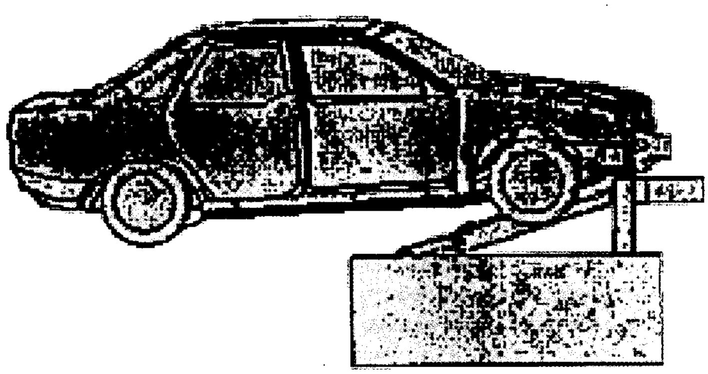


Figure.9 Car Riding up on Buffer Structure [4]

Table.1 Analysisi Cases

Performance	Structure	Collision Speed (km/h)
	No fence	80
Car redirecting performance a)	Basic structure	80
Side collision safety performance c)	Basic structure	80
Collision buffering performance b)	Basic structure and buffer structure[1]	80, 60
	Buffer strucutre [2], [3]and [4]	60

a) Collision shown in Fig.1A), b) Collision shown in Fig.1B), c) Collision shown in Fig.1C)

Table.2 Results of Simulation Study

(OK: satisfies the evaluation criteria, X: does not satisfy the evaluation criteria)

Performance	Car redirecting performance a)		Side collision safety performance c)	Collision buffering performance b)			
				Collision with the end of buffer fence		Collision with the support structure	
Collision speed	80km/h		80km/h	80km/h	60km/h	80km/h	60km/h
Evaluation items / Structure	Body redirecting	Deceleration (m/s^2)	Body deformation	Deceleration (m/s^2)	Deceleration (m/s^2)	Deceleration (m/s^2)	Deceleration (m/s^2)
No fence	X	X (850)	X				
Basic strucutre	OK	OK (160)	OK	X (710)	X (530)	—	—
Buffer strucutre[1]				X (510)	X (330)	—	—
Buffer strucutre[2]					X (300)		—
Buffer strucutre[3]					OK (170)		X (260)
Buffer strucutre[4]					OK (180)		OK (180)

a) Collision shown in Fig.1A), b) Collision shown in Fig.1B), c) Collision shown in Fig.1C)

STUDY OF ILLUMINANCE REQUIREMENTS OF PEDESTRIAN LIGHTING SYSTEMS

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ABSTRACT

This paper reports the results of a study on the influence of illuminance levels on visibility and ease of walking (or riding) for various categories of pedestrian (elderly persons, non-elderly persons, cyclists, and wheelchair users). Five illuminance levels were employed in the study: 1,5, 3, 5, 10, and 20 lx. It was found that at low illuminance levels (1,5 and 3 lx), pedestrians were able to identify obstacles and other pedestrians in their path but were not able to see the road surface properly or identify details such as faces, and some difficulty was experienced in walking. At 5 lx, wheelchair users were still unable to identify the faces of other pedestrians approaching from the opposite direction. It was concluded that 5 lx represents the minimum illuminance level required in order to enable pedestrians to identify salient visual information at night. If wheelchair users are taken into consideration, then the minimum illuminance level is 10 lx, which ensures the safety of all pedestrian categories.

Keywords: illuminance, pedestrian, bicycle, elderly person, wheelchair

1. INTRODUCTION

The population of Japan is aging much more rapidly than in other countries. Japan has the highest rate of population aging in the world. It is important to ensure that elderly people, wheelchair users, and those with visual or other physical impairments are able to lead independent and autonomous lives by providing appropriate support and encouraging participation in wider society. To this end, areas of pedestrian traffic should be designed to minimize, as far as possible, the physical and mental burden on these categories of pedestrians.

In this study, we considered the issue of pedestrian lighting from the perspective of ensuring the safety of pedestrians, particularly elderly and physically disabled pedestrians, at night. We investigated the level of illuminance at the road surface required in order to ensure the safety and security of pedestrian traffic.

2. OBJECTIVES

The level of illuminance required in areas of pedestrian traffic at night varies depending on the individual physical characteristics of each elderly or disabled pedestrian. A visibility evaluation experiment was used to determine the level of illuminance required to ensure the safety and security of all such pedestrians.

3. OUTLINE OF EXPERIMENT

In the experiment, the test subjects were asked to rate visibility while proceeding along a test course lighted to a given level of average road surface illuminance. The test subjects consisted of 10 elderly persons aged 65 years or over, 10 non-elderly persons, and seven wheelchair users. The non-elderly subjects were asked to perform the visibility ratings both on foot and on bicycle.

3.1 Methodology and conditions

Figures 1 and 2 show the experimental set-up. The test course was 182 m in length, lighted by eight luminaires mounted at a height of 5,2 m and spaced at intervals of 26 m. The evaluation zone was confined to the two middle spans of the test course, a length of 52 m, with a width of 4 m. The first span was designated the obstacle zone, and the second span the approaching traffic zone. The obstacles in the obstacle zone consisted of two black rubber strips measuring 60 mm in height and 180 mm in width laid out across the road surface to resemble steps, and seven blue triangular cones of height 700 mm placed on the road surface to resemble obstacles. The test subjects were asked to pass through both zones in succession. The fluorescent mercury discharge lamps (HF250-D) were used as the source lamps in the luminaries. Road surface brightness was regulated using a combination of optical filters of varying degrees of transmittance attached to the luminaire globes.

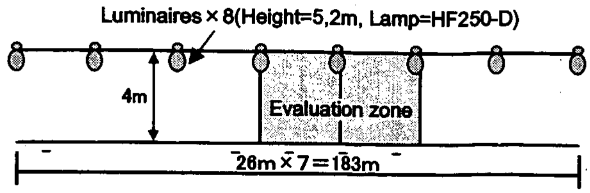


Figure 1. Experimental set-up

Within each span of the test course, the illuminance level was defined as the average of road surface illuminance readings taken at 55 measurement points on a grid created by dividing the span (L 26 m x W 4 m) into 10 sections in the longitudinal direction and four sections in the transverse direction.

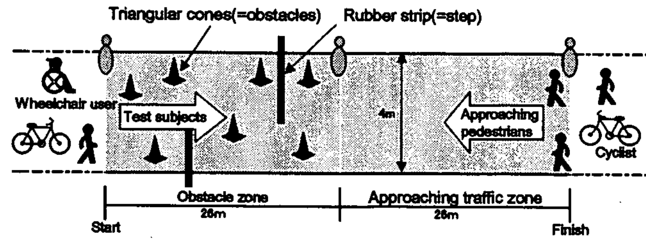


Figure 2. Close-up of evaluation zone

Five illuminance levels were used in the experiment: the four Recommended Levels of Illuminance (3, 5, 10, and 20 lx) given in Japanese Industrial Standard (JIS) Z 9111[1)], which is used extensively for pedestrian lighting design in Japan, and the minimum illuminance level of 1,5 lx recommended by Publication CIE 115-1995[2)], which is based on pedestrian lighting illuminance standards from around the world. To ensure uniform illuminance across the entire test course, the value derived by dividing the minimum road surface illuminance by the average road surface illuminance was kept to a target of 0,2[3)].

3.3 Evaluation method

The test subjects were asked to pass through the obstacle zone and negotiating approaching traffic (both pedestrians and bicycles) in the approaching traffic zone, then answer yes or no to the six-point checklist shown in Table 1. This procedure was repeated at each of the five illuminance levels.

Table 1. Evaluation items

1	Can see steps and obstacles
2	Can see road surface and proceed without difficulty
3	Can see faces of approaching pedestrians
4	Feel no danger from approaching pedestrians
5	Feel no glare by lighting
6	Lighting is uniform at road surface

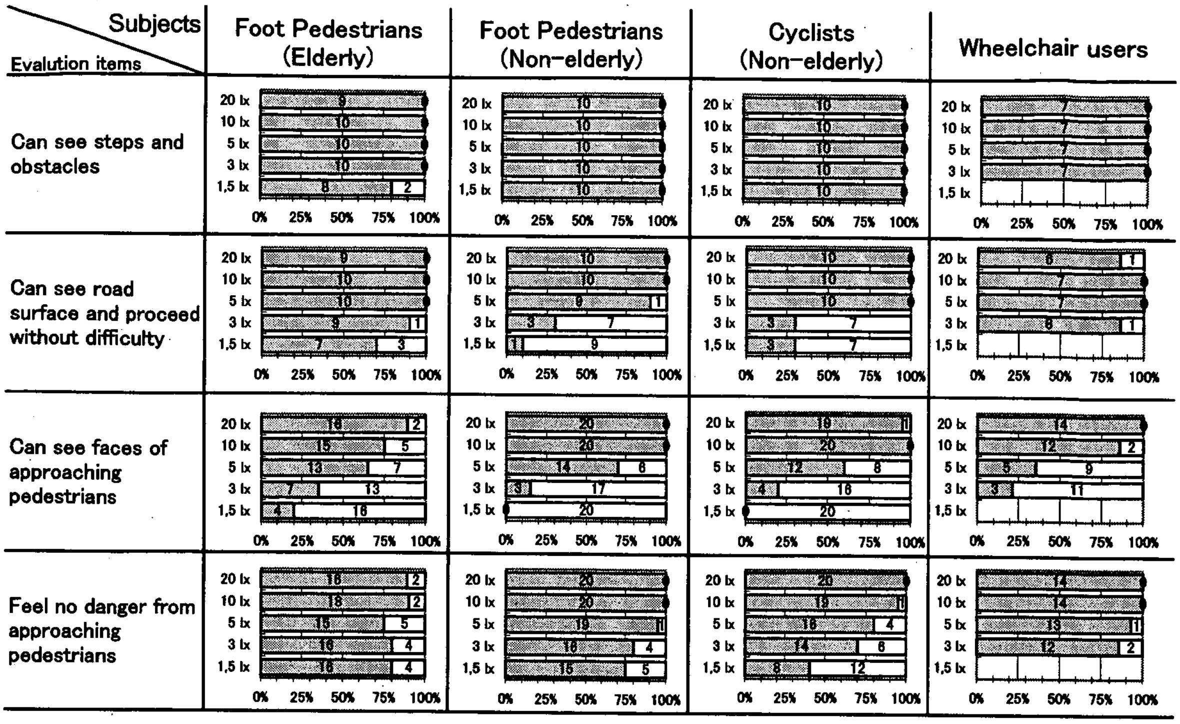
Positive response rates were tabulated in each pedestrian category; thus, for instance, if seven out of ten elderly subjects said that they could see the road surface and proceed without difficulty, this translates into a 70% response rate for that item. Response rates of 50% or more were deemed "high" and response rates of less than 50% were deemed "low."

