Investigations on Safety Measures for Lifts and Escalators; Outcomes from the Researches Funded by the Building Standard Development Promotion Program, Japanese Ministry of Land, Infrastructure and Transport (MLIT)

(Loading Tests for Full-scale Model to Confirm the Critical Strength of Existing Escalator Truss During Severe Earthquakes)

Satoshi Fujita [1] and Motoo Shimoaki [2]

[1] Department of Mechanical Engineering, Tokyo Denki University, 5 Senju-Asahi-cho, Adachi-ku, Tokyo 120-8551, Japan

[2] Japan Elevator Association, Dai2 kuyo Bldg., 5-10-2 Minami Aoyama, Minato-ku, Tokyo 107-0062

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Abstract. For the existing escalators, the fall-off phenomenon on the side where the support interval widens during earthquake can be dealt with by lengthening the supporting margins. However, because the problem on the compression side is difficult to deal with, experimental and analytical studies were carried out to clarify the elasto-plastic restoring force characteristics of the escalator-truss structures and to refine and improve the seismic design guidelines and the Japanese building standard law, and its enforcement order. Series of experimental tests were carried out by using actuator/jack-testing apparatus of Tokyo Denki University. This project was supported by the building standard development promotion program conducted by the Japanese ministry of land, infrastructure and transport (MLIT) in order to improve and maintain the Japanese building standard law, and its enforcement order by applying non-government organizations such as research institutes, private enterprises and universities.

1 INTRODUCTION

The devastating earthquake of Mw9.0 hit the Tohoku district, northeast part of Japan on March 11, 2011. About 16,000 people died and 3,000 people were missing due to the strong motion and the tsunami. The economic damage was estimated about 16.9 trillion yen (115 billion British Pounds) excluding the influence by the nuclear accident of Fukushima Daiichi Nuclear Power Plant. In addition to the main shock, many strong aftershocks occurred in the long term until June in 2011. The industrial facilities, power plants, or research facilities were damaged in these earthquakes, and various kinds of mechanical equipment set in these facilities were damaged.

During this earthquake, four fall-off accidents of the escalators, utilized in three steel framed shopping mall buildings, occurred. One of the main causes of the fall of escalators is due to the lack of sliding margin of the non-fixed joints between the escalator-truss and the supporting beam mounted on the building horizontal frame due to the unexpected excessive story-deflexion of the building structures caused by the earthquake. The other causes are considered that the escalator-truss structures collide with the supporting beam, as described above, in the non-fixed end and the compression force induced during collision might give elasto-plastic deformation and residual displacement to the escalator as a result. In this case, the escalator might not only lose the vertical load supporting ability but also the shortening of the length of the truss might reduce the sliding margin.

For the existing escalators, the fall-off phenomenon on the side where the support interval widens during earthquake can be dealt with by lengthening the supporting margins. However, because the problem on the compression side is difficult to deal with, experimental and analytical studies were carried out to clarify the elasto-plastic restoring force characteristics of the escalator-truss structures and to refine and improve the seismic design guidelines and the Japanese building standard law, and its enforcement order. Series of experimental tests were carried out by using actuator/jack-testing apparatus of Tokyo Denki University. And this project was supported by the building standard development promotion program conducted by the Japanese ministry of land, infrastructure and transport (MLIT) in order to improve and maintain the Japanese building standard law, and its enforcement order by applying non-government organizations such as research institutes, private enterprises and universities.

1.1 The building standard development promotion program conducted by the Japanese ministry of land, infrastructure and transport (MLIT)

The Ministry of Land, Infrastructure, Transport and Tourism announced a survey project with the issue of "Study on securing safety of existing escalators against earthquakes" in order to prevent future escalator fall-off in coming severe earthquakes such as earthquakes directly under the capital city, Nankai Trough Earthquake and so on. Regarding this subject, Fujita Laboratory and Tachibana Laboratory of Tokyo Denki University, and Japan Elevator Association planned and considered the following contents for this issue.

