Survey Report on Sandal Entrapment Accidents in Escalators

(Product Safety Test)

May, 2008

National Institute of Technology and Evaluation

Table of contents

1. Background and objectives of the Survey

In August 2007, a child wearing resin sandals (*) got her foot caught in an escalator and suffered a fractured middle toe. The manufacturer/importer of the sandals reported the accident to the Ministry of Economy, Trade and Industry under the mandatory reporting system of serious accidents. A series of accidents relating to the sandal entrapment were reported to the National Institute of Technology and Evaluation, NITE, since last August. NITE issued an alert (NITE Alert No.82) on September 6, 2007 to call on consumers to take extra cautions.

Accidents, however, continued to be reported. NITE has received 66 cases of the kind as of March 31, 2008.
In view of the frequency of accidents, NITE has conducted safety tests of these sandals in the market.

(*) In this report, soft plastic sandals, with a shape of covering instep and toe as shown in the picture, are referred to as “resin sandals”. These sandals have been popular for their comforts.

2. Survey contents

(1) To conduct a reproduction test to confirm whether sandals get caught in escalators.

(2) To examine material characteristics (such as hardness, elasticity etc), and investigate a connection between these characteristics and entrapment risks.

3. Test samples

The sample products were purchased widely from the market. A total of 26 products of 22 brands by 20 manufacturers were chosen; resin sandals of 7 brands by 7 manufacturers (a total of 11 pairs in different sizes), rubber boots of 5 brands by 5 manufacturers, flip-flops of 5 brands by 5 manufacturers and canvas shoes of 5 brands by 4 manufacturers respectively.
The samples were collected in a size 18cm to eliminate a variation in result associated with size. On resin sandals other sizes were also prepared to study effects in entrapment by sizes.
Test samples are listed in Table1.

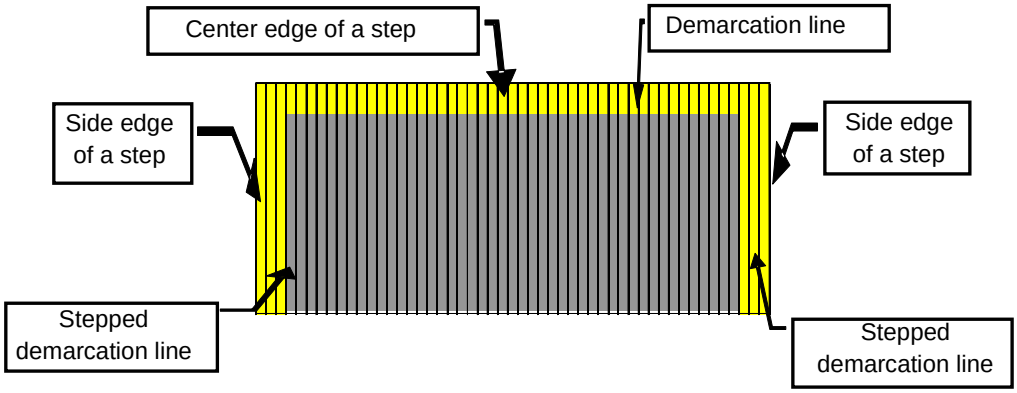
Table 1: Sample list

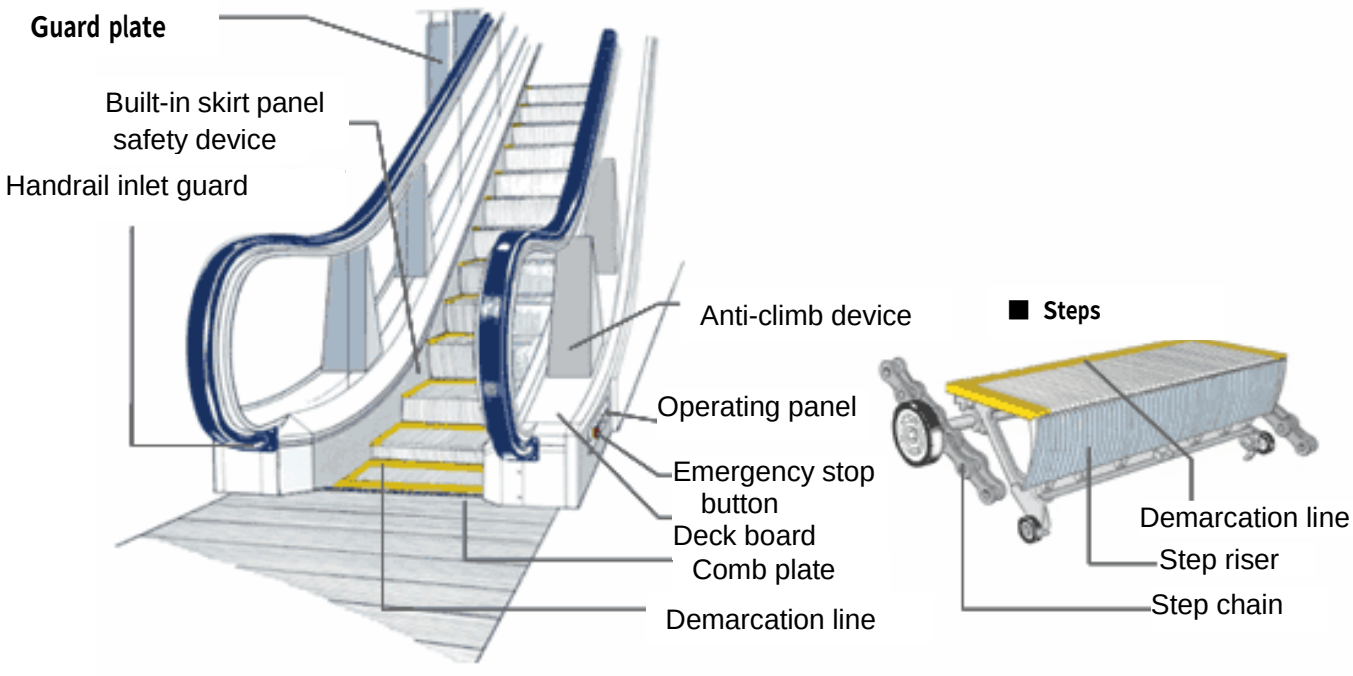
Sample No.	Size(cm)	Kind of footwear	Composition labeling
(1)	14	Resin Sandals	Polyethylene
	18		
	24		
(2)	18		No labeling
	24		
(3)	18		EVA
(4)	17		EVA
(5)	18		No labeling
	19		
(6)	18		EVA
(7)	18		No labeling
(8)	24.5	Flip-Flops	No labeling
(9)	17		EVA
(10)	18		EVA
(11)	18		Artificial Rubber
(12)	18		No labeling
(13)	18	Rubber Boots	Polyvinyl Chloride Resin (Lining: Nylon, Cotton)
(14)	18		Synthetic Rubber
(15)	18		Rubber
(16)	18		(Outside) Polyvinyl Chloride Resin (Inside) Nylon
(17)	18		No labeling
(18)	18	Canvas Shoes	No labeling
(19)	18		(Instep part) Cotton (Sole part) Rubber
(20)	18		No labeling
(21)	18		(Instep part) Cotton (Sole part) Rubber
(22)	18		No labeling

Note: EVA stands for ethylene-vinyl acetate copolymer.

4. Names of escalator parts

Names of escalator parts are described in this report as follows.





【Adopted from The Japan Elevator Association (JEA)】

5. Entrapment of sandals in other countries

NITE received 66 accident reports on escalator entrapment of footwear such as sandals from August to December in 2007.
Most resin sandals involved in these accidents have been popular overseas recently or their imitations.
The survey of escalator entrapment incidents shows that incidents have been occurring both at home and abroad.

Countries where escalator entrapment accidents were confirmed are marked with ◎. Europe is marked with one red circle because the accidents cannot be identified country by country.

6. Situation of accident occurrence

6.1 Footwear involved in accident

Figure 1: A child injured her toe in an accident.

Figure 2: A child injured her toe in an accident.

6.2 Accident occurrence

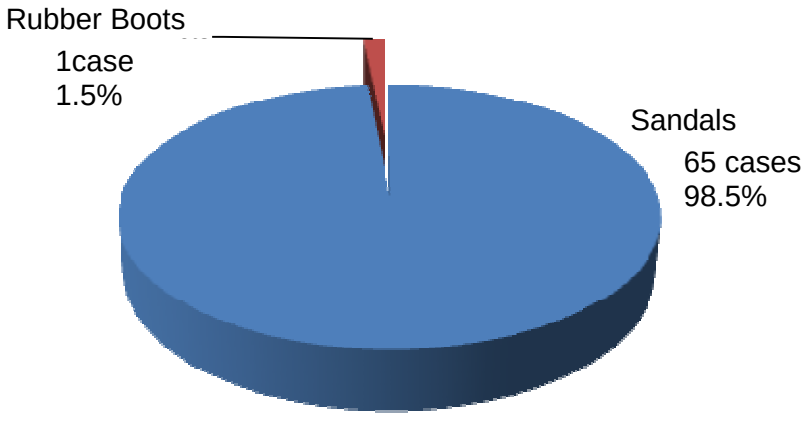
The below charts indicate the breakdown by product classification of the 66 cases of escalator entrapment reported to NITE:

(1) Entrapment accidents classified by type of product
About 99% of the accidents were associated with sandals.

Table 2: Entrapment accidents classified by type of product

Classification of footwear	Cases	Ratio
Sandals	65	98.5%
Rubber Boots	1	1.5%
Total	66	100.0%

Figure 3: Entrapment accidents classified by type of product



(2) Entrapment accidents classified by structure of sandals

About 51% of the accidents were associated with resin sandals whose instep parts are covered.

Table 3: Entrapment accidents classified by type of sandals

Sandal Structure	Cases	Ratio
Instep part is covered	33	50.8%
Toe part is not covered	1	1.5%
Unknown (Not described in accident reports)	31	47.7%
Total	65	100.0%

Figure 4: Entrapment accidents classified by structure of product

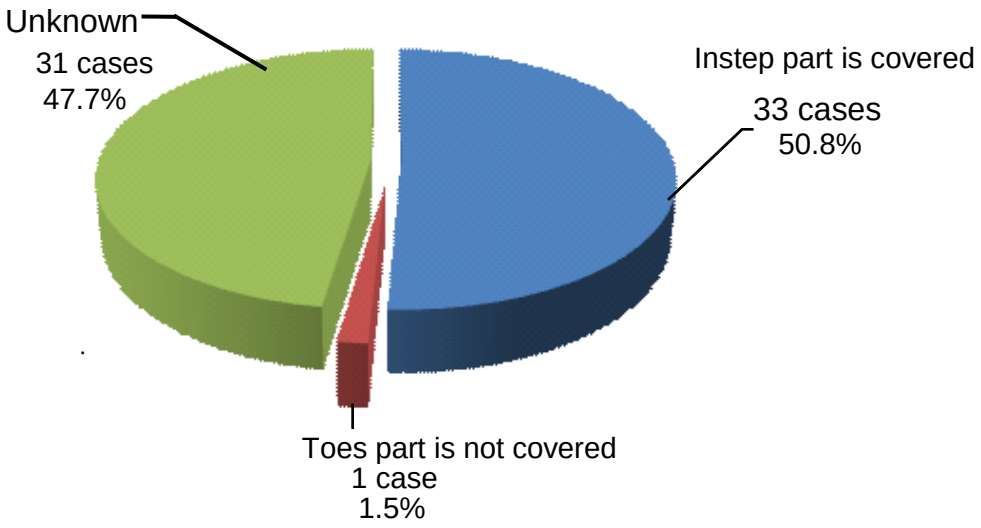
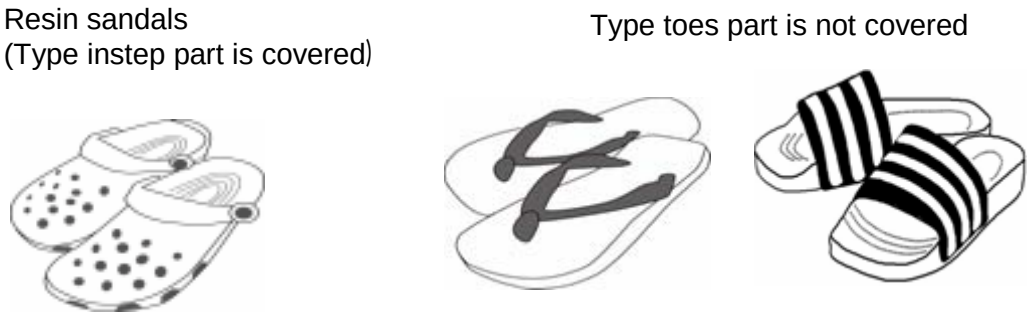