4. RESULTS

Figure 3 shows the visibility evaluation results by subject category. On each graph, the Y-axis represents the level of illuminance while the X-axis represents the positive response rate.

It can be seen that the positive response rate to the "can see steps and obstacles" question was high irrespective of the illuminance level. Similarly, high responses were obtained for the "felt no glare by lighting" and "lighting was uniform at road surface" question at all illuminance levels, so these have been omitted from the discussion here.

- Pedestrians (elderly and non-elderly): At 1,5 lx and 3 lx illuminance, both elderly and non-elderly pedestrians had a low response rate in the "can see faces of approaching pedestrians" category. Non-elderly pedestrians also had a low response rate in the "can see road surface and proceed without difficulty" category. Response rates in other categories were high for all illuminance levels.
- Cyclists: At 1,5 lx, cyclists had a low response rate in the "feel no danger from approaching pedestrians" category. Response rates in other categories were similar to those for foot pedestrians.
- Wheelchair users: At illuminance levels of 5 lx and below, wheelchair users had a low response rate in the "can see faces of approaching pedestrians" category. Response rates were high in all other categories irrespective of illuminance level. Wheelchair users were not asked to do the experiment at 1,5 lx.



YES NO

Figure 3. Visibility ratings by subject category
(The X-axis represents the positive response rate. The Y-axis represents the level of illuminance)

5. DISCUSSION OF RESULTS

There was a pronounced difference in the response rates of elderly and non-elderly subjects in the "can see road surface and proceed without difficulty" and "can see faces of approaching pedestrians" categories. Whereas 70% of elderly subjects felt that an illuminance level of 1,5 lx was sufficient to see the road surface and proceed without difficulty, only 10% of non-elderly subjects agreed. Thus, elderly people are more likely to be satisfied with a lower level of lighting than non-elderly people in order to see the road surface and proceed without difficulty. The non-elderly subjects were all able to see the faces of approaching pedestrians at a luminance level of 10 lx, whereas some of the elderly subjects were still unable to do so even at 20 lx.

The threshold visibility level needed for pedestrians is influenced significantly by the spatial frequency characteristics of the visual objects. It has been shown[4)] that people can usually walk without difficulty so long as it is possible to discern the general shape of obstacles; this type of visual information is called "low spatial frequency band information." In order to determine a person's gender and recognize a known face, however, it is necessary to identify facial details such as the profile and the eyes and nose; this is called "high spatial frequency band information." Our ability to discern the spatial frequency threshold of an object is governed by factors such as age and surroundings brightness. Mitsui et al[5)] studied the relationship between contrast sensitivity and age for different spatial frequency bands and found that sensitivity in the low spatial frequency band changes little with age, while sensitivity in the high spatial frequency band declines rapidly. The "can see road surface and proceed without difficulty" category in our experiment thus corresponds to the low spatial frequency band, which is why elderly subjects were able to recognize objects and proceed without difficulty even at low luminance levels. Meanwhile, "can see faces of approaching pedestrians" corresponds to the high spatial frequency band, and this is why some of the elderly subjects found it difficult to recognize faces even at high illuminance levels of 10 and 20 lx. However, the link between spatial frequency characteristics and declining contrast sensitivity with age does not adequately explain why elderly subjects had a higher positive response rate than non-elderly subjects in the "can see the road surface and proceed without difficulty" category at low illuminance levels. It may be that concepts such as "can see easily" and "can proceed without difficulty" constitute subjective evaluations of convenience, which are influenced by lifestyle differences and past personal experience that can vary considerably with age. At this stage, we do not know the sorts of factors that govern concepts such as visual comfort and brightness. Further investigation is required in this area.

5.2 Foot pedestrians, cyclists, and wheelchair users

In the experiment, the non-elderly foot pedestrian subjects doubled as the cyclist subjects. They reported that it was harder to discern the faces of approaching pedestrians at low illuminance levels both on foot and on a bicycle. At 1,5 lx, the subjects did not feel any danger when walking but they did feel danger when riding. Riding is faster than walking, which means that a rider has less time than a walker to assess the traffic conditions ahead. In other words, an illuminance level of 1,5 lx is dangerous for cyclists because they are unable to determine whether evasive action is required.

Wheelchair users, who travel more slowly than foot pedestrians, had trouble identifying the faces of approaching pedestrians at illuminance levels of 5 lx and under. This is probably attributable to the fact that their eyes are at a lower level, which means that they can't see as far as foot pedestrians, and also the fact that propelling the wheelchair involves a back and forth movement which means that they have less opportunity (in terms of frequency and period) to look up and assess approaching traffic conditions such as the road lines and the direction in which others are moving. Wheelchair users therefore require higher levels lighting than foot pedestrians in order to provide the same degree of visibility of visual information.

6. SUMMARY BY ILLUMINANCE LEVEL

The findings discussed above can be summarized as follows:

- At 1,5 and 3 lx: Pedestrians can discern the presence of obstacles and approaching pedestrians but experience difficulty seeing the road surface and recognizing details such as facial features and are not able to negotiate their way forward with ease.
- At 5 lx: Pedestrians are able to discern obstacles and see the road surface easily (the basic prerequisites for pedestrian traffic at night), and can also recognize details such as the facial features of approaching pedestrians. Wheelchair users are unable to recognize the facial features of approaching pedestrians.
- At 10 lx and above: Pedestrians of all types are able to proceed safely and securely.

7. CONCLUSIONS AND FUTURE ISSUES

In this study, we evaluated five average road surface illuminance levels with respect to six evaluation items in four pedestrian categories in order to determine the level of the average road surface illuminance required to enable pedestrians of all types to proceed safely and securely in area of pedestrian traffic. Future studies should look at the influence of colour temperature and colour rendering of the source lamp on the perception of visibility in the pedestrian area.

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標識等の情報量・形態と判読時間に関する実験*

安藤　和彦[1)]

An Experiment on Interpretation Time of Traffic Sign Information

Kazuhiko Ando

Public information for road users are presented by traffic signs and variable message sign boards on roads. The amount/form of information for these facilities has not fully been discussed until now. An experimental and analytical study of the amount/form of information was conducted using interpretation time of information as an index of understanding degree of information. It has been shown by the results of this study that the interpretation times of familiar information are shorter than those of unfamiliar information, and that road signs are understood as pattern and influence of their color is little.

Key Words: Visibility, Road, Information System, Driver Behavior/Amount of Information, Chinese Character, Traffic Sign⑬

1. は じ め に

道路標識や道路情報板に表示される情報は、道路標識については‘道路標識設置基準[1)]’、道路情報板では‘道路情報表示の規格について**’などで標準的な表示形態が示されている。しかし、現在の設置状況を見ると、一つの板に表示される情報量が多くなる傾向にあり、運転者が安全に理解できる情報の量や形態を把握し、運転者にとってわかりやすい情報提供を行っていくことが道路管理者に求められている。

運転者に提供する情報の理解度に関する研究はこれまでも行われてきている[2)]が、道路標識等に表示される地名や道路情報等を対象として、情報の複雑さや地名に対する慣れ等による理解しやすさとの関係について研究されている事例は少ない。そこで本研究は、標識や情報板に対する運転者の理解度を把握するための基礎的研究として、パソコン画面上に提示された情報を判読する時間を計測し、情報量（文字数）や情報形態（文字情報、図形情報等）と判読する時間との関係を実験・解析したものである。

2. 実験目的

漢字を組み合わせた地名、案内標識、情報板表示、図形、など各情報の判読性および理解度を、情報をパソコン画面上に表示してから運転者が判読するまでの時間（以下判読時間という。）により検討する。

3. 実験方法

3. 1　実験情報の製作

実験に用いる情報として、Table.1に示す情報をパソコン上で表示できるように製作した。

ここで、漢字の使用頻度の判断は、新聞における出現頻度などを基に調査を行っている事例[3)]もあるが、ここでは漢字単体のなじみの程度として、常用漢字で、小学校までに習得する漢字であり文字単体で意味をなすものと、漢字単体ではあまり用いられないもので区分した。表示地名のなじみの有無は、被験者が居住している地域に近い地名をなじみあり、遠方の地名をなじみなしとした。また情報板文字は、通常情報板に使われている文字情報を単語として組み合わせるものとし、一連の意味づけを行った組み合わせ、単語相互間に一連の意味を持たない組み合わせの2種類について行った。図形情報は、標識令で定められた図案および、情報板などで一般的に見受けられる模擬図案をそれぞれ採用した。

3. 2　実験方法

（1）被験者

実験における被験者数は37名で、年齢、性別等でなるべく偏りが生じないように選定した。年齢は非高齢者として50歳代までとした。また、地名理解度について統一性を持たせるため、被験者は全て茨城県または近県在住者とした。視力条件は、矯正可で両眼視力0.7以上とし、普通免許を保有するものとした。

（2）実験環境

実験条件を統一するために、屋外光を完全に遮断可能な室内で実施した。

・使用パソコン及びディスプレイ：DELL Optiplex GX 1、17インチ液晶モニタ（画面解像度 1024×768 ピクセル）

・ディスプレイ－被験者間の距離：250 cmに固定（標識文

*2002年8月29日受理．2001年7月25日自動車技術会春季学術講演会において発表．
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**建設省道路局企画課長発道企発第52号、昭和47年9月