1) In order to verify the case where the main structure of the existing escalator (truss structure and beam structure, hereinafter referred to as "truss etc.") was compressed by the seismic load induced in the building beam during severe earthquakes, the experimental tests were conducted. And, simulation analysis was followed for newly utilized and existed escalator trusses to clarify the buckling behaviors of trusses under various conditions in which the joining conditions of members.

2) The compression experimental tests of a full-size truss etc. were carried out to demonstrate the validity of the simulation analysis from the comparison of the simulation analysis results with the experimental results.

3) From these results, even in the case of receiving compressive force from building beams induced by the excessive story drift due to severe seismic inputs, it is to demonstrate that the truss etc. of the existing escalator is safe against fall-off and to clarify the conditions that need to be confirmed in the design stage. In addition, we propose a draft standard that confirmation by actual size experiment can be omitted.

The Building Standards Development Promotion Program will publicly invite business operators such as university corporations to gather technical knowledge etc. for the improvement of technical standards pertaining to the Japanese Building Standard Law, etc. by the Ministry of Land, Infrastructure, Transport and Tourism (MLIT). The results of the survey are compiled according to the survey items and recommendations are proposed for the building standard laws concerning structural design methods and so on.

1.2 Escalator fall-off damage occurred in the 2011 off the Pacific coast of Tohoku Earthquake of March 11, 2011

The 2011 off the Pacific coast of Tohoku Earthquake (hereinafter referred to as " Great East Japan Earthquake") that occurred at 14:46 JST (05:46 UTC) on Friday 11 March 2011, with the epicenter approximately 70 kilometres east of the Oshika Peninsula of Tōhoku and the hypocenter at an underwater depth of approximately 29 km is a huge earthquake that recorded the seismic intensity 7 (moment magnitude Mw=9.0), and the large scale tsunami spread to the Pacific coastal area immediately after the earthquake. After that, aftershocks continued to occur for a long period of time until July, and both the main shock and aftershocks caused damages to the lifts and escalators, which are building facilities, along with the buildings in a wide area from the eastern Japan area to the Kanto, Hokuriku and Chubu areas.

Due to the main shock, four escalators that were installed in three shopping malls dropped from the upper floor to the escalator on the lower floor. Figure 1a, 1b and 1c respectively show examples of fall-off accidents of escalators [1]. Because, in conventional seismic design for shopping centre design as described in 1.3, value of story drift is becoming extremely large especially against the severe earthquake such as Great East Japan Earthquake, the criteria of the overlap allowance between escalator truss and the lateral beam of the building where the escalator is placed on must be reviewed.

Figure 1a Shopping centre in Saiwai-cho, Sendai City

Figure 1b Shopping centre in Izumi-Osawa, Sendai City

Figure 1c Shopping centre in Koriyama City, Fukushima Pref.

1.3 Conventional seismic design of building

Table 1 shows the calculation method of building story drift angle against marginal earthquake ground motion for the seismic design of building structures by the Japanese building law. In seismic design of shopping centre buildings, Type (D) design method is usually used. If the story height of the building is 4,000 mm for example, the story drift deformation is obtained as follows.

$$4{,}000 \times \frac{1}{24} = 166.7\, mm$$

Although this value itself is very large, it is confirmed that the story deformation angle in these types of building exceeds 1/30 even in a real scale large building earthquake resistance experiment using a large shake table. Therefore, it was confirmed that this value must be considered when the escalator is installed.