Figure 5: Classification of sandals



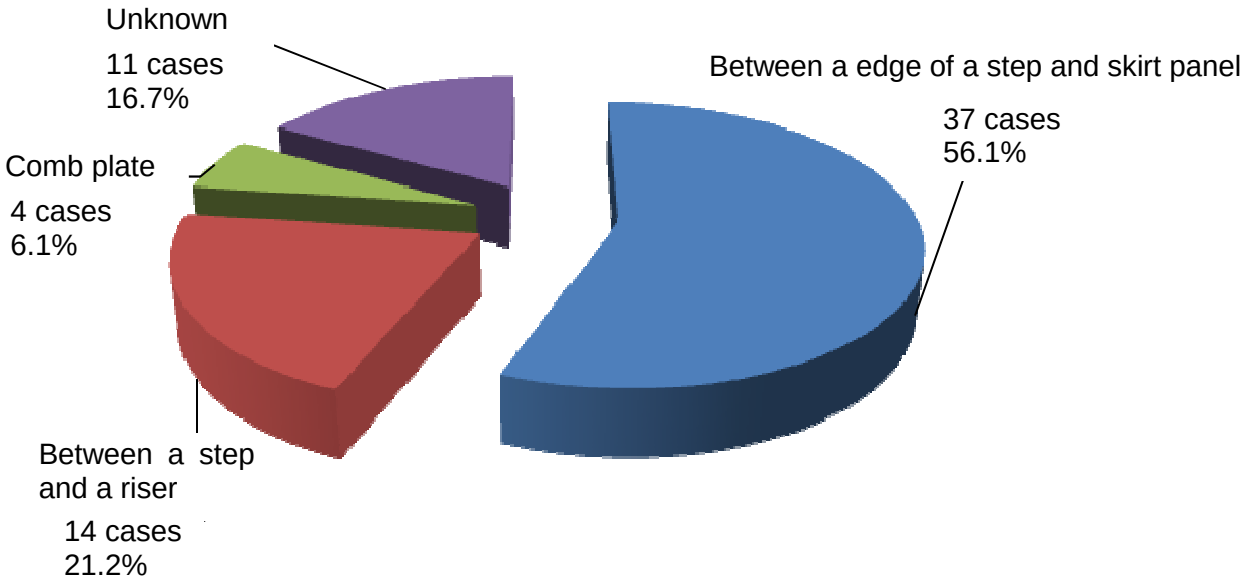
(3) Accidents classified by part of escalators where sandals got caught

The most potential part of entrapment case is, about 56%, gaps between a step edge and a skirt panel.

Table 4: Accidents classified by part of escalators

Part of escalators	Cases	Ratio
Between edge of a step and skirt panel	37	56.1%
Between a step and a riser	14	21.2%
Comb plate	4	6.1%
Unknown (not described in accident reports)	11	16.7%
Total	66	100.0%

Figure 6: Accidents classified by part of escalators



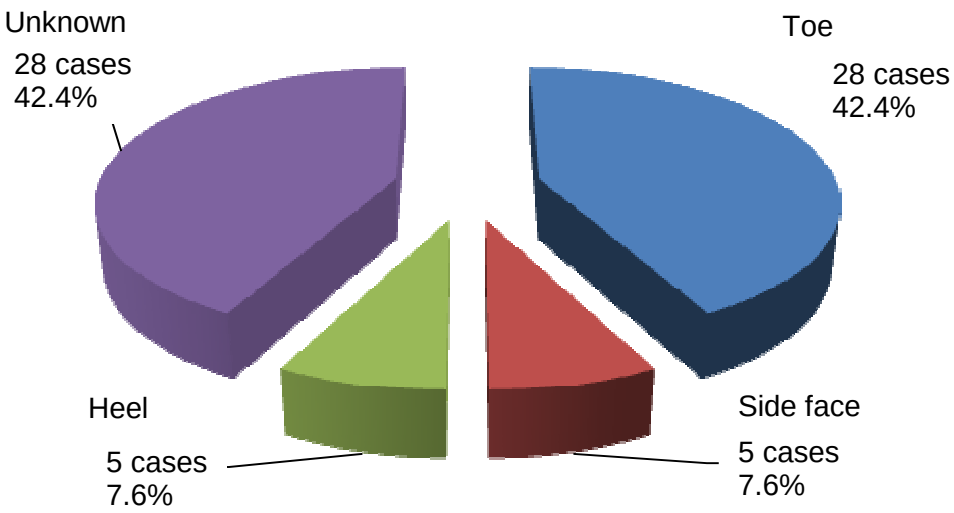
(4) Accidents classified by part of footwear

The most potential part of footwear entrapped in escalators is toe part which accounts for about 42%.

Table 5: Accidents classified by part of footwear

Part of footwear	Cases	Ratio
Toe	28	42.4%
Side face	5	7.6%
Heel	5	7.6%
Unknown (not described in accident reports)	28	42.4%
Total	66	100.0%

Figure 7: Accidents classified by part of footwear



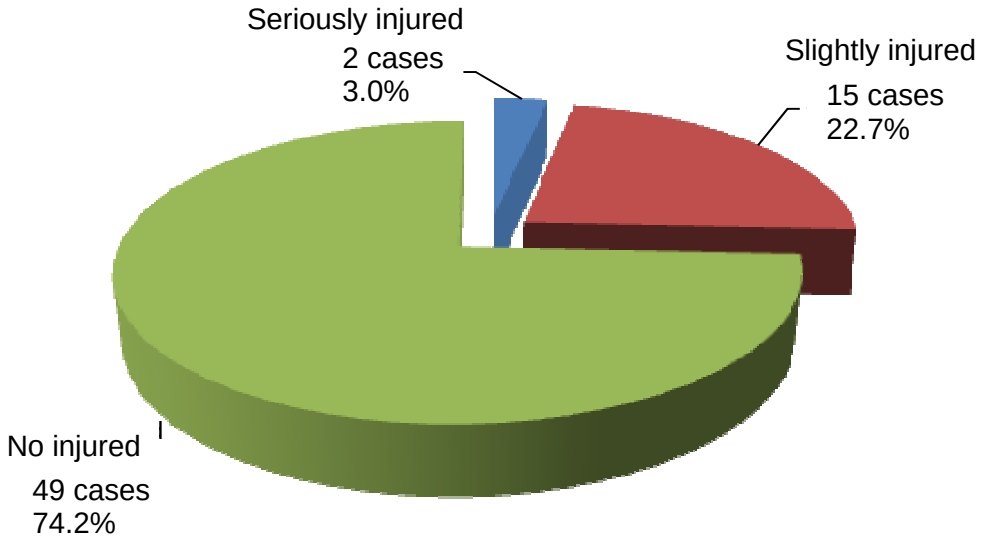
(5) Accidents classified by extent of damage

74% of accidents caused no harm. 2 cases of accidents, 3%, resulted in serious injury.

Table 6: Accidents classified by extent of injury

Extent of Injury	Cases	Ratio
Seriously injured	2	3.0%
Slightly injured	15	22.7%
No injured	49	74.2%
Total	66	100.0%

Figure 8: Accidents classified by extent of injury



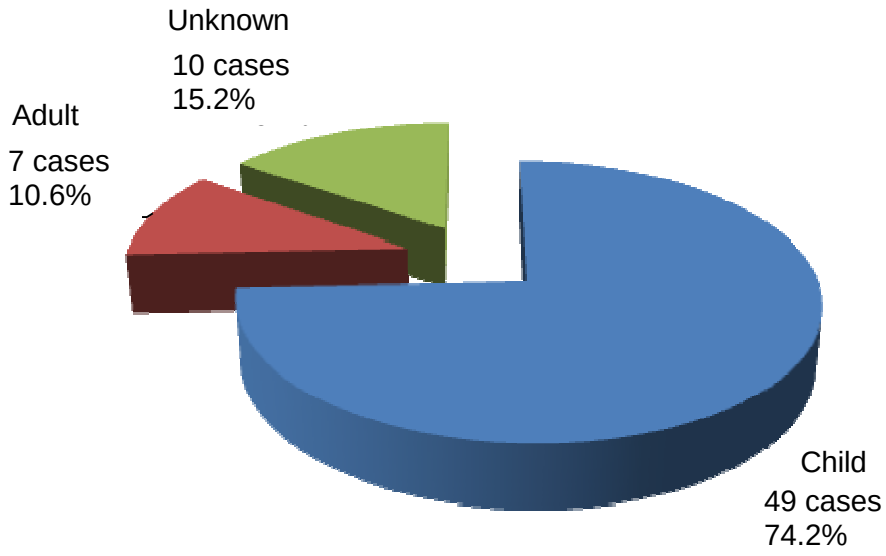
(6) Accidents classified by type of wearer

Sandal users who suffered entrapment accidents are mainly children and it reached about 74 percent.

Table7: Accidents classified by wearer (adult or child)

Classification by wearer (adult or child)	Cases	Ratio
Child (child 10 years and under or footwear for child was involved)	49	74.2%
Adult (Footwear for adult was involved although age was not identified)	7	10.6%
Unknown (Not described in accident reports)	10	15.2%
Total	66	100.0%

Figure 9: Accidents classified by wearer (adult or child)



7. Methodology and results of reproduction test using escalators

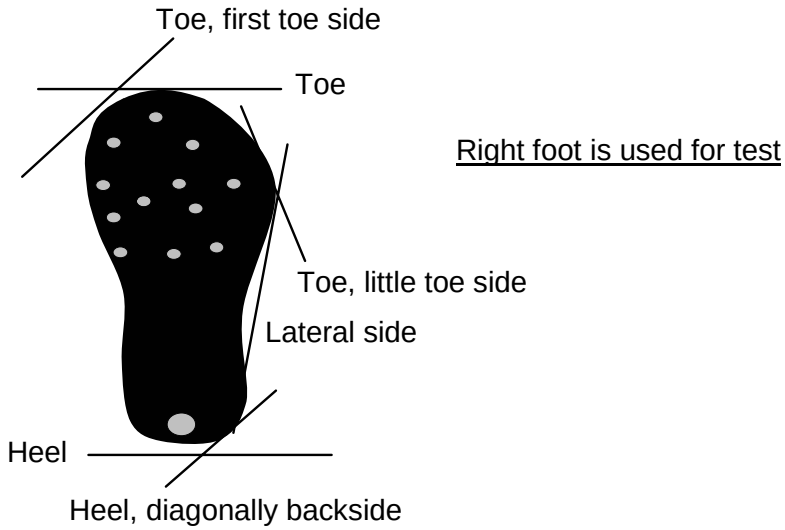
7.1 Methodology of reproduction test

The test was implemented as follows to verify whether a similar phenomenon would be reproduced. The test was conducted with 4 units of escalators at 3 facilities, both in ascending and descending.

(1) Area of contact

a) toe b) toe, first toe side c) toe, little toe side d) lateral side e) heel f) heel, diagonally backside

Figure 10: Area of contact



(2) Contact condition

Apply load of about 1 Kgf/cm2 by hand horizontally and at an angle of 45 degrees to the samples placed on a step.