Table.1 Contents of Information Used in the Experiment

Kind	Form	Content
Character	Chinese character	High use frequency：5 strokes(玉、兄)、10 strokes（梅、夏）、15 strokes（横、箱）
		Low use frequency：5 strokes（処、末）、10 strokes（俵、桑）、15 strokes（輝、盤）
	Place Name	Familiar name：柏(Kashiwa)、土浦(Tsuchiura)、水海道(Mitsukaido)、常陸太田(Hitachi-Ohta)
		Unfamiliar name：牧(Maki)、三瀬(Mitsuse)、大多喜(Ohtaki)、宇治田原(Uji-tawara)
Sign	Regulate・Warning	Stop (red background-black letter, red background-white letter), Under construction (black background-orange pictograph, yellow background-black pictograph), Admit approach to directions pointed out only (black background-orange allow, blue background-white allow)
Variable Message Sign Board	Text	1：強風(Strong wind)、2：事故・冠水(Accident・Covered with water)、 3a：落石・通行止・迂回路有 (Falling of rocks・Road closed・There is a detour)* ＊meaning combination of words 3b：越波・凍結・渋滞(Covered with waves・Freeze・Congestion)** ＊＊meaningless combination of words
Graphic	Symbol	Snowman(Snow fall) (black background-orange figure, blue background-white figure)

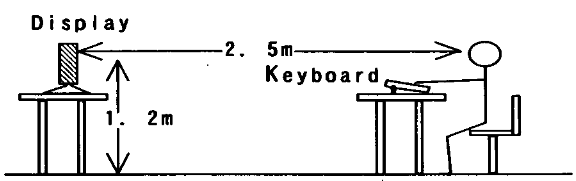


Figure.1 Experimental Condition

字高 40cm を約 50m 手前から視認した場合を想定)
・室内はできるだけ太陽光が入らないように、黒いブラインドで遮断し室内照明を点けて行った。

（3）実験方法・手順

室内に設置したパソコンの前に着席させる。被験者は、実験情報が提示された後内容を理解した時点で被験者の前に設置されたキーボードのエンターキーを打鍵する。打鍵により表示画面は消え、表示開始時点から打鍵までに要した時間が画面上に1/1000秒単位で表示される。計測員は、画面上の秒数を判読時間として記録する。また計測員は、表示された情報の意味を被験者に対してヒヤリングし、理解度として記録する。

このとき解析に用いた判読時間は、計測された判読時間からキーを押す時間（反応時間）を引いた時間とし、反応時間は、別途計測した（Figure.2）。

なお、理解度の正誤を判定するチェック項目については

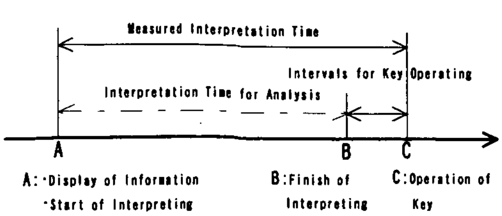


Figure 2. Flow of Interpreting of Information

実験による回答方法が異なるため、別途定めた。これに関し、地名や文字情報は知識による個人差があるため、実験で使用した地名や文字についてどの程度の認識しているのかヒアリングを行い、認識の程度を確認した。

実験情報の提示順序としては、実験の順番を決める場合、比較的簡単な文字情報から始めると早押し実験と思われてしまう恐れがあるため、標識図形から始めることとした。また、順序効果を排除するため、被験者を3群に分類し、群毎に実験毎の提示順序をランダム化して配置した。各実験パターン毎に最初のものについては、2回目以降より時間がかかることが予想され、順序効果の有無について確認するため、各実験要素毎に、一番最初に提示した群の平均値と2回目以降に提示群の平均値に有意な差がないかをｔ検定した。

判読時間の計測結果には、特定の被験者のみの固有の要因（読み方を知らなかった等）が作用していると思われるデータを異常値とし、異常値を除いた正常データについて分析を行うこととした。なお、各ケースにおける全データの標準偏差(SD)で±2SD 以上となったもの異常値とした。

4．実験結果

実験結果についてｔ検定を行った結果では、順序効果に有意差はみられなかった。

実験結果では、情報に対するなじみの程度によって判読時間に差が生じた。実験では、漢字については比較的接する機会の多いと考えられるものとそうでないもの、地名については被験者が居住している地域で比較的多く見かける地名をなじみのある地名として選定している。以下では、これら状況を踏まえ、漢字の使用頻度の多寡や地名のなじみの程度などを総じて‘なじみ度’とする。

4．1 異常値

基準に従って異常値を判定すると、漢字については‘なじみのない地名の回答について悩んだ’、図形では‘意味がよくわからなかった’等の理由で異常値が抽出された。被験者毎にみると異常値の割合が全体の２割以上を占めた被験者は４名おり、特定の被験者が抽出されている反面、計測中1回でも異常と判断された被験者は約５割に上り、情報になじみがなければ、だれでも判読時間が大きくなる可能性があることがわかった。

４．２　判読時間の計測結果

各情報における平均値、標準偏差（±SD）を求めるとともに、母平均の有意差検定（有意水準0.05）で有意差がないとされた情報についてグループ分けを行った。以下ではそれらの結果を示す。

４．２．１　漢字1字の比較

漢字１字の計測結果は、Figure.3のとおりとなった。

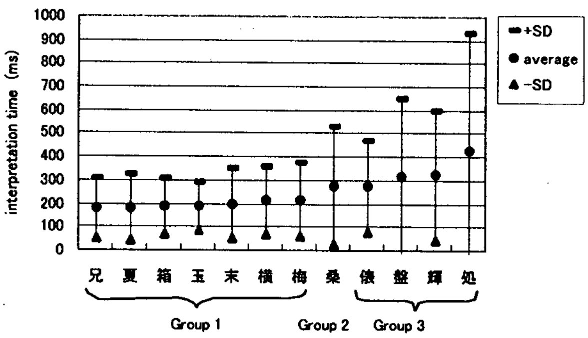


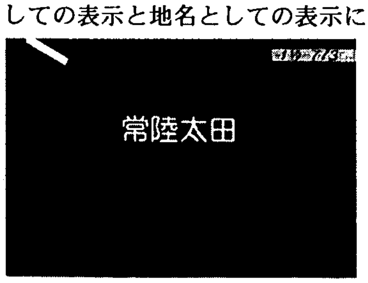
Figure.3　Interpretation Times of 1 Chinese Characters

実験に用いた漢字の選定は、なじみ度の高いもの（兄、夏、箱、玉、横、梅）となじみ度の低いもの（末、桑、俵、盤、輝、処）に分けて行ったが、グループ毎の特徴を見ると、なじみ度が高い、あるいは画数が少ないものがグループ１に、なじみ度が低く画数が多いとして設定された漢字がグループ３に区分されており、グループ１とグループ３では150ms程度の差が現れている。

４．２．２　表示地名

実験に用いた漢字の表示形態はFigure.4のとおりである。また、地名情報数と判読時間との関係をFigure.5に示す。

漢字１字の‘柏’が、平均値で300ms程度あり、Figure.3の漢字１字に比べて50ms秒程度長くなっているが、これが単なる漢字としての表示と地名としての表示による差で



(Text ; White,　Background ; Blue)

Figure.4　An Example of Display of Place Names

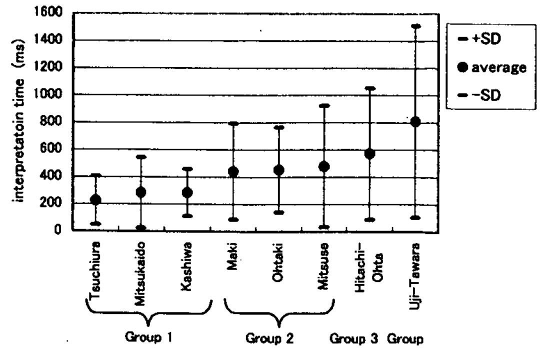


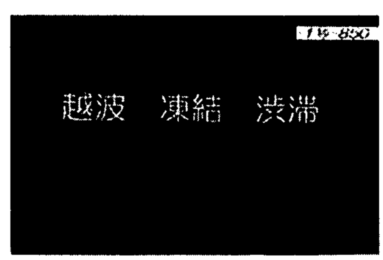
Figure.5　Interpretation Times of Place Names

あるかどうかは不明である。図をみると、地名数３文字程度まででであれば、地名の漢字数に係わらず、なじみ度の高い地名は判読時間が短く、なじみ度が低いと平均的に200ms程度長くなっている。またなじみのある地名でも4文字地名の場合、実験に用いた地名は２文字ずつに分けて読むことができることから、２地名分を読むこととなり１地名読む場合の約2倍の時間を要している。例えば、地名としてなじみのある‘常陸太田’は‘常陸’と‘太田’に分けられ、‘常陸太田’の判読時間570msは、‘柏’の280msの２倍にほぼ等しい。また、‘宇治田原’は被験者にとってそれほどなじみのある地名ではないことから、判読時間は810msであるが、これは同じくなじみのない地名‘牧’の判読時間450msの２倍に近い。

４．２．３　文字情報の情報数による比較

情報板に表示されている各種の文字による警報情報を想定し（Figure.6）、時間の差を比較したものがFigure.7である。

図によれば、１情報は500ms、２情報は1,000ms、３情報



(Text ; Orange,　Background ; Black)

Figure.6　An Example of Display of Texts

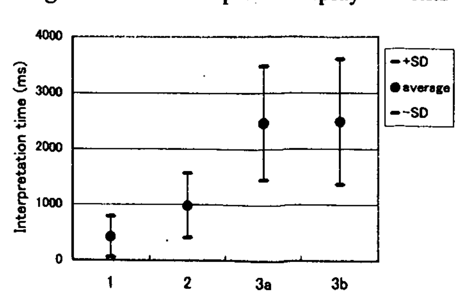


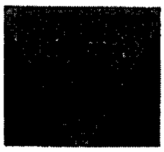
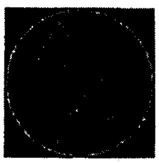
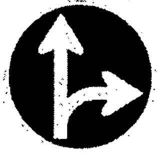
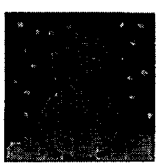
Figure.7　Interpretation Times of Texts