Table 1 Calculation method of building story drift angle for marginal earthquake ground motion

Type of design		Story drift angle must be considered
(A) 5 times the story drift angle (within 1/200 in principle) of the building calculated by usual calculation (Japanese Building Standard Law Enforcement Ordinance Article 82-2)	➡	**1/40 in principle**
(B) Steel structure with small amount of deformation, reinforced concrete structure that can be calculated using allowable stress degree calculation (Route 1)	➡	**1/100 or more**
(C) Large scale buildings etc. which obtained the story drift deformation angle by special investigation and research (time history response analysis and limit strength calculation)	➡	**If the calculated value is less than 1/100, it is 1/100 or more**
(D) When not obtained by structural calculation	➡	**1/24 or more**

2 CRITERIA OF LAWS AND ORDINANCES AT THE TIME OF THE TOHOKU GREAT EARTHQUAKE

When expressing the magnitude of the shaking of the building during an earthquake, not only do you express the response acceleration, but also the amount of story deformation or the story drift angle.

Recently, after these fall-off accidents, in the design stage for installing escalators in buildings to be newly built, the designer of the building considers and presents the value of the story drift deformation or the story drift deformation angle of the building calculated from the response analysis against the design earthquake inputs to the designer of the escalator, then the designer of the escalator considers fall prevention countermeasures etc.

On the other hand, in the case of existing escalators, they are designed according to laws and regulations prior to the current law, elevator seismic design and construction guidelines, etc. For this reason, the "clearance" between the building and the escalator or the overlap allowance sometimes does not satisfy current laws and regulations. Figure 2 shows the clearance between the escalator truss and the building beam and the overlap allowance.

In the case of an existing escalator installed with less "clearance", when the building shakes greatly due to the severe earthquake inputs, the "gap" decreases and when the building further shakes, the building beams may hit and collide with the escalator truss structure. When the escalator is compressed from the building, the escalator truss, which is a strength member, receives the most of its forces and deforms by the compressive force. In addition, when the overlap allowance is not sufficient to the displacements, it can be assumed that the supporting angle of the escalator will come off the beam of the building due to the large sway of the building.

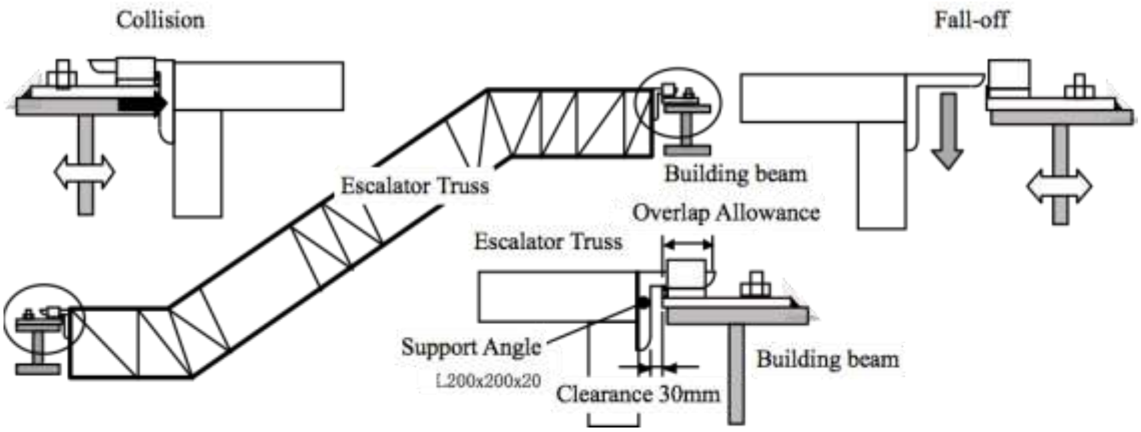

Figure 2 Clearance between the truss and the building beam and overlap allowance

3 EXPERIMENTAL TEST FOR CONSIDERATION OF DEFORMATION OF ESCALATOR TRUSS DURING SEVERE EARTHQUAKE

3.1 Consideration of deformation of escalator truss during severe earthquake

In the escalator truss, in general, members such as upper chord members are arranged in the same direction as the horizontal axis direction. For this reason, when a building causes large story deformation in the same direction of the horizontal axis direction of the escalator due to seismic inputs and the escalator truss is compressed and deformed in the same direction, the truss members are deformed and might cause buckling deformation, and then strength of members will be greatly reduced.