. Picture 3: Contact condition

Apply the sole of a sandal horizontally to the step

Horizontal

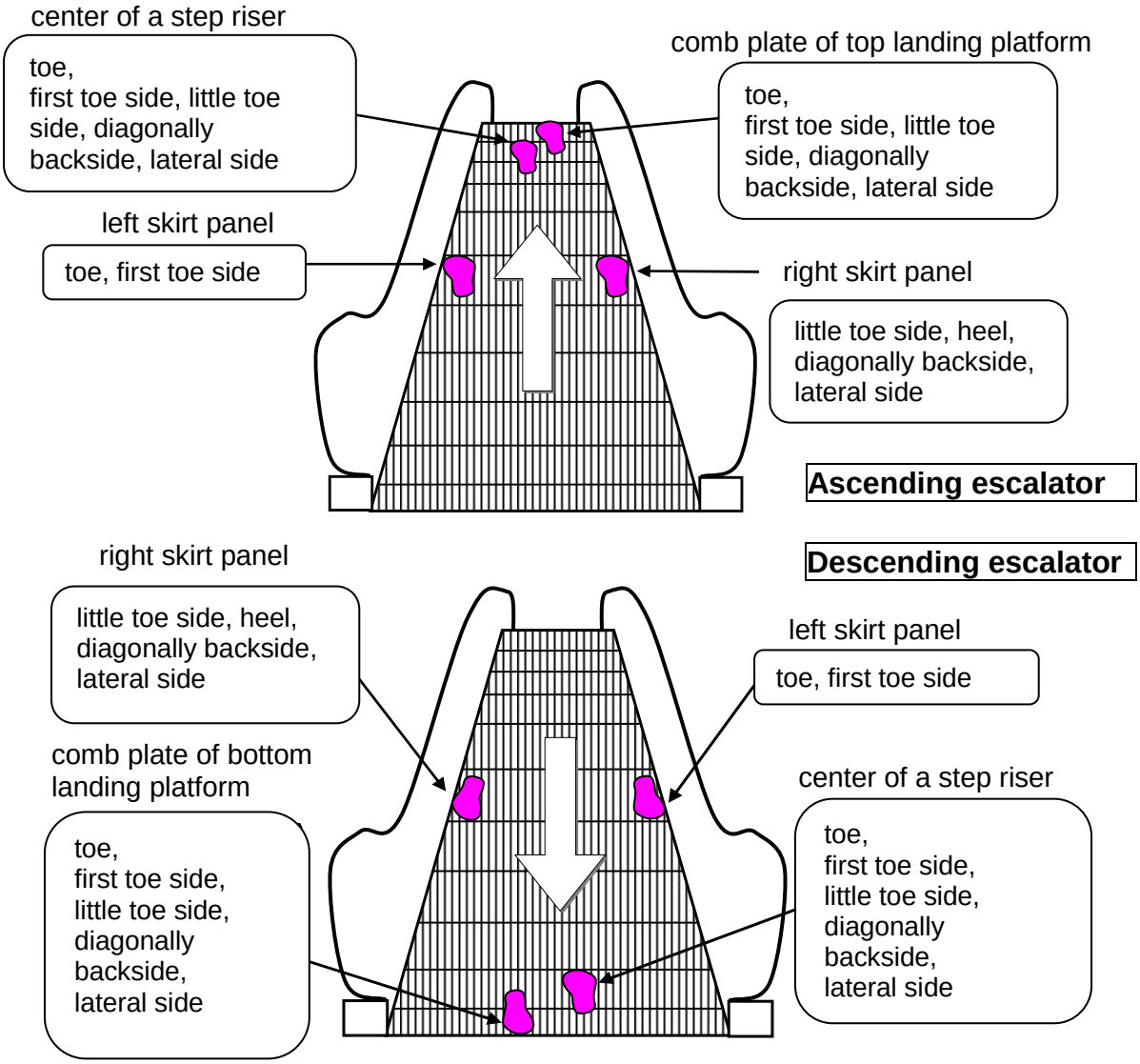
Apply the sole of a sandal to the step with an angle of about 45 degrees, which makes a sandal contact to the step with its instep instead of its sole.

Declined (About 45degrees)

(3) Location of contact

The samples were contacted to the location of escalators respectively as follows.

Figure 11: Location of contact



Picture 4: Reproduction test

Ascending

Descending

(4) Condition of four escalators

ES Ⅰ : Lubricant (silicon oil) is applied to the skirt panel
ES Ⅱ : No lubricant is applied to the skirt panel
ES Ⅲ: No lubricant is applied to the skirt panel
ES Ⅳ: No lubricant is applied to the skirt panel
(Condition setting was rather tough except ES Ⅰ for not applying silicon oil to lubricate the escalators.)

Under the above conditions, 60 reproduction tests per sample were performed on each escalator, coming to a grand total of 240 tests in four escalators. Reproduction tests are shown in Table 8.

Table 8: Contact condition table

Escalator / Footwear		*Escalator Direction	Location of Contact			
			Step (center)	Skirt panel (right or left)	Comb plate top landing platform	comb plate of bottom landing platform
Toe A		A				
		D				
First toe side B	Horizontal	A				
		D				
	Angle of 45 degrees	A				
		D				
Little toe side C	Horizontal	A				
		D				
	Angle of 45 degrees	A				
		D				
Heel D		A				
		D				
Heel, diagonally backside E	Horizontal	A				
		D				
	Angle of 45 degrees	A				
		D				
Lateral side F	Horizontal	A				
		D				
	Angle of 45 degrees	A				
		D				

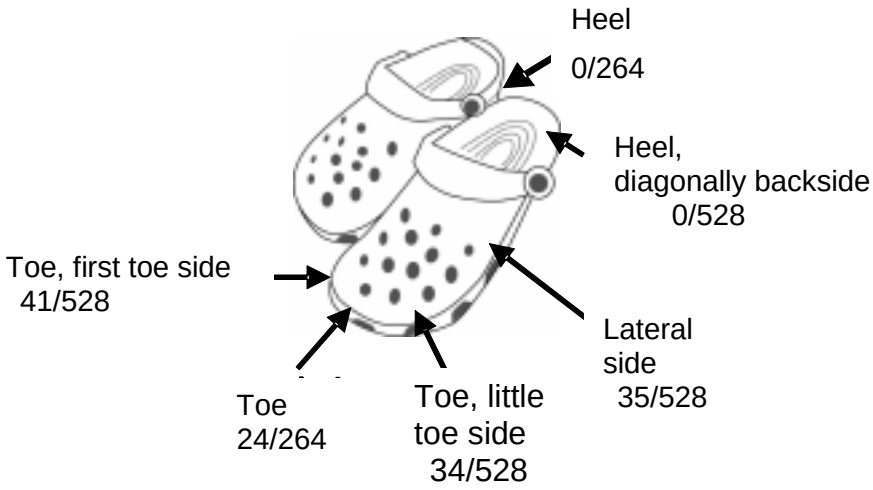
*A: Ascending D: Descending

7.2 Results of reproduction tests

(1) Resin sandals

The number of entrapment by area of contact is shown in figure 12 and the number of entrapment by samples is shown in table 9.

Figure 12: Number of entrapment (Resin sandals)



Note: Reproduction test was conducted to right side footwear.

Calculation of number of tests

Example 1: Total number of test is 2640.

60 ∗4 ∗11 = 2,640

(number of contact conditions: table 8) ∗ (number of escalators) ∗ (number of samples)

Example 2: Number of test of toe is 264.

6 ∗4 ∗11 = 264

(number of contact conditions: table 8) ∗ (number of escalators) ∗ (number of samples)

Table 9: Number of entrapment (Resin sandals)

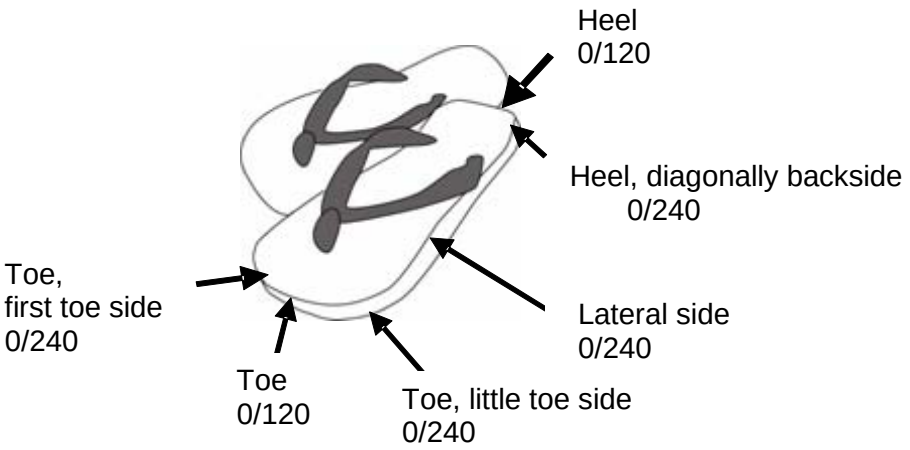
Sample No. (Brand No.)	Size (cm)	Type	Results of reproduction tests in 4 escalators (✓= Not got caught in escalators) (# = number of entrapment)							
			ES I Lubricant (silicon oil) is applied	#	ES II No lubricant is applied	#	ES III No lubricant is applied	#	ES IV No lubricant is applied	#
(1)	14	Resin sandals	✓	0	✓	0	<Up> First toe got caught in the side of a step. Toe (angled) got caught in the side of a step.	2	<<Up and Down> All area got caught in the side and the step by contacted both horizontally and at 45degree angle.	28
	18		✓	0	✓	0	<Up> First toe got caught in the side of a step. Toe (angled) got caught in the side of a step.	2	<Up and Down> All area got caught in the side and the step contacted both horizontally and at 45 degree angle.	28
	24		✓	0	✓	0	✓	0	<Up> All area got caught in the side contacted both horizontally and at 45 degree angle. <Down> Toe got caught.	8
(2)	18		✓	0	<Down> Lateral side got caught in the step contacted at 45 degree angle.	1	<Up> First toe got caught in the side of a step. Toe (angled) got caught in the side of a step.	2	<Up and Down> All area got caught in the side contacted both horizontally and at 45 degree angle.	14
	24		✓	0	✓	0	✓	0	<Up and Down> All area got caught in the side contacted both horizontally and at 45 degree angle.	14
(3)	18		✓	0	✓	0	<Up> First toe got caught in the side of a step. Toe (angled) got caught in the side of a step.	2	<Up and Down> All area got caught in the side contacted both horizontally and at 45 degree angle.	14

(4)	17	Resin sandals	<Down> Little toe side almost got caught in the side.	0	✓	0	<Up> First toe got caught in the side of a step. Toe (angled) got caught in the side of a step.	2	<Up and Down> All area got caught in the side contacted both horizontally and at 45 degree angle.	14
(5)	18		✓	0	✓	0	✓	0	✓	0
	18		✓	0	✓	0	✓	0	<Up> First toe got caught in the side of a step. Toe	1
(6)	18		✓	0	✓	0	✓	0	<Up> First toe got caught in the side of a step. Toe	2
(7)	24.5		✓	0	✓	0	✓	0	<Down> Little toe side almost got caught in the step.	0

(2) Flip-flops

The number of entrapment by area of contact is shown in figure 13 and the number of entrapment by samples is shown in table 10.

Figure 13: Number of entrapment (Flip-flops)



Note: Reproduction test was conducted to right side footwear.

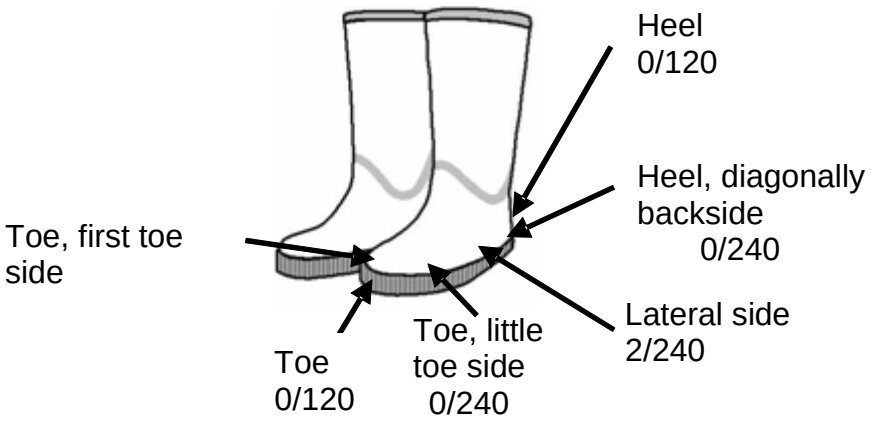
Table 10: Number of entrapment occurred (Flip-flops)

Sample No. (Brand No.)	Size (cm)	Type	Results of reproducing test in 4 escalators (✓= Not got caught in escalators) (# = number of entrapment)							
			ES I Lubricant (silicon oil) is applied	#	ES II No lubricant is applied	#	ES III No lubricant is applied	#	ES IV No lubricant is applied	#
(8)	17	Flip-flops	✓	0	✓	0	✓	0	✓	0
(9)	18		✓	0	✓	0	✓	0	✓	0
(10)	18		✓	0	✓	0	✓	0	✓	0
(11)	18		✓	0	✓	0	✓	0	✓	0
(12)	18		✓	0	✓	0	✓	0	✓	0

(3) Rubber boots

The number of entrapment by area of contact is shown in figure 14 and the number of entrapment by samples is shown in table 11.