では2,500msと、情報数に比例して判読時間は長くなり、情報数の違いによって有意水準1％で有意な差があったが、3情報の‘落石通行止迂回路有’(3a)と‘越波凍結渋滞’(3b)には有意差がなかった。

4．2．4　規制・警戒標識、シンボルマーク等の比較

実験に用いた情報をTable.2に示す。

Table.2　Design of Graphic Information

	Dummy (D)	Formal (F)
「Stop」	Text;Black, Sign figure;Red 	Text;White, Sign figure;Red 
「Admit Approach to Directions Pointed out Only」(A.D.)	Figure;Orange, Background;Black 	Figure;White, Background:Blue 
「Under Const-ruction」(U.C.)	Figure;Orange, Background;Black 	Figure;Black, Background;Yellow 
「Snow Fall」	Figure;Orange, Background;Black 	Figure;White, Background;Blue 

一時停止、指定方向外進入禁止および道路工事中の規制・警戒標識と、雪だるまのシンボルマークについて、従来の情報板で提供されている情報形態を模擬した図案と、正規・正常な色彩を使った正規図案により比較を行った結果をFigure.8に示す。

図によれば、標識図案では他の色彩を使って模擬的に表示された図案と正規の色彩で表示された図案に、大きな差はみられないが、雪だるまのシンボルマークのように雪を白く表示した正常の図案では、雪だるまを橙色で表示した模擬図案より判読時間は短くなっている。

グループ1の一旦停止標識は、図案内に止まれの文字が表示され、このため、判読時間、標準偏差ともに小さくなっているものと思われる。また同じグループの雪だるまは見慣れた図案であり、グループ2の情報より200ms程度判読時間は短くなっている。被験者間の判読時間のばらつきは大きい。

グループ3は、ばらつきが非常に大きく、情報に見慣れている、情報の意味を知っている被験者とそうでない被験者間等で判読時間に大きな差が生じることが推測される。

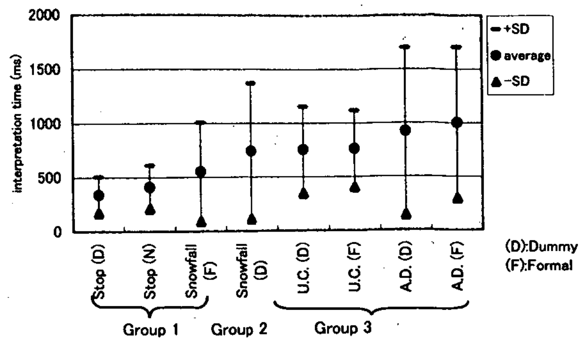


Figure. 8　Interpretation Time of Graphic Information

4．3　実験結果のまとめ

判読時間の分析結果をまとめると以下のとおりである。

① なじんだ情報は判読に要する時間が少ない。

② 文字情報は3文字程度まででであれば文字数に関係なく判読するのに300〜500ms程度要する。

③ 文字情報は2情報になると1情報の倍（1秒）程度の判読時間となる、また3情報になると判読時間は大きく増加し2,000〜3,000ms程度必要となる。

④ 複数の文字情報を全て理解するには、全てを読むことになるので短い時間では判読できない。

⑤ 情報が多くなるほど被験者毎による判読時間の差は顕著になり、特に図形標識でその傾向が著しい。

理解度では、文字表示の場合3情報になると内容が完全に理解できない被験者が現れた。情報を増やす場合は、繰り返し表示あるいは情報の補完（情報板と音声情報との組合せなど）が必要と考えられる。また、シンボル情報などでは、標識のように運転者の認知が十分でないことから、適切な色彩を用いることが必要であると考えられる。

5．あとがき

実験結果から、情報量が増えるに従い判読時間が延びる結果となった。また、見慣れた情報の方が判読が早いという傾向がみられた。これらを考えると、判読時間を文字や図形の基本的な情報に対する判読時間およびなじみ度を因子とする関数として、定量化できる可能性があると思われる。判読時間の定量化が可能になれば、標識や情報板の情報内容の設計が適正かつ容易に行えるようになる。今後の課題である。

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83. 霧中におけるLED 発光色の知覚特性

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1. はじめに

近年は交通安全関連施設として LED を応用した発光表示装置が増加しているが，これまで霧中における LED 色光による視認特性に関する研究報告事例はきわめて少ないのが現状である．そこで，霧による低視程条件下における LED 発光体の発光色および発光輝度と視認性との関係を調査することを目的とし，霧中における視認特性に関する基礎実験を行った．

2. 実験方法

実験は国土技術政策総合研究所の標識屋内実験施設において実施した．本施設では天井に設置されたノズルから噴霧された霧を実験室内に充満させることにより人工的に霧の環境を作り出すことができる．実験に使用した供試体は赤，黄，緑，青，白の LED ランプを集合し縦横 150mm 角のエリアに敷き詰めたものである．

はじめに実験室内に十分な霧を発生させ，供試体を消灯状態から徐々に発光強度を増して点灯する．各供試体の発光強度はあらかじめ視感度補正された測定器により光度を測定してある．被験者は実験室内の霧を通して 30m 離れた観測室から両眼にて観測し，発光体の存在を確認した時点で 1 回目のスイッチを，光色を確認した時点で 2 回目のスイッチを押すのである．スイッチが押されたときの供試体の設定光度と実験室内の霧の透過率が自動的に記録される．発光色の呈示順序はランダムとした．被験者は色覚正常者 6 名である．

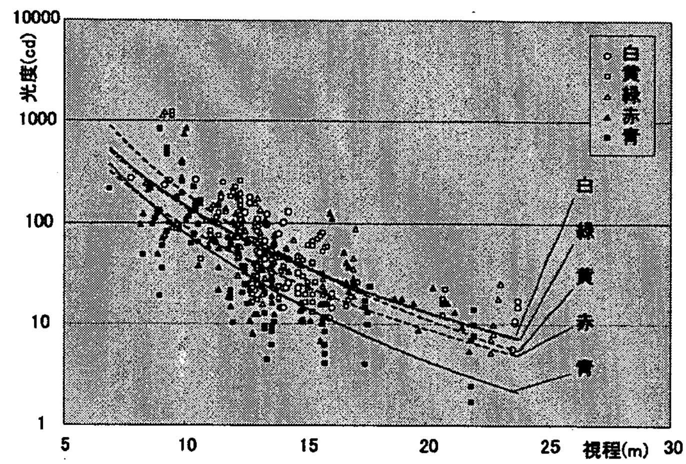

図 1 視程と光覚閾との関係

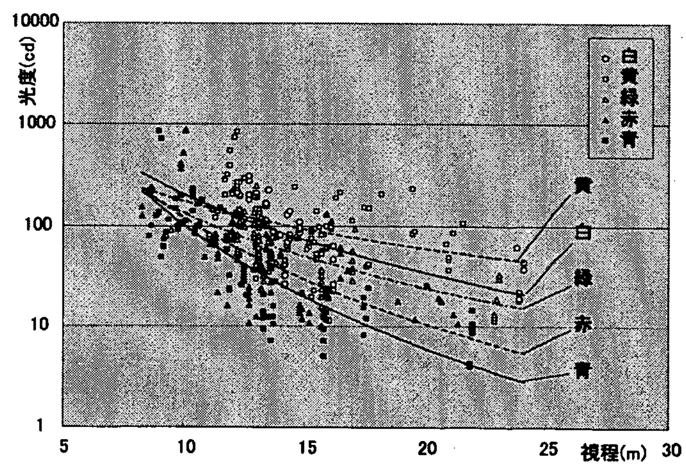

図 2 視程と色覚閾との関係

3. 結果及び考察

図 1 に霧中における視程と光覚閾との関係を示す．同様に図 2 は視程と色覚閾との関係である．データにはばらつきが見られるが，図中に挿入した近似線が全体の傾向を現している．結果より，視程 5m～30m の霧中では，発光色により光覚閾および色覚閾に差が認められ，光覚閾に関しては青色光および赤色光の閾値が比較的低いことが確認できた．また色覚閾に関しても同様で，青色光および赤色光の閾値が比較的低いということが確認できた．

4. 謝辞

本実験の一部は照明学会「悪天候下の交通視環境に関する研究調査委員会」における共同研究として実施されたもので，委員各位ならびに国土交通省国土技術政策総合研究所の多大なるご協力に感謝の意を表します．

Perception Characteristic of Luminous color of Light Emitting Diode in dense Fog
Santaro Nakajima, Akio Kanemori, Mamoru Takamatsu, Yoshio Nakashima, Kazuhiko Ando

02026

高齢者を考慮した標識設計に関する検討

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同　　　　　　　　　　　　森　望

1．　はじめに

本報告は、現在一般道路の案内標識の設置位置や文字高（文字の大きさ）の設定に用いられている設計方法について、運転者の心身特性が関連する因子およびそれら因子の諸数値を整理し、それらの数値が高齢者の心身特性を考慮した場合にも妥当であるかどうか、また、高齢者の心身特性を踏まえた場合、現在設定されている標識の文字高や設置位置が妥当であるかどうかを、既往の調査研究等をもとに検討したものである。

2．　道路標識の設置に係る運転者の心身特性

（1）　案内標識の設計に係る運転者の心身特性

現在案内標識の設計は、道路標識設置基準[1)]（以下設置基準という。）により行われている。設置基準では、道路条件に応じて、運転者が標識の文字を読み終えてから交差点等で右左折行動等をとるまでの一連の流れを踏まえて、標識の設置位置や標識の文字高が決定される。このとき、運転者の心身特性は重要な因子となる。標識設計における運転者の心身特性が関連する因子としては、判読距離：標識を読み終えた位置から標識までの距離、視野範囲：標識に接近して視野からはずれるまでの視認の範囲（視野角度）、判断時間：標識判読後行動を判断する時間、車線変更距離：多車線道路で標識判読後別の車線に進入終了するまでの距離、減速度：標識判読後次の行動に向けて減速するときの減速度、などがある。