On the other hand, when the story drift displacement in the orthogonal direction occurs, the escalator truss shows rotational displacement in either one of the upper end or the lower end as the rotational centre, so that compared with the case that the escalator truss is forced and deformed in the horizontal axis direction, the deformation of the truss member is considered slight, and the risk of fall-off is considered to be small.

From the above reasons, it was decided to examine whether or not the horizontal axis direction deformation would cause a hazard in safety to the truss member will occur and the strength evaluation method against it.

For that purpose, to acquire knowledge through experiments using real size escalator truss is indispensable. Therefore, an experimental apparatus capable of applying forced displacement in the long side direction to a full-size truss was designed and manufactured, and a full-scale experiment was conducted to confirm the deformation state of the truss. Full-scale experiments to confirm the deformation of escalator trusses were conducted from November 4, 2014 to the end of December, at the Building Technology Research Centre of the Tokyo Denki University Chiba New Town campus.

3.2 Experimental apparatus

The overall view of the experimental apparatus is shown in the installation view of the experimental frame and test specimen (see Figure 3). Experimental situations in which escalator trusses are actually installed are shown in Figure 4 and Figure 5. In designing and manufacturing the experimental apparatus, we considered the following points.

(1) The upper and lower racks and the loading device were designed, manufactured and utilized with the maximum long side direction load of 1,000 kN and the maximum forced displacement amount of 200 mm.

(2) The lower rack on which the support angle of the lower end of an escalator truss is placed is designed to be able to slide in the horizontal axis direction so that the escalator truss can be applied the force for compressing in the horizontal axis direction. This foundation was firmly fixed using a PC steel bar to the reaction force floor of the experiment site.

(3) The lower rack and the hydraulic device giving the force to the truss were connected firmly by rods (PC steel bars). They are provided at two positions on the left and right ends of the truss, and the left and right hydraulic devices are operated synchronously by electric control.

(4) The upper rack, on which the supporting angle of the upper end of a truss is placed, was firmly fixed to the vertically standing reaction wall in the experiment site using a PC steel bar. In addition, in order to prevent the support angle of the upper end from floating up during the experiment, the support angle at the upper end of the escalator and the upper mount were fastened with bolts.