Figure 14: Number of entrapment (Rubber boots)



Note: Reproduction test was conducted to right side footwear.

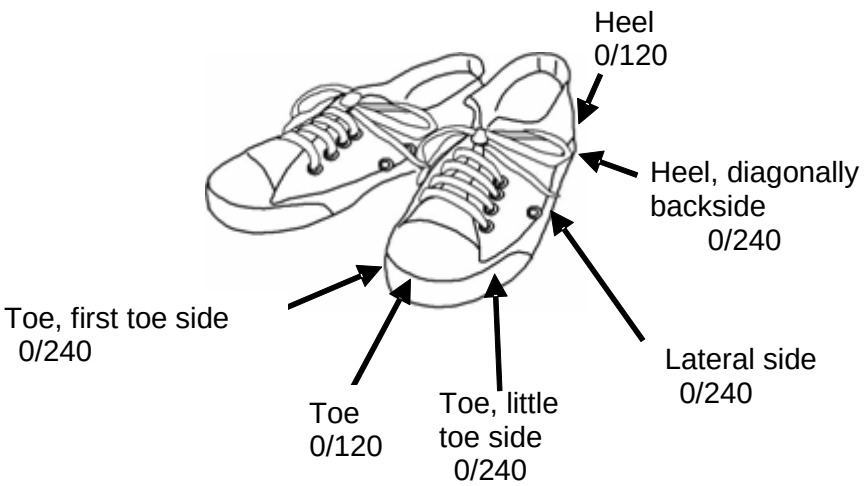
Table 11: Number of entrapment (Rubber boots)

Sample No. (Brand No.)	Size (cm)	Type	Results of reproduction test in 4 escalators (✓= Not got caught in escalators) (# = number of entrapment)							
			ES I Lubricant (silicon oil) is applied	#	ES II No lubricant is applied	#	ES III No lubricant is applied	#	ES IV No lubricant is applied	#
(13)	18	Rubber boots	<Up> Little toe side almost got caught in the side.	0	✓	0	✓	0	<Up and Down> Lateral side got caught in the side.	2
(14)	18		✓	0	✓	0	✓	0	✓	0
(15)	18		✓	0	✓	0	✓	0	✓	0
(16)	18		✓	0	✓	0	✓	0	✓	0
(17)	18		✓	0	✓	0	✓	0	✓	0

(4) Canvas shoes

The number of entrapment by area of contact is shown in figure 15 and the number of entrapment by samples is shown in table 12.

Figure 15: Number of entrapment (Canvas shoes)



Note: Reproduction test was conducted to right side footwear.

Table 12: Number of entrapment (Canvas shoes)

Sample No. (Brand No.)	Size (cm)	Type	Results of reproduction test in 4 escalators (✓= Not got caught in escalators) (# = number of entrapment)							
			ES I Lubricant (silicon oil) is applied	#	ES II No lubricant is applied	#	ES III No lubricant is applied	#	ES IV No lubricant is applied	#
(18)	17	Canvas shoes	✓	0	✓	0	✓	0	✓	0
(19)	18		✓	0	✓	0	✓	0	✓	0
(20)	18		✓	0	✓	0	✓	0	✓	0
(21)	18		✓	0	✓	0	✓	0	✓	0
(22)	18		✓	0	✓	0	✓	0	✓	0

The results of the reproduction test show that almost of all the resin sandals got caught as shown in table 9. One brand of rubber boots got caught as shown in table 11, however, neither flip-flops nor canvas shoes got caught in as shown in table 10 and 12.
They also indicate that entrapment can be influenced by the condition of escalators (e.g. application of lubricant).

8. Test methods and results of material characteristics

8.1 Analysis of composition

(1) Test method

Components were analyzed by ATR method (multiple reflection method) of the infrared spectrometry. The analyzed areas were; instep (and toe) coverings for resin sandals and rubber boots, soles for flip-flops, and both instep coverings and soles for canvas shoes.

(2) Test result

1) Among 7 resin sandals, 6 brands of products were made from EVA (ethylene-vinyl acetate) while one brand was made from low crystalline polyethylene.
2) Flip-flops were made from EVA (ethylene-vinyl acetate), polyvinyl chloride and polybutadiene rubber.
3) Rubber boots were made of chloroprene rubber and polyvinyl chloride.
4) For canvas shoes, cotton and polyurethane were used for instep (and toe) coverings while polyvinyl chloride, chloroprene rubber and styrene-butadiene rubber were used for soles.

8.2 Cross section observation

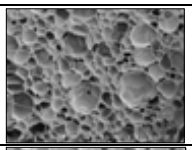
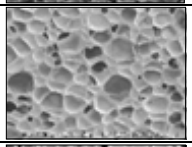
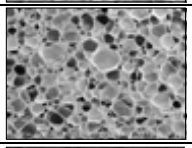
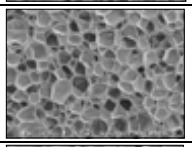
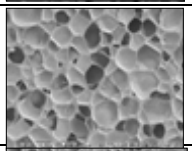
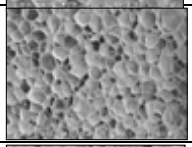
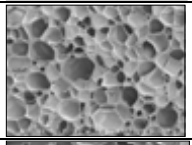
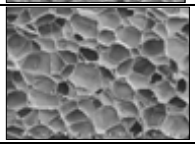
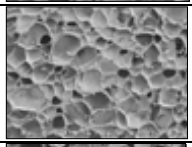
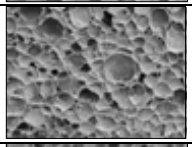
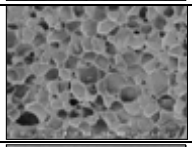
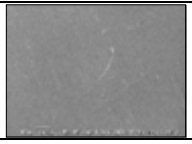
(1) Test method

Each cross-section was observed with a scanning electron microscope at 100-fold magnification. The observed areas were; instep (and toe) coverings for resin sandals and rubber boots, soles for flip-flops and canvas shoes.

(2) Test result

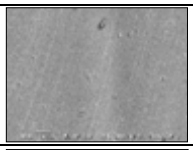
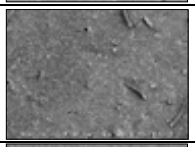
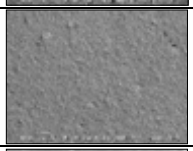
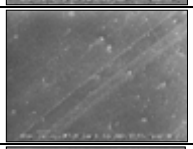
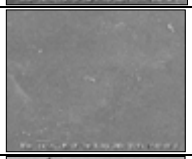
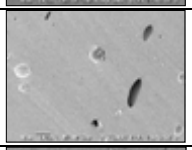
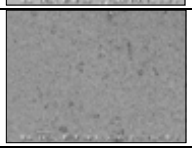
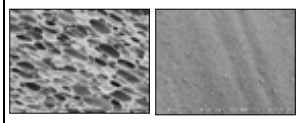
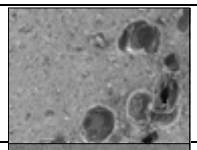
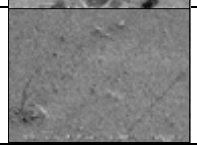
1) All resin sandals showed the cross-sections of resin foams.
2) Cross-sections of 4 sample flip-flop soles indicated resin foams while that of the other sole showed non-foamable resins.
3) All rubber boots and canvas shoes indicated non-foamable resins.

Table 13: Composition and a cross section shape of material

Sample No.	Size(cm)	Kind of footwear	Composition labeling	Analysis of Composition (Main composition of resin)	Shape of a cross section (SEM)
(1)	14 18 24	Resin sandals	Polyethylene	Instep: low crystalline polyethylene	
(2)	18 24		No labeling	Instep: EVA	
(3)	18		EVA	Instep: EVA	
(4)	17		EVA	Instep: EVA	
(5)	18 19		No labeling	Instep: EVA	
(6)	18		EVA	Instep: EVA	
(7)	24.5		No labeling	Instep: EVA	
(8)	17	Flip-flops	No labeling	Sole: EVA	
(9)	18		EVA	Sole: EVA	
(10)	18		EVA	Sole: EVA	
(11)	18		Artificial Rubber	Sole: polybutadiene rubber	
(12)	18		No labeling	Sole: polyvinyl chloride	

Note: EVA stands for ethylene-vinyl acetate copolymer.

(Continued)

Sample No.	Size(cm)	Kind of footwear	Composition labeling	Analysis of Composition (Main composition of resin)	Shape of a cross section (SEM)
(13)	18	Rubber boots	Polyvinyl chloride Resin (Lining: Nylon, Cotton)	Instep: polyvinyl chloride	
(14)	18		Synthetic rubber	Instep: chloroprene rubber	
(15)	18		Rubber	Instep: chloroprene rubber	
(16)	18		(Outside) polyvinyl chloride Resin (Inside) Nylon	Instep: polyvinyl chloride	
(17)	18		No labeling	Instep: polyvinyl chloride	
(18)	18	Canvas shoes	No labeling	Instep: polyvinyl chloride	
(19)	18		(Instep part)Cotton (Sole part)Rubber	Sole: chloroprene rubber	
(20)	18		No labeling	Sole: (white) EVA (blue) acryl acid ester silicone (silver) polyvinyl chloride	
(21)	18		(Instep part)Cotton (Sole part) Rubber	Instep: polyurethane Sole: styrene-butadiene rubber	
(22)	18		No labeling	Sole: chloroprene rubber	

Note: EVA stands for ethylene-vinyl acetate copolymer.

8.3 Tensile strength

(1) Test method

The test was implemented according to the Japan Industrial Standards JIS K7113, tensile strength test method for plastics.
The analyzed areas were; instep (and toe) coverings for resin sandals, rubber boots, and canvas shoes, soles for flip-flops. One sample flip-flop (No.12) had a sole which was too hard to measure.
This test was conducted to identify strength characteristics of each sample at the point of rupture, as a basic test prior to measuring various properties.

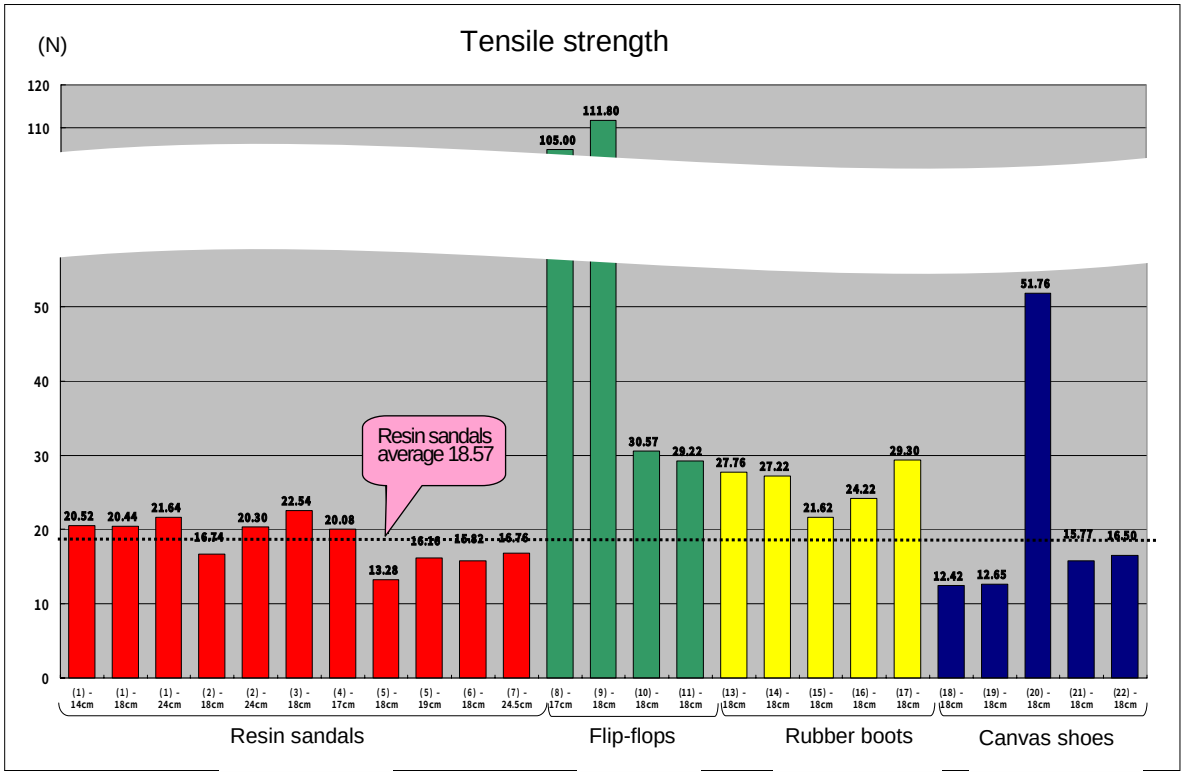
(2) Test result

As indicated in below Figure 16.