（2）　高齢者の心身特性の検討

（1）の運転者特性について、高齢者に着目した心身特性の変化を、既往の調査研究をもとに整理した。その結果を以下に示す。

1）判読距離：標識の距離は運転者の視力や文字の読解能力などが影響し、年齢とともに低下し、その比率は、おおよそ20代：30代：60代：70代：80代＝1：1：0.85：0.5：0.5である[2)]。ただし実験[2)]により計測されたは判読距離自体は、80代でも、設置基準が示す必要判読距離より3割程度余裕があり、設置基準は安全側（余裕側）の設定となっている。

2）視野範囲：高齢者になると視野範囲が狭くなり、また左右各40度を過ぎると視力の低下が著しくなるが、標識視認に影響のある左右各20°の範囲では高齢者、非高齢者とも大きな差異は見られない[3)]。高齢者の夜間の視認性は大きく低下する[4)]。

3）判断時間：高齢者は、非高齢者より長くなるが、ほとんどの人は2秒を下回る[5)6)]。

4）車線変更距離：車線変更距離は、他の車両の交通状況をみながら隣接する車線に進入するための距離であり、運転者の運転操作能力や判断能力が要求されるが、高齢者の車線間変更距離は、極力短い時間で行わせる場合2秒程度で可能であり、60km/hとして概算すれば約35mで車線変更できる[7)]。

5）減速度：道路構造令の解説と運用[8)]では、平均的急ブレーキとして$2.5m/s^2$（0.26g）が見込まれている。汽車の正常の減速度は0.1～0.2g、高速エレベータの平均加速度は0.1～0.2g[9)]であり、これらは特に高齢者にとって不快となる減速度ではない。

（3）　高齢者を踏まえた標識設計用因子

上記の検討結果を踏まえると、高齢者を考慮した標識設計の諸数値として、以下のような考え方ができる。

1）　必要判読距離の計算は、設置基準によって算出されたもので80代でも余裕を持った判読ができていることから、設置基準の計算式をそのまま用いることができる。

2）視野範囲：視野については、運転者が標識を視認する場合広範囲の視野を必要としないことから、現在の設定視野であれば高齢者に対しても問題ない。
3）判断時間：現行基準で問題ないが、設置基準内の最大値を目安にする。
4）車線変更距離：現行基準で特に問題ない。
5）減速度：現行基準で特に問題ないが、基準内の最小値を目安にする。

表－1　諸数値の検討結果

因子	現況の設定値	高齢者を踏まえた設定値
判読距離	L=f・k1・k2・k3・h 各係数の設定値は設置基準による	同左
判断時間	2.0～2.5sec	2.5sec
車線変更距離	120m	120m
減速度	0.75～1.5m/s²	075m/s²
視　野	迎角　7度	迎角　7度
	左右角　15度	左右角　15度

3．標識設計方法の妥当性検討

3．1　現行設計方法の妥当性

上記の検討結果によれば、各因子について設置基準に示された中で最も厳しい数値を用いているものの、全て設置基準の範囲内のもであり、設置基準は高齢者にとっても満足するものとなる。

3．2　現状の非高齢者と同等の視認性を確保する場合

運転者はかなり手前から標識を判読しており、設置基準で設計を行えば余裕をもって判読でき、高齢者に対しても適用できるものであることがわかった。しかし上述しているように、高齢者は非高齢者より判読距離がかなり低下することから、高齢者に対して非高齢者に対する現行のサービスレベルと同等の水準を確保するとすれば、文字を大きくするなどの対策が必要となる。特に、複雑な道路構造の場所や交通が混雑している多車線道路などでは、標識を十分視認する時間がとれない可能性もあるので、現在の一般道路の標準文字高の20cmに対して、30cm～40cmとすれば高齢者にとってもさらに余裕を持った利用が行えるであろう。

4．まとめ

高齢者を踏まえた標識の設計について、高齢者の心身特性などを把握し、現在の設計方法の妥当性について検討した結果、以下のことがわかった。

・高齢者は、標識の判読性、判断時間、視野等の身体能力が非高齢者に比べて低下する。
・現行の標識設計は、心身特性が低下する高齢者に対しても基本的な視認性能は確保している。ただし、非高齢者に比べて余裕は少なくなる。
・道路条件や交通状況などの関係で、標識を十分視認することが困難となる道路では、高齢者に対する標識視認性のサービスレベルをさらに高めるために、文字高をさらに大きくすることも考える必要がある。

5．今後の課題

高齢者は、前期高齢者（65歳～74歳程度）と後期高齢者（75歳程度以上）によって心身特性が変化していくことが考えられるが、前期・後期の別を明確にしている研究事例が少ない。また、今回の対象は一般道路であるが、高速道路で高齢者の心身特性がどのように変化するか等も明確でなく、これらについてさらに検討が必要である。

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歩行者用照明の光源色が交通視環境に与える影響に関する検討

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1． はじめに

現在の交通安全施設は、様々な道路利用者の身体特性を考慮し、より安全性を高めた設計・設置が求められる。また、道路整備に要求される利用者のニーズは多様化しており、これら要求を満たすべく様々な道路付属施設が今後さらに望まれている。本研究では、夜間の歩行者の交通安全を確保するために重要な役割を担っている歩行者用照明に着目し、歩行者用照明の光源色の違いが、歩道等の交通視環境に与える影響について検討した。

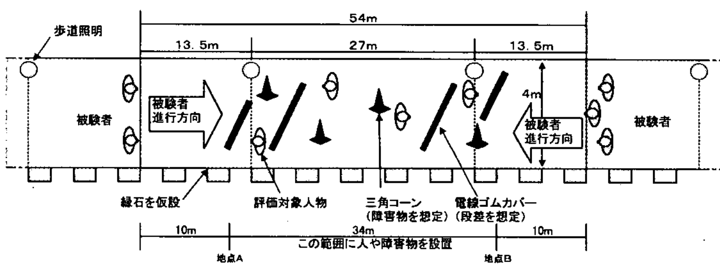
2．研究内容

本研究は、歩行者用照明に使用される光源を対象として、光源色（色温度）の違いが歩道通行者の視認性や快適性にどのような影響を及ぼしているかについて、高齢者、非高齢者を対象として視認性評価実験を行い明らかにした。

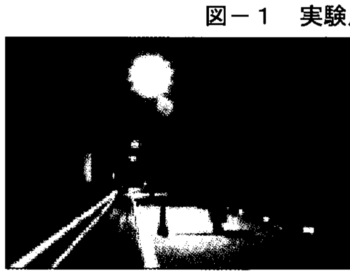
3．視認性評価実験

（1）実験概要

国土技術政策総合研究所内の試験走路に歩道を仮設し、評価実験を行った。設定条件は1.5／3／5／10／20(lx)の5段階とし、光源色は、色温度 2050K、3900K、6500K の3種類とした（光源はそれぞれ高圧ナトリウムランプ、蛍光水銀ランプ、メタルハライドランプを用いた）。被験者は65歳以上の高齢者10名、65歳未満の非高齢者10名で行った。実験対象区間は、延長81m の区間を歩道照明4基で照明した（**図－1、写真－1、2**）。



図－1　実験用歩道概要図



写真－1　色温度2050Kの実験風景

写真－2　色温度6500Kの実験風景

（2）評価項目

被験者はこの実験対象区間を照明光源毎に、設定した各段階の照度レベルにおいて通常の速度で歩行したときの人や障害物の視認性、安心感、危険感、快適感などについてアンケートに回答した。アンケートの評価項目は**表－1**のとおりである。

表－1　評価内容と評価項目

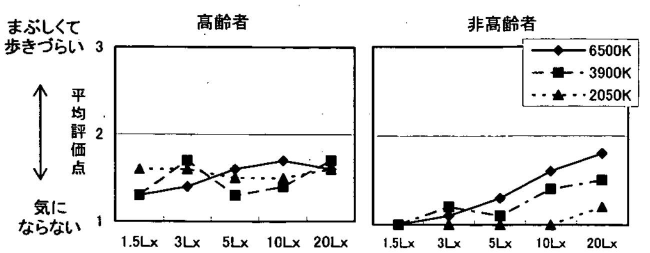
評価内容	評価項目	評価尺度
安全性	障害物の存在の視認性	視認性 1:よく見える、2:まあまあ見える、3:かろうじて見える、4:見えない 安全感（障害物や段差につまづく／人や物にぶつかりそうな感じがするか？） 1:安全だと感じた、2:やや危険を感じた、3:危険を感じた 危険感（通りすがりの人に狙われるような感じがするか？） 1:感じない、2:やや感じる、3:危険を感じた 安心感 1:安心だった、2:やや不安だった、3:不安だった 快適感 1:快適だった、2:やや不快だった、3:不快だった まぶしさ感 1:気にならない、2:気になるが歩くのに支障は無い、3:まぶしくて歩きづらい 明るさ感 1:明る過ぎる、2:ちょうど良い明るさ、3:やや暗い、4::暗い
	段差の視認性	
	安全感	
防犯性	人の存在の視認性	
	人の顔の視認性	
	危険感	
	安心感	
快適性	快適感	
	まぶしさ感	
	明るさ感	
	照明された歩行空間の印象・雰囲気※1	

※1　照明された歩行空間から感じた印象・雰囲気を下記に分類された形容詞26個から3つ選択する
暖かい、楽しい、わくわくする、軽々しい、派手な、やわらかい、動的な、さわやかな
寒い、寂しいびくびくする、重々しい、地味な、かたい、静的な、むさくるしい
落ち着く、にぎやかな、安全な、安心できる、陽気な
落ち着かない、わびしい、危険な、怖い、陰気な

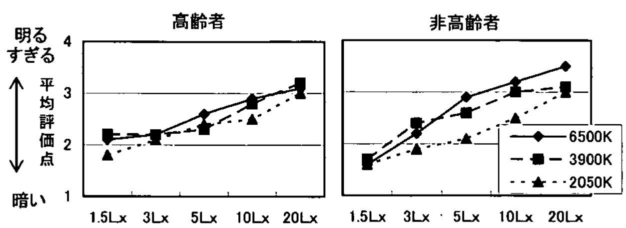
（3）実験結果

光源色の違いが主に歩道通行者に影響を与

えているのは「まぶしさ感（**図－２**）」「明るさ感（**図－３**）」および「印象・雰囲気（**図－４**）」であることが分かった。一方、「障害物や人の視認性」「危険感」「安心感」「快適感」の評価では、色温度の低い光源の評価が若干低くなる傾向が見られたものの大きな差はなく、光源色の違いによる影響はほとんどないことが分かった。高齢者・非高齢者別の評価では、非高齢者は照度の増加、色温度の増加とともに明るさ、まぶしさを感じやすくなっていくのに対して、高齢者は低い照度のときからすでにまぶしさを感じていることが分かった。



図－２　まぶしさ感の評価



図－３　明るさ感の評価

※ 数値は回答数を表す

照度（明↑↓暗）	2050K	3900K	6500K
20lx	安心できる 16 安全な 11 落ち着く 11	安全な 12 安心できる 11 落ち着く 10	安全な 15 安心できる 13 落ち着く 7
10lx	安全な 9 安心できる 8 暖かい 8	安心できる 12 安全な 11 落ち着く 9	安全な 12 安心できる 11 落ち着く 10
5lx	落ち着く 9 暖かい 7 安全な 6 やわらかな 6	安全な 8 寂しい 8 落ち着く 6 6	安全な 8 落ち着く 8 さわやかな 6
3lx	寂しい 7 暖かい 6 陰気な 6	寒い(涼しい) 7 寂しい 7 落ち着く 6 地味な 6	寒い(涼しい) 9 寂しい 6 地味な 5 安全な 5 さわやかな 5
1.5lx	寂しい 11 暖かい 6 わびしい 6	寂しい 12 怖い 7 寒い(涼しい) 6 陰気な 6 地味な 6	寂しい 9 寒い(涼しい) 8 陰気な 7 怖い 7

低 ← 色温度 → 高

図－４　印象・雰囲気の評価

（４）考察

実験結果から、各光源色の特徴をまとめた。

①色温度 2050K

光色から暖かみのある柔らかな印象を与え、他の光源色に比べ、照度レベルが高い場合でもまぶしさを感じにくい。市街地中心地のように活気を必要とする歩道よりも、コミュニティーゾーンや公園周辺の道路のように落ち着きのある空間の演出に効果的であると考えられる。また、季節としては冬期での利用が考えられる。

②色温度 3900K

評価の良し悪しや印象について特に突出した傾向が見られない。照明による演出を特別に必要としない、一般的な歩道での適用が考えられる。

③色温度 6500K

他の光源色に比べ、まぶしさを感じやすいので、周辺が特に暗い歩道に用いることには問題が有る。市街地中心街のように周辺の照度が高く、活気や明るさ感を必要とする歩道への適用が効果的であると考えられる。光色からさわやかな涼しい印象を与えるので、夏期での利用が考えられる。

４．まとめと今後の課題

歩行者が歩道を通行するときに最も重要な因子となる歩道上の「障害物や人の視認性」は光源色の違いによる影響は受けず、適切な照度の設定が重要であることを把握した。一方、光源色から受ける印象が歩行時の快適性に少なからず影響を及ぼすことが判明した。これらの成果は、道路管理者が今後歩行者用照明の光源選定を行う際の基礎資料として寄与するものとなる。

今回は歩行者用照明を対象としたが、道路照明を対象とした場合も、光源色の違いが自動車運転者の交通視環境に何らかの影響を及ぼすことが考えられる。この検討は今後の課題としたい。

DEVELOPMENT OF AESTHETIC BARRIERS (ORDINARY ROAD TYPE AND EXPRESSWAY TYPE) IN JAPAN

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Abstract
The Ministry of Land, Infrastructure and Transport (MLIT), Japan revised the barrier regulations in 1998. New regulation provided as the performance-based regulation by abolishing the structural criteria of the old regulation to incorporate the landscape aspects into the infrastructure. Scope of this study is the development of the standardized aesthetic barrier based on the revision of the barrier regulation from the structural regulation to the performance-based regulation. The reason for writing this paper is to introduce the process of the development of an aesthetic barrier in Japan, and also to discuss the importance of an aesthetic barrier for a landscape of road. This paper discussed the development process of the new barriers that satisfied the new regulation. The objectives of this development are to create and maintain a good landscape of road with the aesthetic barrier. In this paper, based on the analysis on landscape aspects of the conventional barriers in Japan, the fundamental designs to solve the problems of the barrier in the viewpoint of landscape were examined. Through the results of the collision tests with the trial products and the social impact assessments after the installation of new barriers, it was confirmed that the new barriers attained the initial development objectives. The new barriers developed were adopted as one of the standard barriers for the vehicle by the MLIT in March 1999. It is, hence, expected that the new barriers will be widely utilized in the areas with picturesque scenery as well as urban areas in Japan.

1. INTRODUCTION

Japan has used standardized barriers that were defined by barrier regulation in 1972. Each kind of barriers such as guardrail, guard pipe, guard cable, etc. has been designed in accordance with only the design speed of each road. It was impossible for a long time to develop a new type of barrier, considering landscape along the roads since structures, shapes, and even measurements were included in the regulation. Even in the places where picturesque sceneries are observed, therefore, the standardized barriers have been installed and spoiled landscape.

In view of this, Tohoku Regional Bureau, Ministry of Land, Infrastructure and Transport MLIT , formerly known as Ministry of Construction, decided to develop a new barrier with better design, a committee was established. Because it was scheduled that old regulation would be revised to performance-based regulation in 1998. The authors led the new barrier development, as a chairperson of the committee, committee member, member of secretariat, development partner. This paper describes the research and the process of the development of new type barriers and its social effect.

2. LANDSCAPE ASPECTS OF THE CONVENTIONAL BARRIERS

Three kinds of barriers (guardrail, guard cable, and guard pipe) are usually used at general national highways in Japan. Since structures and dimension of these barriers were defined by the regulation, it was impossible to incorporate landscape quality along the roads. Regarding color, (only) white was used with some exceptions. While developing a new barrier, the authors analyzed the landscape aspects of the conventional barriers.

2.1 Guardrail

The guardrails are the most commonly utilized along roadsides and boundaries of sidewalk and roadway in Japan. The center of beam is located at the 60cm above from road surface.

The landscape aspects of the guardrail are as follows:

•: from a viewpoint of the passenger

•The view from the passenger car is interrupted since the visual point level of passenger is approximately 110cm;

•Guardrail installed at median gives a complicated impression because it has two beams for both sides of lanes; and

•The line of beam emphasizes the impressions of road alignment, and also is effective for visual leading.

♦: from a viewpoint of outside of the road

♦ When it is installed at picturesque places, the view from outside of the road has big damage because guardrail has white continuous line.

♦ Bolts and nuts of zinc plating on white beam give a complicated impression;

♦ A joint point with a support and a beam is complicated and conspicuous, because many elements gather it;

♦ Dirty of white painting and rusty of damage points give a poor-looking impression; and

♦ Beam and support has not a sense of unity because of corrugated shape of a beam and existence of a bracket.

2.2 Guard Cable

The guard cables are frequently utilized at a banking or cutting section in country areas and mountain areas. The guard cables have the structure to respond vehicle by a pulling power of three to five cables.

The landscape aspects of the guard cable are as follows:

•♦Guard cables don't interrupt both views from the passenger and from the outside because of there visual permeability;

•A support of zinc plating give a cold impression;

•A joint point with a support and a beam is complicated and conspicuous, because many elements gather it;

•A terminal support give a complicated impression, because a form is complicated and a bolt to conclude a cable is exposed; and

• Guardrail installed at median gives a complicated impression because it has two beams for both sides of lanes.

2.3 Guard Pipe

Usually, guard pipes are installed along boundaries of sidewalk and roadway. The conventional guard pipes have the structure to respond vehicle by the three-beam pipes. Therefore, it is superb at a view to the road outside. And, that has (with) a light impression. However, at a joint with a beam pipe and support, a number of pieces of a bolt also give a complicated impression to a pedestrian, greatly.

The landscape aspects of guard pipe are as follows:

- ◆ A shape composed of a thin line gives a light impression;
- ◆ According to an artistic balance of a form, it can give a different impression;
- ◆ A guard pipe is inconspicuous in comparison with a guardrail. However, when a general standardized product is continuously installed, lines of a white painted pipes are apt to be conspicuous;
- ◆ Guard pipes don't interrupt both views from the passenger and from the outside because of there visual permeability; and
- ◆ A joint point with a support and a pipe is complicated and conspicuous, because many elements gather it.

3. CONSIDERATION ON FUNDAMENTAL DESIGN OF THE BARRIERS

3.1 Design Conditions

Necessary conditions for the development of new barriers concentrated on the following five points:
a. To have a necessary strength of B class (former standard) that is the greatest used at a national highway;
b. To become a substitute of a current guardrail (possible for throwing itself to inside soil);
c. Beautiful shape.;
d. Not to prevent a view to the roadside; and
e. Low cost.

With these necessary conditions, Designer Ono who was one of the committee members designed the fundamental shape of the new barrier, considering the following three points as the primary principles of design.

(1) As structure of a guard pipe type, increase visual permeability.
It was recognized that the new barrier would be installed on both of roadsides and boundaries of sidewalks and a roadway in the jurisdiction area under MLIT. To avoid interrupting views, high visual permeability was considered one of the design conditions. Structure of guard pipe type was chosen for the structure of new barriers.
(2) As using a general material (such as Japanese Industrial Standards (JIS) steel pipe), lower a price.
The conventional barriers are very inexpensive because mass production is formed already. And, at Japan today, a cost decrease in public works is claimed as a policy. Inexpensiveness was an important design condition. Using general materials was required as one of design conditions to lower price.
(3) As considering continuity between a general section and a bridge section, adopt a shape of block-out type.
The shape of a barrier in a bridge section is defined as a block-out type in old regulation. In the viewpoint of a sequence of a road landscape, a form of a barrier should not be changed between a general section and a bridge section. Therefore, a shape of block-out type was adopted as one of design conditions.