1) Resin sandals had lower tensile strengths in comparison with flip-flops and rubber boots.
2) As the size of the sample resin sandal got larger, the tensile strength tended to get higher.
3) Flip-flops indicated high tensile strengths as they were measured at the thick soles.
4) All canvas shoes except one brand had lower tensile strengths than resin sandals.

The tensile strength is a load at the point of product rupture. The result showed no direct link between tensile strengths and entrapment risks.

Figure 16: Tensile strength



8.4 Compressive load

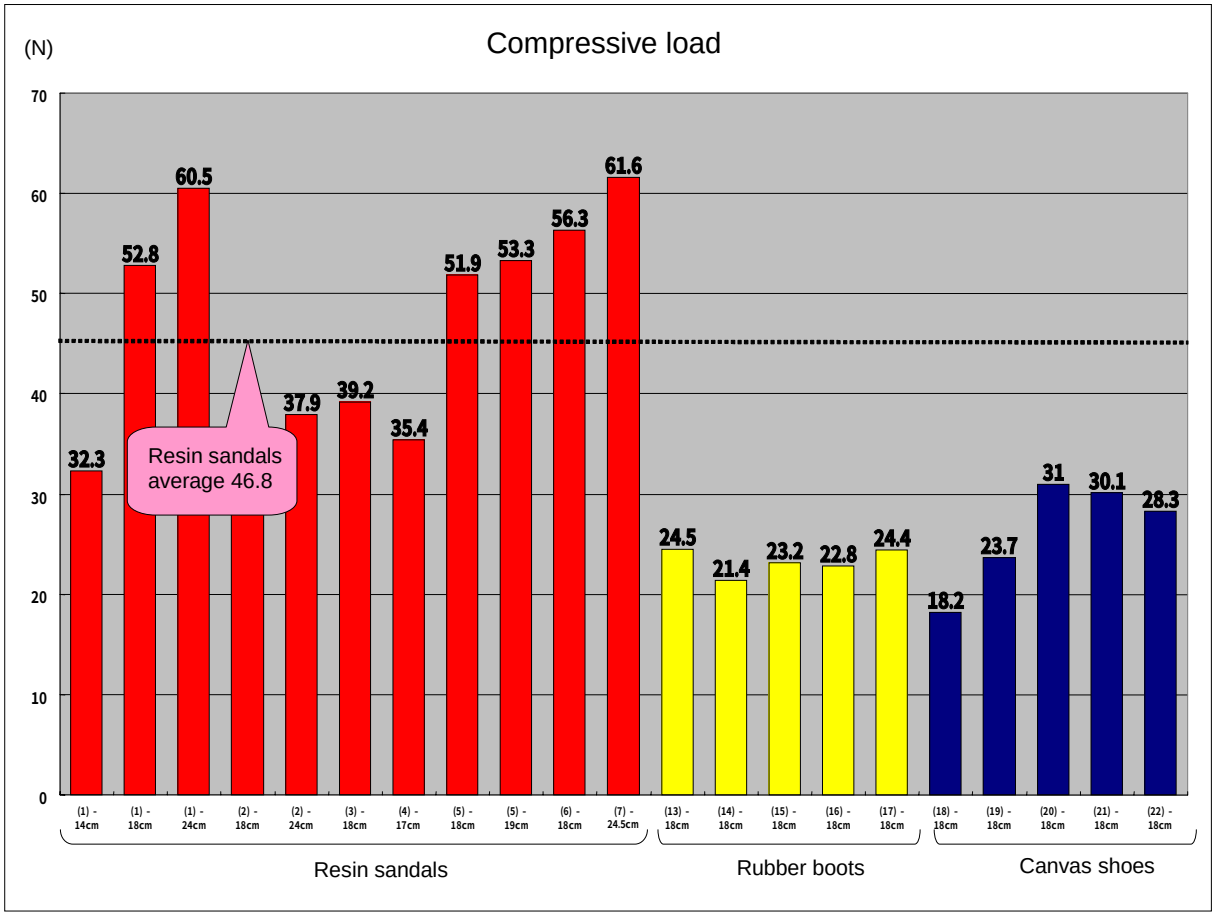
(1) Test method

The test was implemented according to the JIS K7181 compression property test method for plastics.
The pressing loads were measured at the points where toe and instep coverings of resin sandals, rubber boots and canvas shoes were compressed until the covering parts were just about to reach their soles.
Flip-flops were not subject to this test since they had no instep coverings.
The compress load was measured to examine whether it was one of the factors leading to entrapment hazards on the assumption that objects are prone to get caught in escalator gaps more when they are more crushable under smaller load.

(2) Test result

As shown in below Figure 17.
Resin sandals indicated higher values compared with rubber boots or canvas shoes.
Thus, the test results indicated no relationship between compress loads and entrapment risks.

Figure 17: Compressive load



8.5 Hardness

(1) Test method

The test was implemented according to the JIS K6253 hardness test method for vulcanized rubber and thermoplastic rubber.
Surface hardness of each sample was measured to examine whether it was one of the factors leading to entrapment hazards assuming that objects are prone to get caught in escalator gaps more when their materials are softer and more deformable. The areas measured in this test were instep (and toe) coverings for resin sandals, rubber boots and canvas shoes, while flip-flops were measured at the soles as they had no instep coverings.

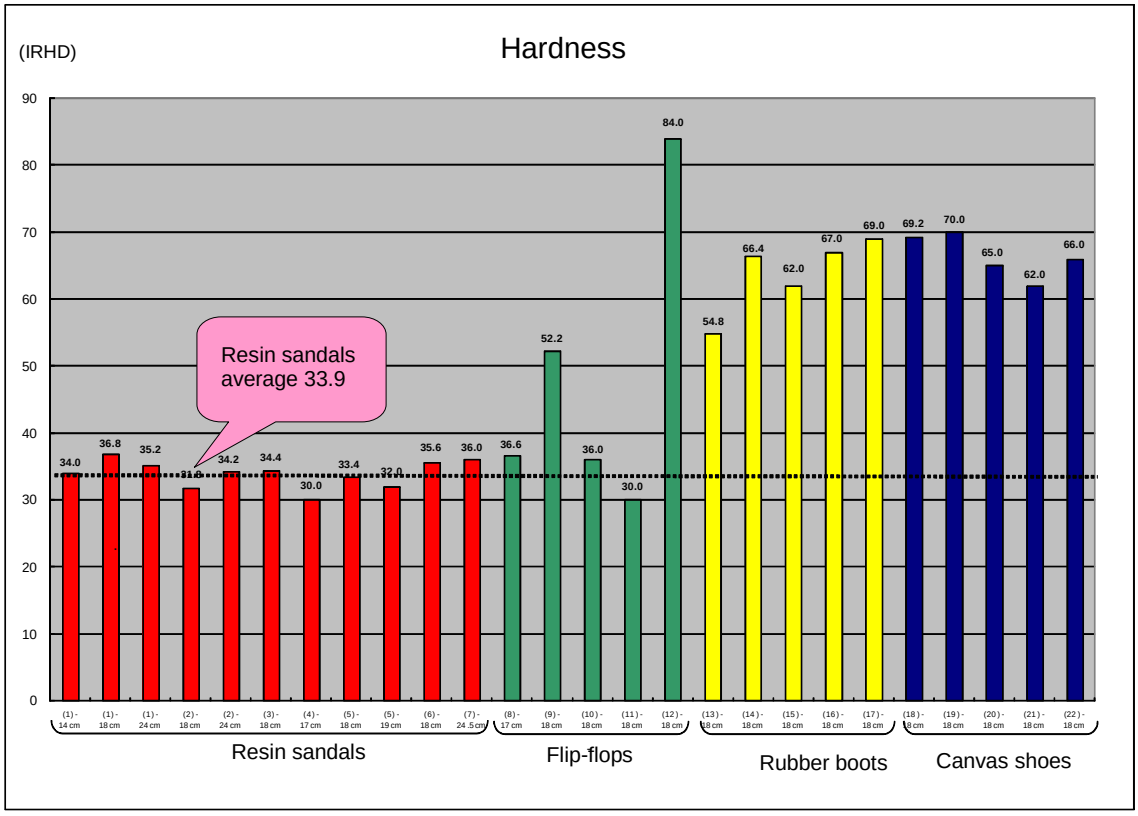
(2) Test result

As shown in below Figure 18.

1) The materials for resin sandals indicated lower values compared to those of rubber boots and canvas shoes, which suggests that resin sandals have softer materials.
2) No difference was observed between different sizes of resin sandals.
3) There were flip-flops whose soles were as soft as instep coverings of resin sandals; however their thickness supposedly prevented them from getting caught in escalator gaps.

Resin sandals have softer characteristics compared to materials of other samples. The test result suggests a relationship between material softness and escalator entrapment.

Figure 18: Hardness



8.6 Tensile force at 10% strain

(1) Test method

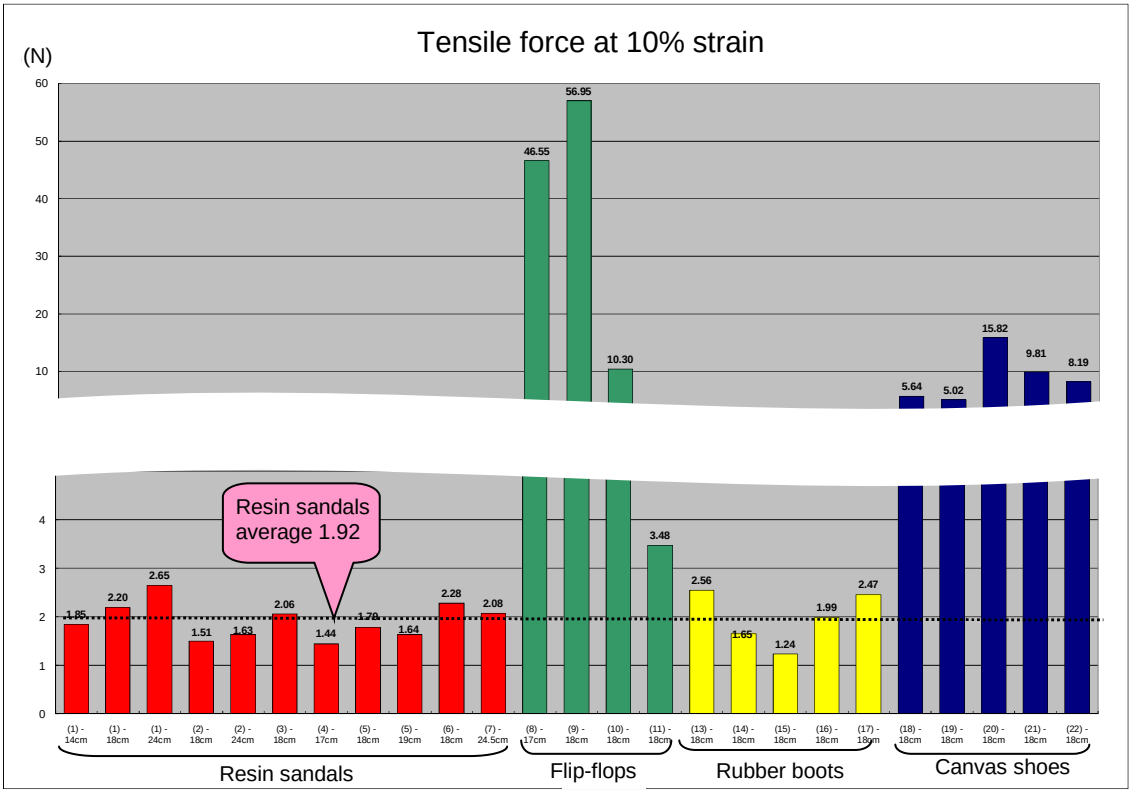
The test was implemented according to JIS K7113 tensile strength test method for plastics.
The areas measured in this test were instep (and toe) coverings for resin sandals, rubber boots and canvas shoes, and soles for flip-flops. One of the sample flip-flops (No.12) had a sole which was too hard to measure.
In this test, the tensile stress at 10% elongation(*) was measured to examine whether it was one of the factors leading to entrapment hazards under the assumption that objects are getting caught in escalator gaps more easily when they start the first elongation by a smaller force. (*The lower this value indicates, the smaller power the sample requires for the first stage elongation. That means the sample can be stretched by a small power, thus stretched easily.)