3.2 Decision Of A Fundamental Shape And Measurement

The next figure shows the barrier that Ms. Designer Ono prepared, concerning the above-mentioned three points.

4. SELECTION OF TECHNICAL DEVELOPMENT PARTNER AND MANUFACTURE

A fundamental design was decided by applying knowledge of committee members about structures and landscape. Consequently, it was necessary to verify strength, construction method and cost. Therefore, we implemented the technical proposal competition based on this fundamental design for manufacturers to be able to produce these barriers in a large scale.

4.1 Selection Of The Development Partner Through The Technical Proposal Competition

There were 35 proposals to a technical proposal competition.

(1) Material
As Main material, 34 proposals used steel, and one proposal used stainless steel.
As Upper section connector, 25 proposals used spherical graphite casting iron, five proposals used heat growth thin board, two proposals used aluminum casting, and three proposals were others.
(2) Cost (Material unit price per 1 meter)
About 3 beams type, average price was 19,252 yen, minimum price is 10,090 yen, and maximum price was 54,000 yen. About 2 beams type, average price was 16,255 yen, minimum price was 8,320 yen, and maximum price was 37,900 yen.
(3) Selection of development partner
All proposals were evaluated in the five viewpoints of function, design, economy, construction, and maintenance management. Therefore, Shinko Kenzai.Ltd. was selected as a development partner.

The criteria for the selection were summarized in the following three points:
- Following a fundamental design, a design with an upper section beam and connector has a neat impression;
- Their proposal allows for support to stand upright; and
- Concealing a bolt of back of supports by means of unique technology, it has a neat shape.

4.2 Trial Production

Shinko Kenzai. Ltd. made a trial production, and more detailed design was discussed by the committee. By the way, this trial production was exhibited at " YUME - HAKU (exposition) " that was held at that time at Sendai City and obtained great appraisal from many visitors.
• Structure
About a support interval, with data of a simulation of a collision, it was confirmed to satisfy a generally functional condition at support interval of 3 meters. Consequently, tests with real car collision at support interval three meters. About snow weight, a weight test was done and that was considered in the support interval in a snowy region with its result.
• Design
About a design, Amano and Ono advise a detailed design gradually.
• Color
Comparative analysis and examination for the selection of the color for the new barrier were carried out among the four colors, and dark brown was chosen. Also, to improve the function of barrier, color reflection tape as visual guidance was added.

5. TESTS FOR THE DEVELOPMENT OF ORDINARY ROAD TYPE BARRIER

5.1 Outline Of The Tests

Collision tests were conducted three times in order to confirm the performance of the fences. At first, collision test was planned for once both the three beams type and the two beams type, respectively. However, a lot of deformation and damages that were not expected occurred at the first test for the three beams type. Therefore, another test was added for the three beams type that was improved based on the results of the first test.

5.2 Conditions on Collision Tests

Test No.1 was for three beams type (prototype), test No.2 was for two beams type, and test No.3 was for three beams type (improved).
All conditions of crash tests for Ordinary road type were as follows: Vehicle Type (Truck) is middle-sized truck, vehicle mass is 8 ton, impact speed is 50 km/h, impact angle is 15 degrees, and impact severity is 52 kJ.

5.3 Structure Of The Test Specimens

The structures shown in figure 2 were used as the test specimens. Three beams structure of test No.1 was the prototype barrier. In the test No.1, lower beam was broken down because of colliding of wheel rim, and lack of elongation of bracket that made of casting caused the collapse of the lower beam. Structure of two beams type, therefore, was improved in terms of the lower beam height and bracket material. Structure of test No.3 was improved in terms of height of the barrier and the bracket material.

5.4 Results of Tests

Results of tests and an example photograph of the collision are presented in the Table 1 and Figure 2, respectively.

5.5 Evaluation Of Barrier Performance

(1) Test No. 1 (three beams type (prototype type))
The behavior of a vehicle after collision against the barrier was stable, and the vehicle was smoothly guided after colliding with it. However, when a vehicle came in contact with a barrier, the left front wheel of vehicle greatly changed as pressing down a lower beam, and a lower beam was dropped.
Hence, the following two points were considered. A connector between a lower beam and a support was made of cast iron, therefore the brittle failure of a connector was occurred.
A wheel contacted directly and pressed down a lower beam because its height.

(2) Test No.2 (two beams type)
From the first result of test No.1, the height of a lower beam was decided not to contact with a wheel, and the material of a connector was changed from cast iron to steel. The behavior of a vehicle after collision against the barrier was stable, and the vehicle was smoothly guided after colliding with it. As the result of such modification, a lower beam did not drop. Through this result, these modification countermeasures were justified.

(3) Test No.3 (three beams type, (improved))
Test No.3 was carried out with modification like test No.2 (the height a lower beam, and material of connector) based on the result of test No.1 and test No.2. As the result of such modification, behavior of a vehicle after collision against the barrier was stable without a dropping of a lower beam. Through this result, the function of the modified type of three beans was confirmed.

According to these experimental results, the development of Ordinary road type barrier was succeeded. Ordinary road type barrier has the same function of level 2 barrier in U.S.A..

6. COLLISION TESTS FOR (THE) DEVELOPMENT OF TYPE A BARRIER

After the revision of the barrier regulation in 1998, development of new barriers is permitted by Ministry of Land, Infrastructure and Transport (MLIT). Shinko Kenzai.Ltd. decided the development of Expressway type barrier based on the same fundamental design (Figure 1) with collaboration of Nittetsu Kenzai Ltd..

6.1 Outline Of The Test

Collision tests were conducted three times in order to confirm the performance of the barriers. At first, collision test was planned once for the large-sized truck and the passenger car, respectively. However, unexpected excessive acceleration occurred at the first test for passenger car. Therefore, another test was added for the passenger car that was improved based on the results of the first test. The improvement was considered without change of form, because this improvement should not influence the result for the large-sized truck.

6.2 Condition on the Collision Test

Test No.1 was for the large-sized truck, test No.2 was for the passenger car (prototype), and test No.3 was for the passenger car (improved). The conditions of collision tests for Expressway type were as follows: For the large-sized truck, in the regulation impact severity should be over 130, vehicle mass is 20 ton, impact speed is 51 km/h, impact angle is 15 degree, and impact severity is 134 kJ. For the passenger car, vehicle mass is 1 ton, impact speed is 100 km/h, and impact angle is 20 degree according as the regulation.

6.3 Structure Of The Test Specimens

The structure shown in the Figure 4 was used as the test specimens. The improvement based on the result of test No.2 was only increase of inner sleeve thickness from 4.5 mm to 6.0 mm.

6.4Evaluation Criteria

The criteria for the Expressway barrier are shown in table 2. Considering these criteria, Expressway type barrier has the same function of level 4 barrier in U.S.A..

6.5 Results Of Tests And Evaluation

The results of tests were shown in Table 3.

According to these results of tests, the development of Expressway type barrier was succeeded.

7. EXAMPLES OF CONSTRUCTION AND THOSE EFFECTS

"The Tohoku Regional Bureau, Ministry of Land, Infrastructure and Transport" (TRB, MLIT) conducted the experimental construction at three sites in 1999, and confirmed that the new type barrier had attained the initial objectives. After that, this type of barrier has been constructed along many roads in Japan. Three quarters from the construction sites were selected to study those effect.

7.1 Examples Of Construction And The Effects

The characteristics of landscape before and after the constructions of the new barriers on three quarters in Tohoku Region, Japan are described below.

a. Route 45 Matsushima Quarter
Matsushima has one of the most picturesque scenery with pine trees in Japan where about 260 islands are located in a gulf. Ordinary road type barrier was constructed along this quarter.

b. Route6 Hattachi Quarter
This stretch is designated as a natural park of Fukushima Prefecture and is crowded with sea-bathing visitors during a summer season. Ordinary road type barrier was constructed along this quarter.

c. Rote 7 Atusmi Quarter
Route 7, Atsumi is a principal national highway stretch in the front of Japanese Sea. Sunset on Japanese Sea and the rough coastal landscape are recognized as beautiful. Expressway type barrier was constructed in this quarter.

7.2 Evaluation From The Examples

(1) Aspect of landscape
The three examples have picturesque coastal scenery. Therefore, whether barriers have effects on the view surrounded or not, regardless their extent, is a vital for landscape. From the site investigation, it was observed that new barrier was not considered as the obstruction to the landscape. Moreover, through the interview at the adjacent drive-in, remarkable improvement of the view along the road was noted.

(2) Function of the visual leading
A primary color of a new barrier was dark brown, therefore it could hardly be seen from the vehicle window. Committee thought to glue a white reflective tape at the top of support in order to be seen and to enhance the function of visual leading.

(3) Ease of construction
Although it was the first time for the construction firm to carry out the construction of the new barrier, little difficulty was observed during the implementation.

8. CONCLUSION

At first, through the analysis of landscape aspects of conventional barriers, the problem of barrier in the viewpoint of landscape is clarified.
Secondly, the process of the development of the aesthetic barriers was introduced. In this process, the first step is the determination of fundamental design, the second step is the selection of a development partner by the technical competition, and the third step is the confirmation of the function of a barrier by the collision tests.
Thirdly, through the evaluation from the examples, the effectiveness of this aesthetic barrier that was developed in this study is confirmed.
Consequently, it is expected that the aesthetic barrier developed will be widely utilized in areas with picturesque scenery as well as urban areas

ACKNOWLEDGEMENT

REFERENCE

The regulation of barriers in 1972, JAPAN
The regulation of barriers in 1998, JAPAN

LIST OF TABLES

TABLE1 Results of Tests

Test		No.1	No.2	No.3
Collision condition	Vehicle mass (t)	8.0	8.0	8.0
	Impact speed (km/h)	50.2	50.2	50.2
		50.0	50.0	50.0
	Impact angle (degree)	15.0	14.6	15.0
		15.0	15.0	15.0
	Impact severity (kJ)	52.1	49.4	52.1
		51.7	51.7	51.7
Barrier condition	Largest remaining modified quantity (mm)	729	383	715
	Tire entering quantity (mm)	400	230	300
	Contact quantity (mm)	14,020	10,765	12,380
Vehicle condition	Breakaway angle (degree)	4.2	5.1	8.2
	Breakaway speed (km / h)	39.6	44.4	-
	Damage situation	Left front part damage, without a car-chamber damage, vehicle can run by itself		

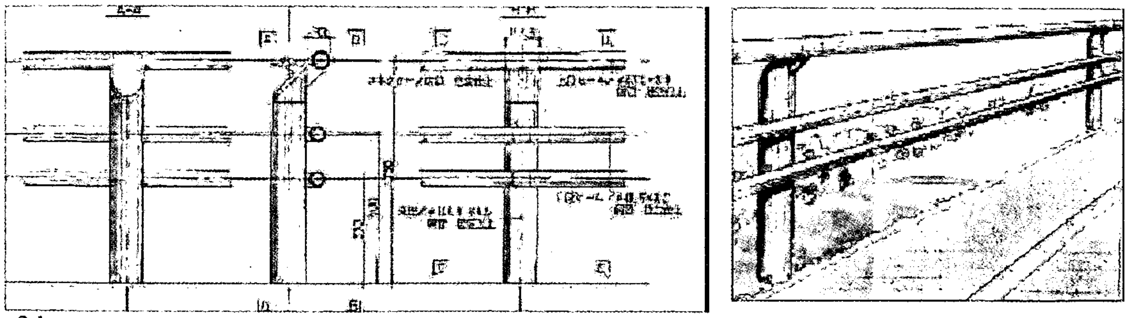
Note) the upper section is the result of experiment, and the lower section is setting up condition in Collision condition

TABLE2 Criterion of Evaluation

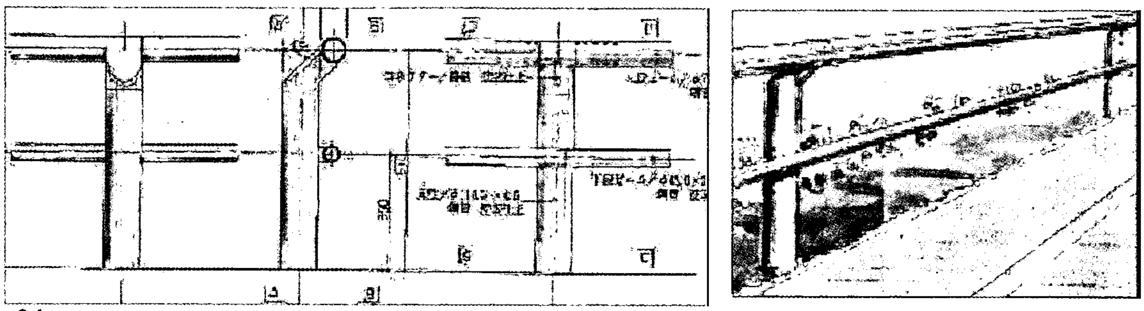
Item	Criteria		Case
Defense of deviation	strength	not breakthrough	for the large-sized truck
	deformation	maximum tire entering quantity < 1.1m	
Security of passenger	both of X (longitudinal) Y (lateral) axis acceleration < $150m/s^2/10ms$		for the passenger car
Guidance for vehicle	not roll sideway		both
	breakaway speed	more than 60% of impact speed	
	breakaway angle	not more than 60% of impact angle	
Defense of scatter of parts	not scatter the component part so much at the impact		

TABLE3 Results of Tests and Evaluation

Test		No.1	No.2	No.3
Tire entering quantity		0.36m<1.1m OK	-	-
Acceleration	X	-	$155.8m/s^2/10ms>150m/s^2/10ms$ NG	$122m/s^2/10ms<150m/s^2/10ms$ OK
	Y	-	$113.8m/s^2/10ms<150m/s^2/10ms$ OK	$122m/s^2/10ms<150m/s^2/10ms$ OK
Breakaway speed		43km/h>31km/h (60%of impact speed) OK	62km/h>60km/h (60%of impact speed) OK	74km/h>60km/h (60%of impact speed) OK
Breakaway angle		7degree<9degree (60%of impact angle) OK	7degree<12degree (60% of impact angle) OK	9degree<12degree (60%of impact angle) OK



3-beam type



2-beam type

Figure 1 Fundamental Design (prepared by Designer Ono)

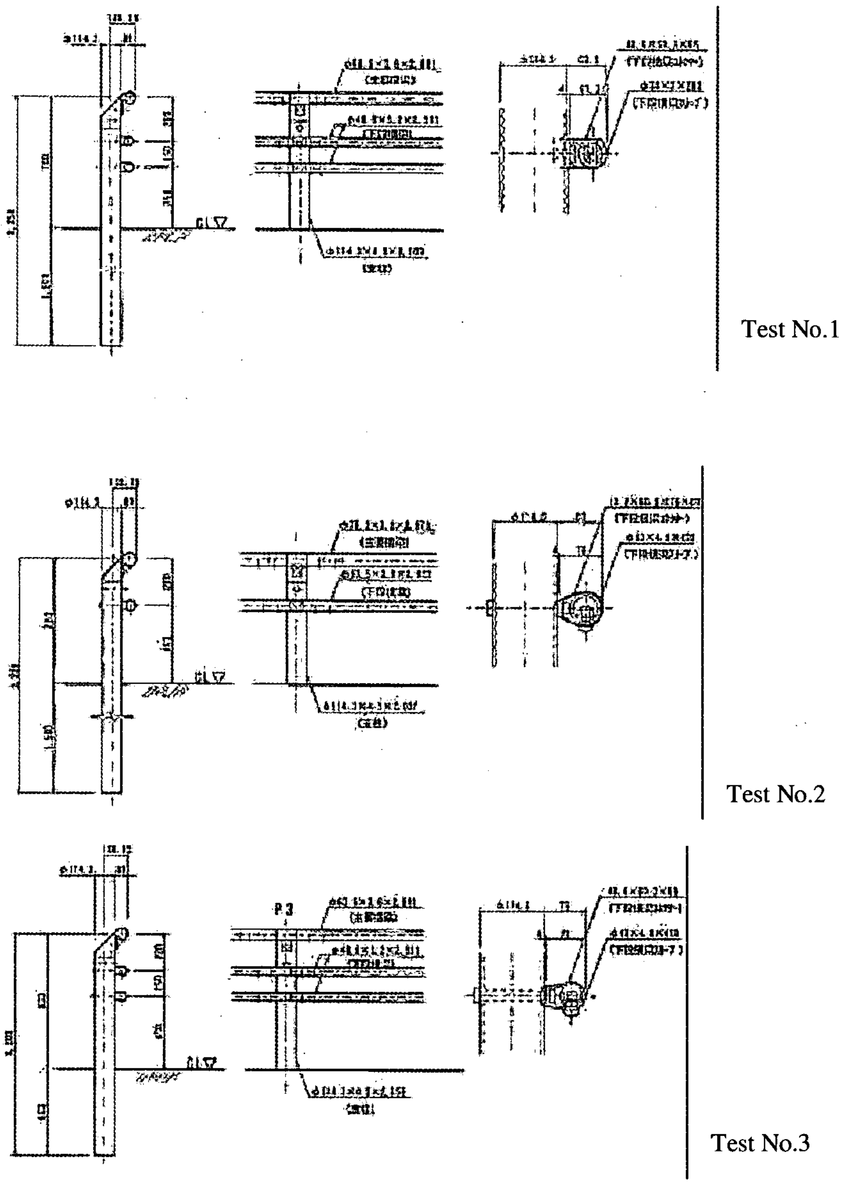


FIGURE 2 Structure of the test specimen

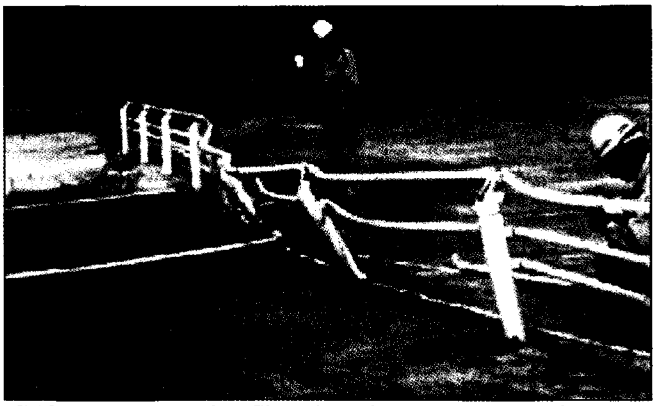


FIGURE 3 Dropping Situation of a Photographic Crossbeam

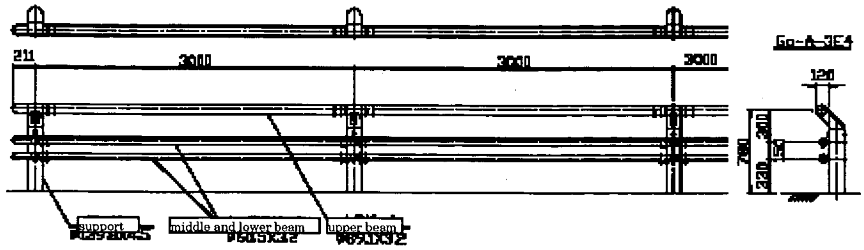


FIGURE 4 Structure of the test specimen (Test No.1,2,3)

FIGURE 5 Route 45 Matsushima Quarter (Before) (After)

FIGURE 6 Route6 Hattachi Quarter (Before) (After)

FIGURE 7 Rote 7 Atusmi Quarter (Before) (After)