(2) Test result

As indicated in below Figure 19.
1) Resin sandals showed the same level of stress values as those of rubber boots.
2) Compared to flip-flops and canvas shoes, resin sandals indicated the significantly low values.

Resin sandals have lower values in 10% tensile stress compared to other samples.
The result suggests a relationship between 10% tensile stress and escalator entrapment.

Figure 19: Tensile force at 10% strain



8.7 Thickness

(1) Test method

The test was implemented according to JIS Z1711 thickness measurement method for bags made of polyethylene film.
In this test, the thickness was measured at instep coverings for resin sandals, rubber boots and canvas shoes, and soles for flip-flops.
The test verified whether material thickness was one of the factors leading to entrapment hazards assuming that objects are prone to get caught in escalator gaps more when their materials are thinner.

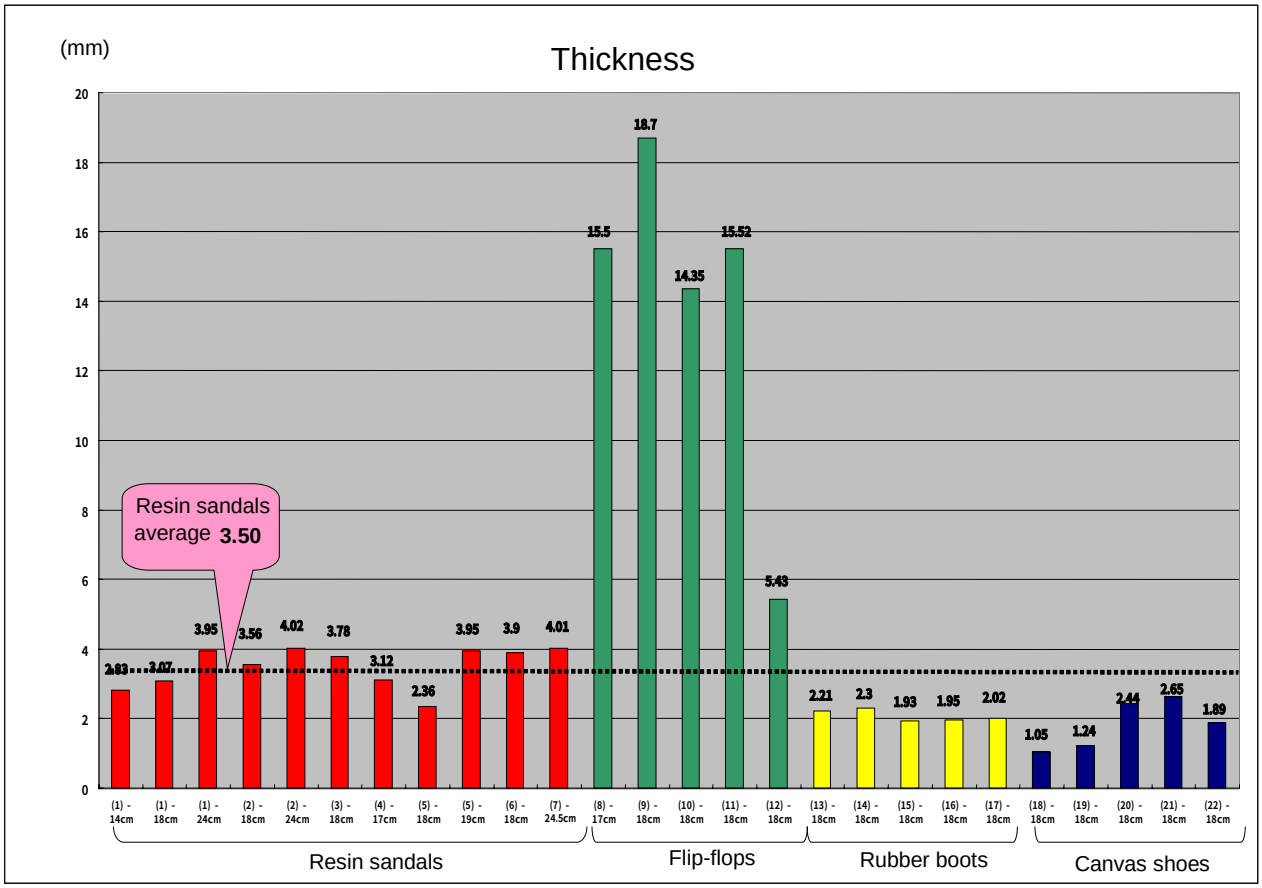
(2) Test result

As shown in below Figure 20.

1) Resin sandals indicated relatively higher values in thickness compared to rubber boots and canvas shoes.
2) For resin sandals, the thickness was proportional to the size; the smaller, the thinner.
3) Flip-flops presented substantial thicknesses for they were measured at soles. This was supposedly one of the factors that flip-flops did not get caught in escalators in the reproducing test despite their stretchable characteristics.

Considering the facts that children's thin sandals were involved in many accidents (as in above 2) and the presumption of flip-flops (as in 3), there is an indication of relationship between thickness and escalator entrapment.

Figure 20: Thickness



8.8 Stretch rate

(1) Test method

The test was implemented according to JIS K7113 tensile strength test method for plastics.
The measured areas of respective samples were; instep coverings for resin sandals, rubber boots and canvas shoes, and soles for flip-flops. One of the sample flip-flops (No.12) had a sole which was too hard to measure.
On the assumption that objects are getting thinner when stretched, thus more entrapment hazards arise, the tests were performed to confirm whether the stretch rate was one of the factors of the entrapment risk.

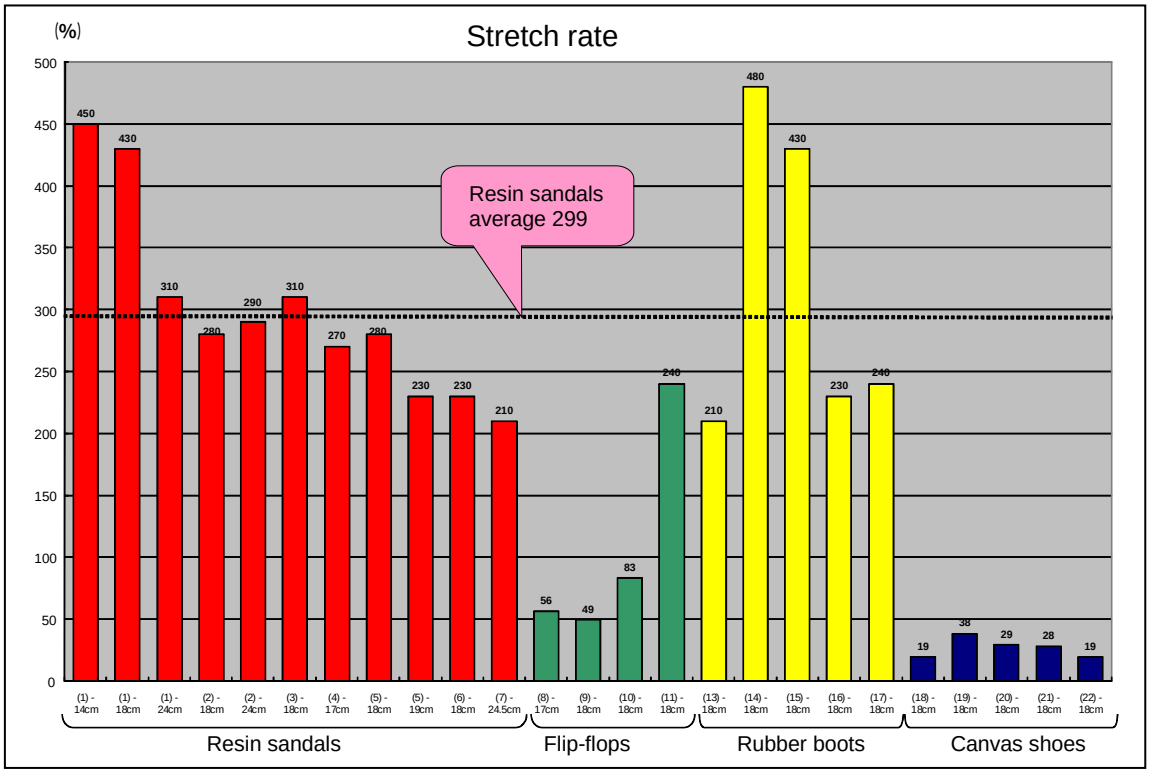
(2) Test result

As indicated in below Figure 21.

1) Resin sandals showed significantly high stretch rate as well as rubber boots. They indicated stretch rates of as high as 200% – 400%.
2) For resin sandals, the value was inversely proportional to the size; the smaller, the higher.
3) Flip-flops and canvas shoes indicated low stretch rates.

Resin sandals have a high stretch rate. The results suggest a connection between elongation property and escalator entrapment risks.
However, the sample rubber boots No.14 and No.15 which indicated remarkably high stretch rates did not get caught in escalators in the reproduction test while the only rubber boot which was caught in escalators (No.13) had a relatively low rate. The results suggest that various factors are mutually related in escalator entrapment risks.

Figure 21: Stretch rate



8.9 Coefficient of dynamic friction

(1) Test method

The test was implemented according to JIS K7125 friction coefficient measuring method for plastic film sheets and sheets.
The measured areas were instep coverings for resin sandals, rubber boots and canvas shoes, and soles for flip-flops. Dynamic friction coefficients were measured utilizing a fluorine resin-coated stainless plate which is used for a skirt panel, under the conditions with or without applying lubricants (silicon oil) to the plate.
The test was performed to confirm whether dynamic friction coefficient was one of the factors leading to the risks under the assumption that objects are getting caught in escalator gaps more when the friction coefficient between skirt panel and footwear is higher. Also evaluated was the effectiveness of applying silicon oil in reducing the dynamic friction coefficient.

(2) Test result

As shown in Figures 22 and 23.

1) Resin sandals and rubber boots indicated relatively high dynamic friction coefficients.
2) Those of canvas shoes and flip-flops were relatively low except for a few samples.
3) The sample No.13, the only rubber boot that got caught in escalator at the test, had the highest dynamic friction coefficient.

The test result suggests a connection between dynamic friction coefficient and the risks as resin sandals showed relatively high values.
Also, Figure 23 shows the comparison of dynamic friction coefficient under the conditions when the lubricant (=silicon oil) is applied or not applied to the stainless steel plates of escalators. As indicated, the values were reduced when the silicon oil was applied. The test result suggests that the application of silicon oil is effective to reduce the entrapment risks.

Figure 22: Coefficient of dynamic friction (without applying silicon oil)

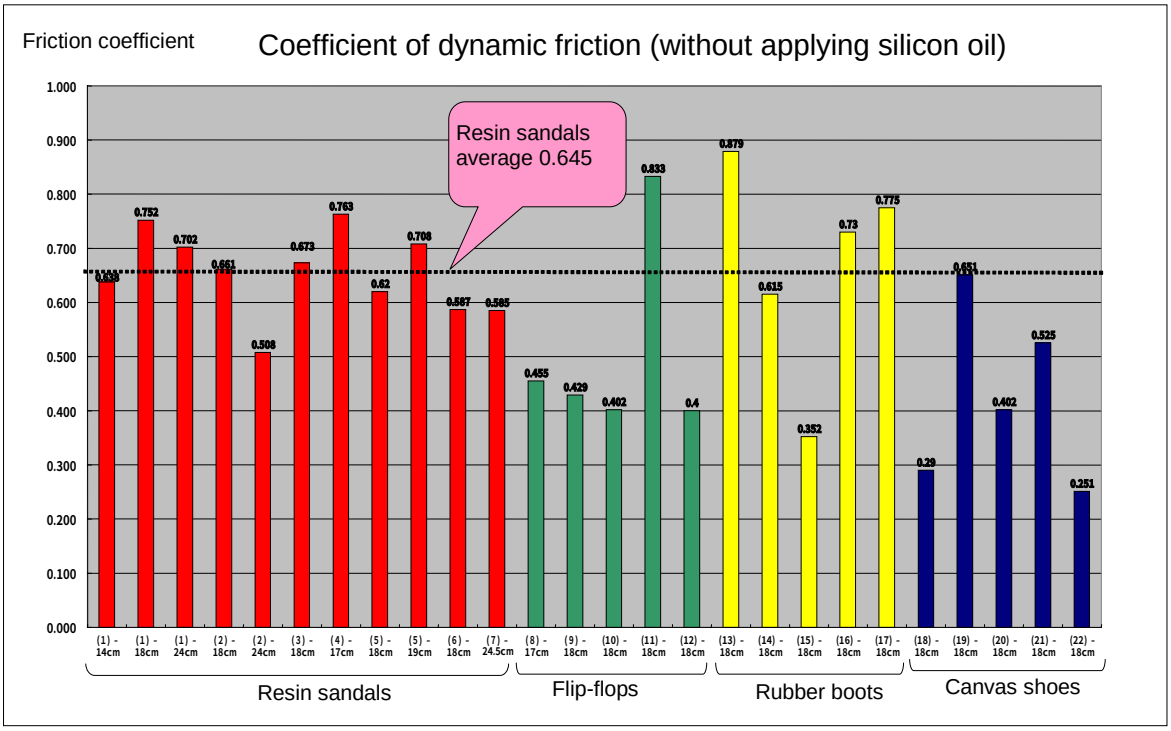
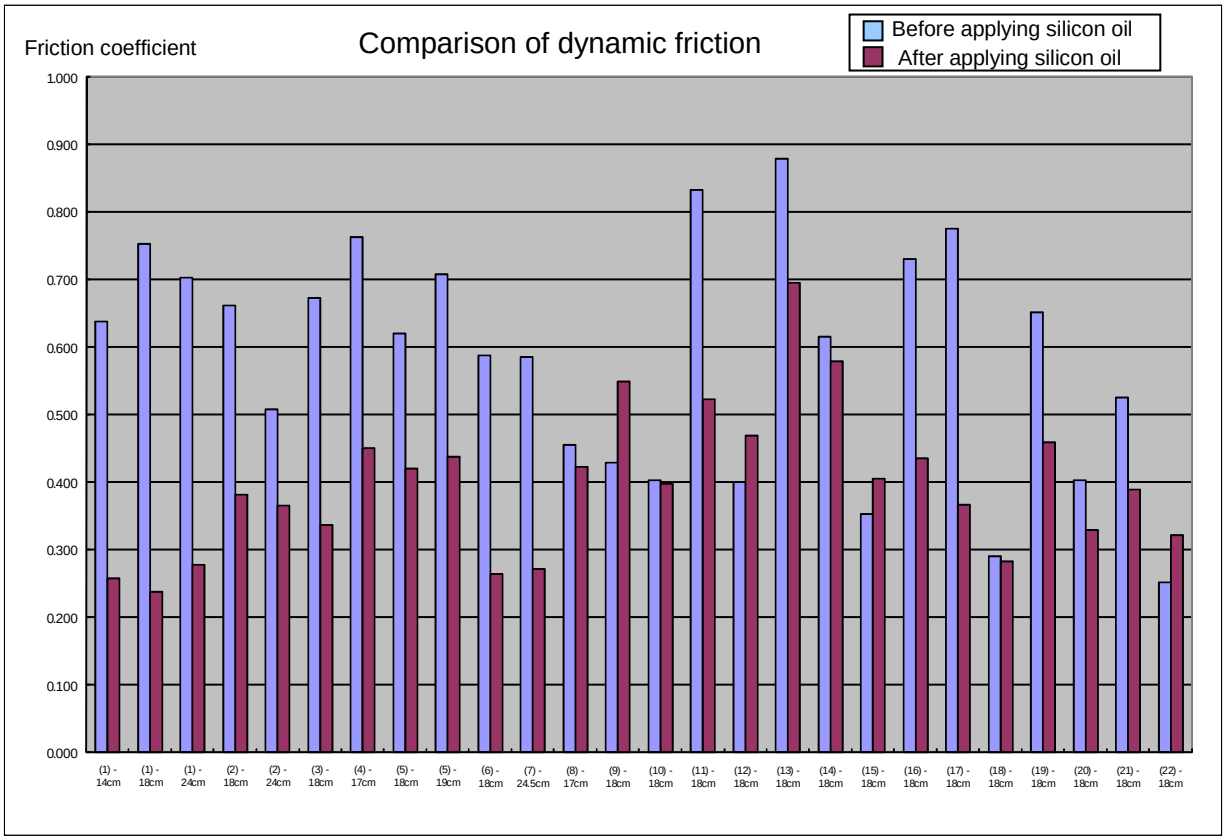


Figure 23: Comparison of dynamic friction



9. Summary of the test results

9.1 Escalator entrapment risks and material characteristics of resin sandals

(1) Among accidents which types of involved sandals were identified, most accidents were associated with resin sandals. Also, all sample footwear which got caught in escalators in the reproducing test was resin sandals except one rubber boot. The result indicates that resin sandals are prone to be trapped in escalators when a wearer stands on a yellow line (demarcation line) drawn on a step with pushing a sandal to the skirt panel or the step riser.

(2) In comparison with other samples, resin sandals had the following common characteristics; 1) soft, 2) easy to stretch, 3) not slip easily. One of the risk factors of escalator entrapment is presumed to have these three characteristics collectively.

(3) Among sandals of the same brand, smaller ones were thinner and had higher stretch rates.

(4) In measuring the dynamic friction coefficient, the fictional force was reduced when silicon oil was applied to the surface.

(5) As mentioned in above (2), resin sandals had a commonality in 5 material characteristics; dynamic friction coefficient, 10% tensile stress, stretch rate, softness and thickness. Figure 24 shows these characteristics of each sample plotted on a graph, while average values of respective product categories are plotted in Figure 25. Cobweb charts are shown from Figure 27 to Figure 31. Figure 26 explains what a cobweb chart is.

Figure 24: Five material characteristics plotted according to sample footwear

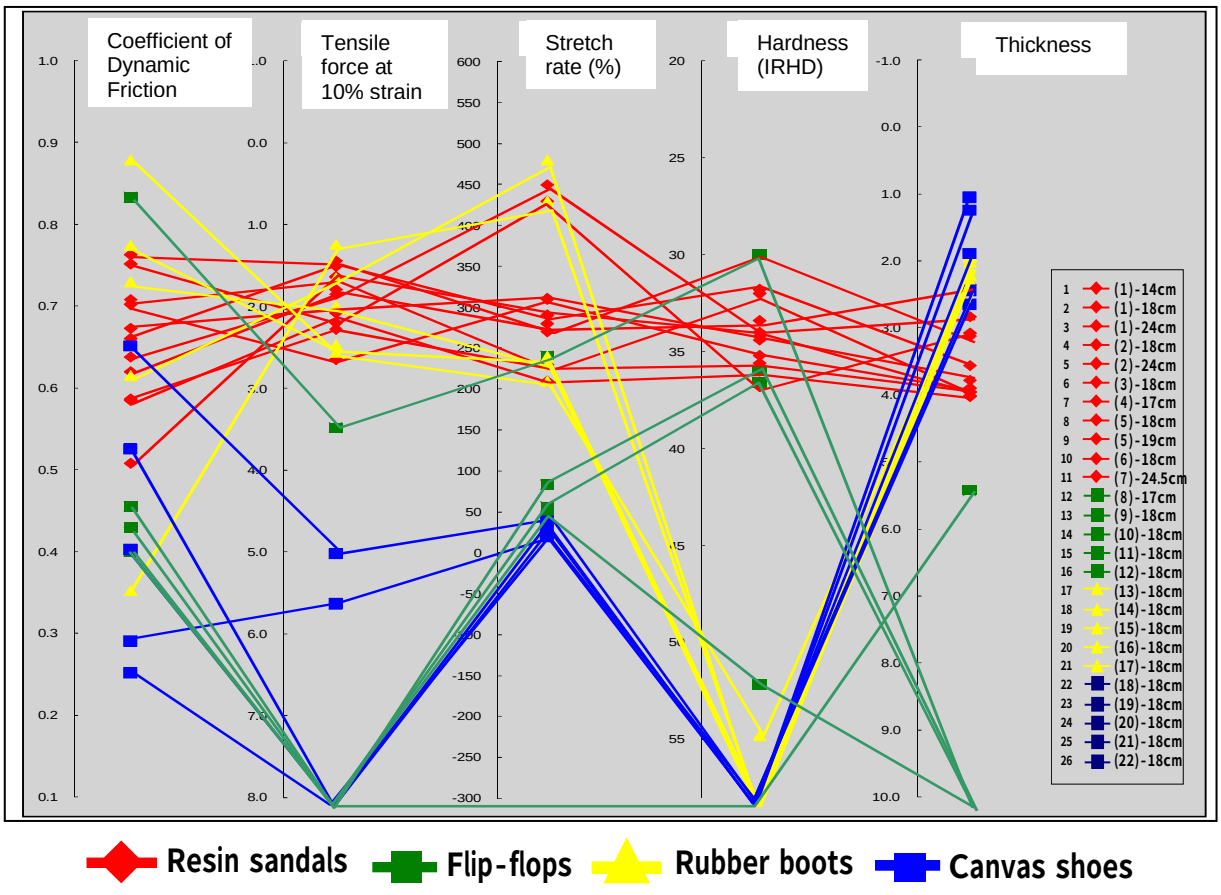


Figure 25: Average values of five material characteristics plotted according to product categories

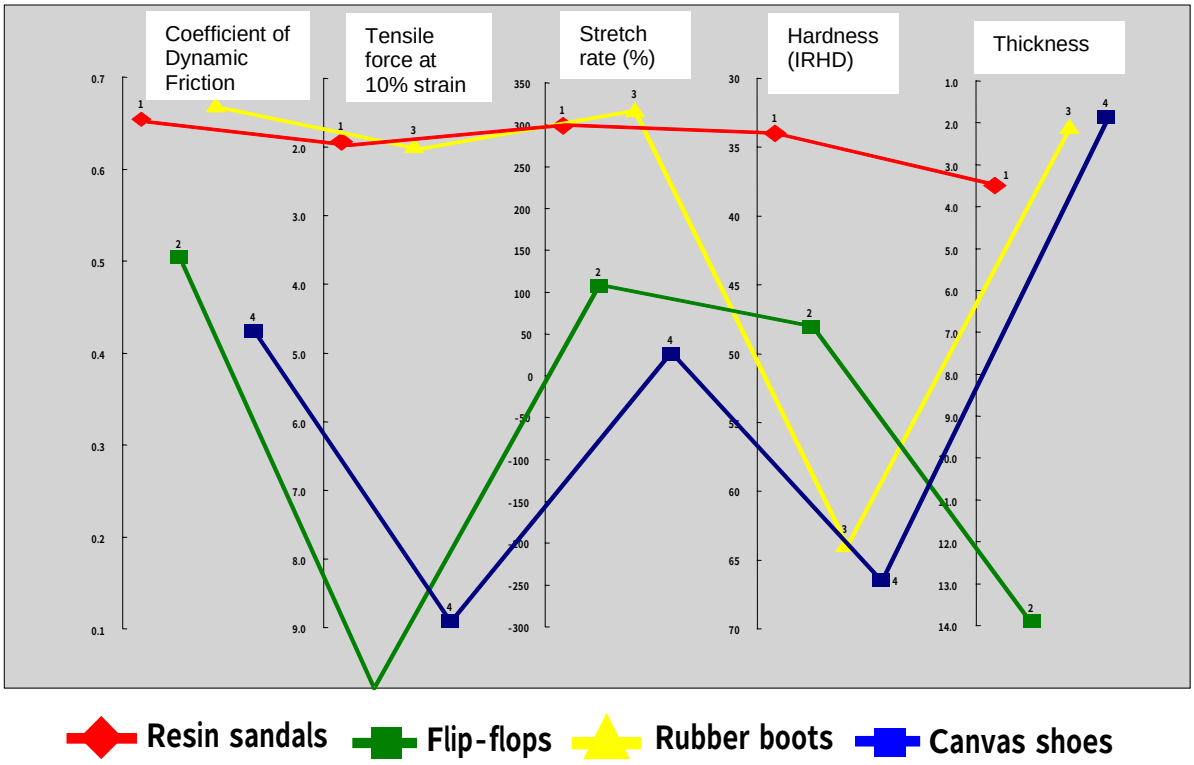


Figure 26: Explanation of cobweb chart

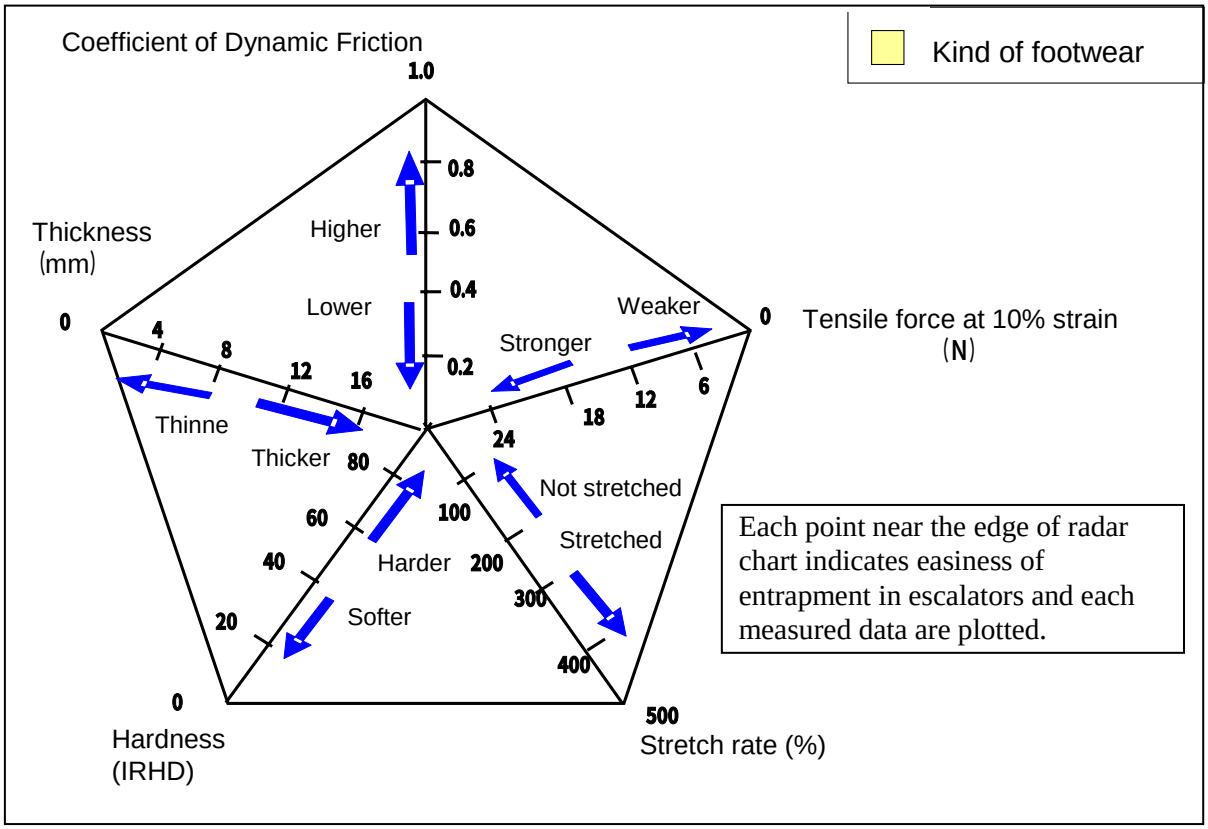


Figure 27: Resin sandals

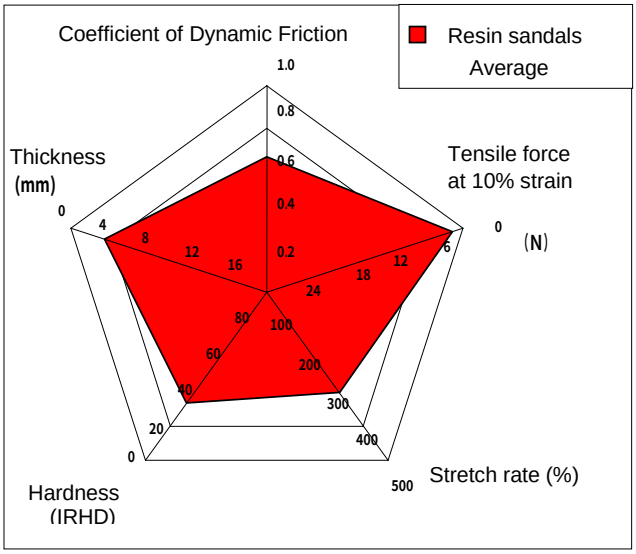


Figure 28: Flip-flops

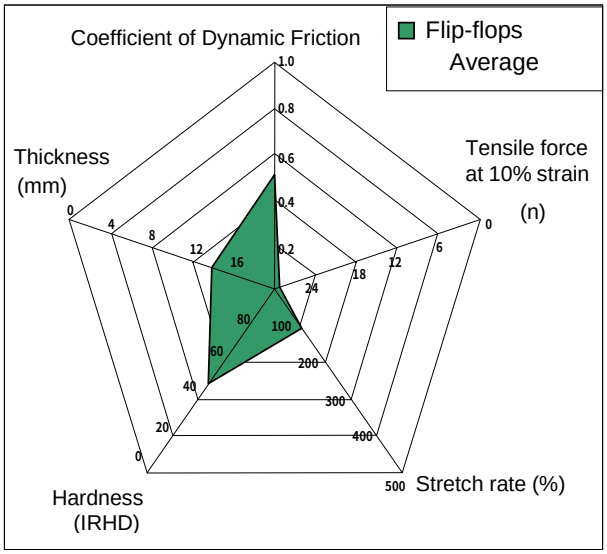


Figure 29: Rubber boots

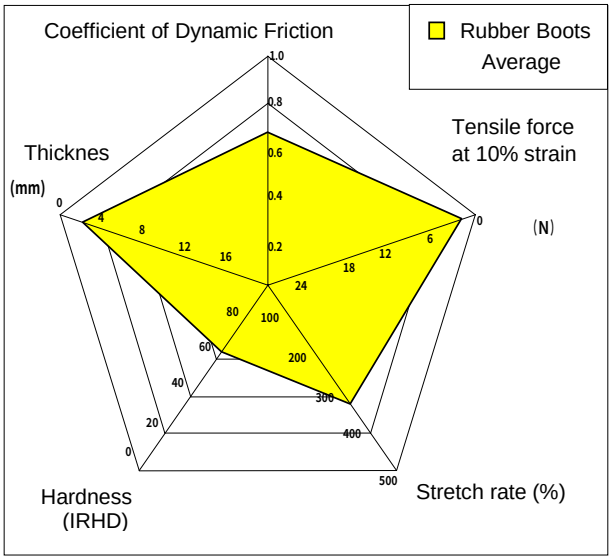
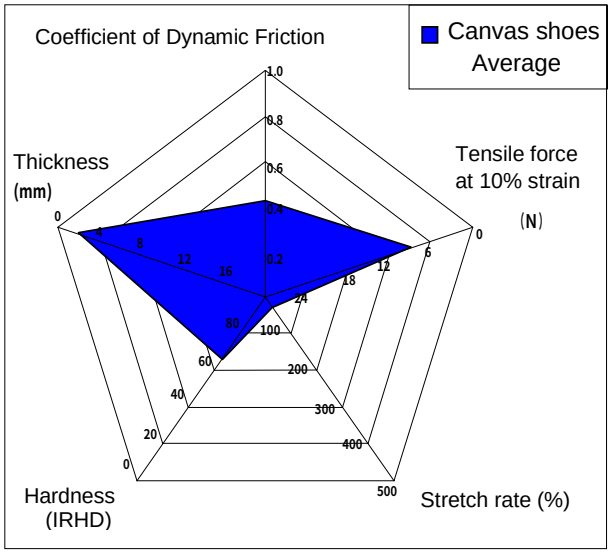


Figure 30: Canvas shoes



9.2 Mechanism of resin sandals getting trapped in escalators

There are three types of case classified by part of escalators in which resin sandals get caught. The mechanisms of each case are presumed as follows.

(1) Sandals getting caught in gaps between edge of a step and a skirt panel

1) Potential parts of escalators
   a) In up escalators, gaps between a step edge and a skirt panel.
   b) In down escalators, gaps between vertical part of a step (edge of step riser) and a skirt panel.

2) Entrapment mechanism
   a) A person wearing resin sandals stands on the yellow line along the step edge, and presses the instep covering to the skirt panel.
   b) Relatively high frictional forces arise between the sandal and the skirt panel due to the high friction coefficient of the material.
   c) The sandal of stretchy nature is stretched thin by friction and pulled into the gaps of the step edge from the instep.
   d) The involved sandal is pulled further inside the gaps due to its stretching property, which is estimated to cause the person's toe stuck in the escalator.

(2) Sandals getting caught in gaps between edge of a step and adjacent step riser

A person wearing resin sandals stands on the yellow line along the step edge, and presses the instep covering to the front step riser in ascending (or to the rear step riser in descending) escalator. The sandal eventually gets caught in the gap between a step and the adjacent front step riser in descending (or rear step riser in ascending) as the step is flattened in reaching landing platforms. The process is similar as the above case (1).

(3) Sandals getting caught in comb plate

There are a few accident reports of the kind, however details are unknown for the entrapment was not occurred in the reproducing test.

10. Conclusion and request

10.1 Conclusion

(1) The accident frequency and the results of the reproducing test indicate that the resin sandals tend to get caught in escalators easily regardless of brand. From this perspective, combining the three common characteristics of the material; “not slip easily,” “soft,” and “stretched easily”, is regarded as one of the key factors of escalator entrapment of sandals.

(2) Other factors include the shape of the footwear, stress level of the footwear to the skirt panel (or step riser), the condition of escalators (e.g. how lubricant is applied to the skirt panel), etc. Accidents are considered to occur as the result of the interaction of various factors.

(3) However, there is no question that these accidents can be avoided by following the precautions for safe riding.

(4) Also, these accidents are marked by the involvement of many children. This is attributed to children’s poor understanding of safe riding and hazards in escalators in addition to the fact that the material of the sandals can get thinner and stretched more easily in smaller sizes.

(5) Applying silicon oil (lubricant) to the skirt panel is presumed to be effective to reduce risks of escalator entrapment as fictional force is reduced when silicon oil is applied to the surface.

10.2 Recommendation and request from NITE

(1) To manufacturers/importers of sandals

1) NITE requests to thoroughly provide care labeling for resin sandals on the tags and packages in a way that is accessible for anybody including children.
2) Also, NITE urges the manufacturers/importers to make adequate improvements including changing materials (e.g. lowering dynamic friction coefficient, reinforcing materials or inhibiting easy stretch) and product design (e.g. remodeling instep not to directly contact escalators easily) to reduce the entrapment risks in case an improper ride should be made.

(2) To maintenance staff and installer of escalators

1) Lowering dynamic friction coefficient of skirt panel is considered as one of the effective measures to reduce the risk. Therefore, NITE requests the industry the use of lubricants such as silicon oil when a routine maintenance is carried out.
2) Thoroughly continue to provide instructions of safety ride (e.g. to stand on a step avoiding the yellow edge) by stickers or announcements.

(3) To consumers

1) When using escalators, follow the instructions which are displayed on the escalators or announced, and ride accordingly. Make extra sure to stand in the center of a step avoiding the areas marked yellow.
2) In view of the fact that most cases involved children, parents should make sure their children ride safely on escalators and make them understand the safety ride.
3) Pay attention to the above instructions 1) and 2) when wearing resin sandals, and further, parents should be aware that any type of rubber or vinyl shoes, not just the relevant ones, shoe laces and long clothing can also be problematic.

11. References

11.1 Caution stickers for the escalator (before accidents)

Examples of caution stickers for the escalator which were prepared by the Japan Elevator Association (JEA), manufacturers and maintenance companies are as follows.

11.2 Caution sticker for the escalator (after accidents)

In response to the accidents, The Japan Elevator Association (JEA), manufacturers and maintenance companies have made new caution stickers and leaflets to prevent the similar accidents. The examples are indicated below.

(Leaflet)

11.3 Educational activities for the safety when riding escalators

The Japan Elevator Association (JEA), manufacturers and maintenance companies are engaging in educational activities for the safety riding on escalators through various media to prevent escalator injuries.

(1) Example of transportation advertising

(2) Examples of DVDs distributed to kindergartens and elementary schools nationwide.

DVD distributed to kindergartens
(About 14,000 kindergartens)

DVD distributed to elementary schools
(About 23,000 schools)