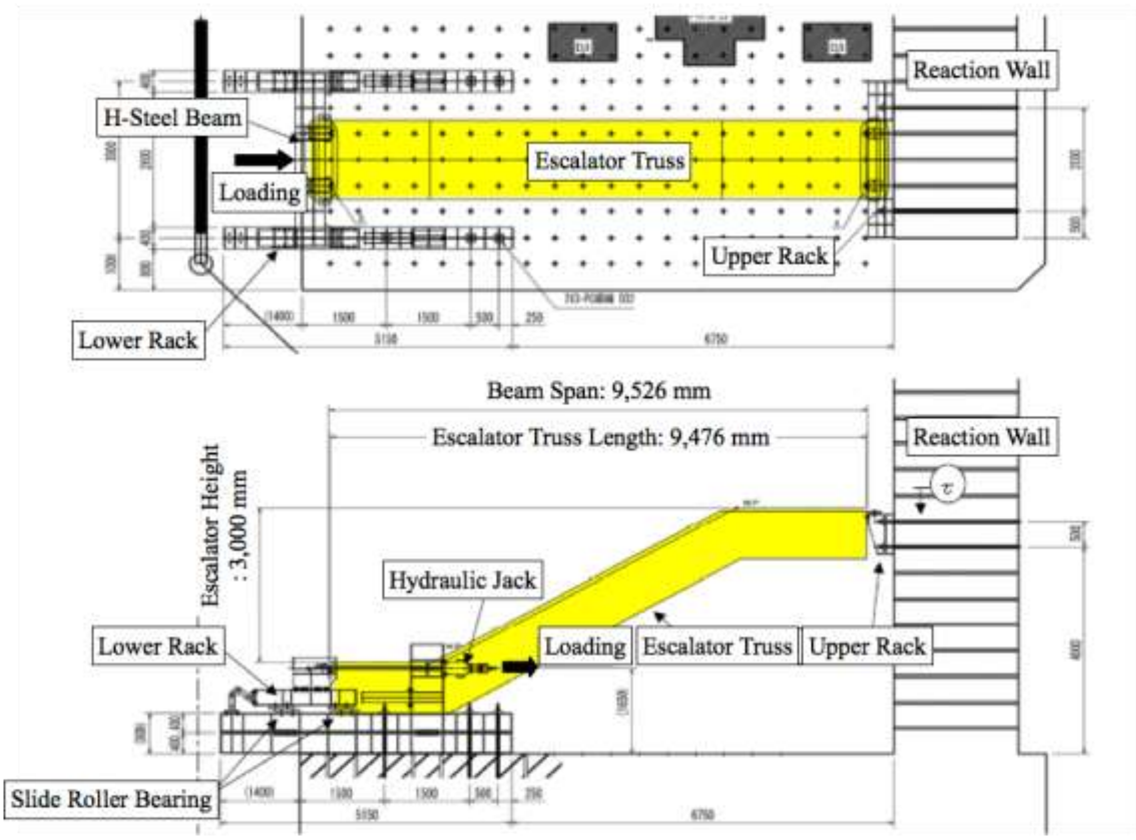

Figure 3 Overall layout of experimental apparatus and test specimen

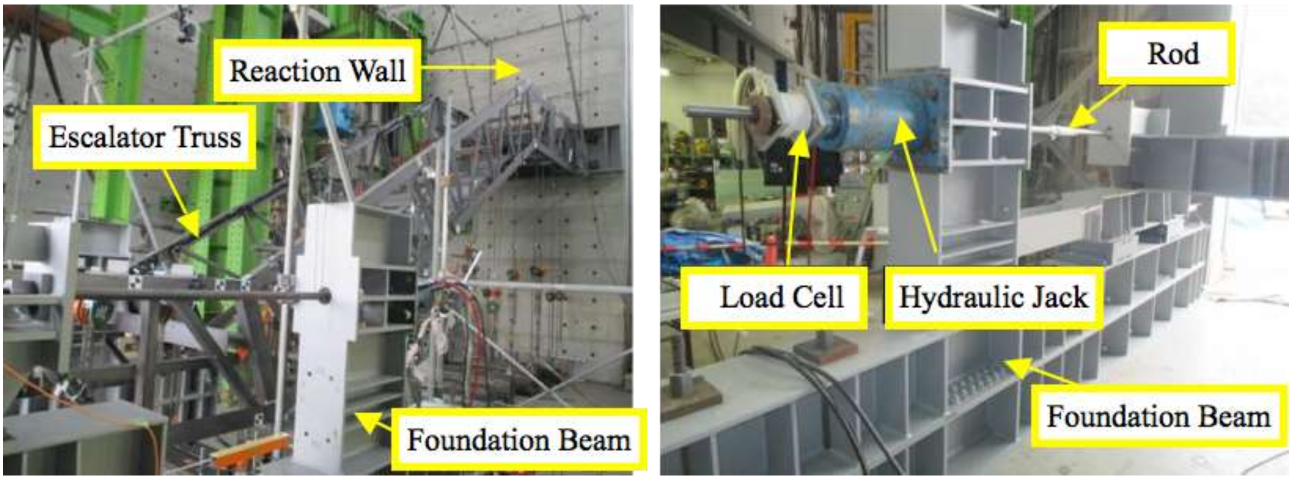

Figure 4 Truss installed to experimental apparatus and test specimen (left) and hydraulic jack for loading (right)

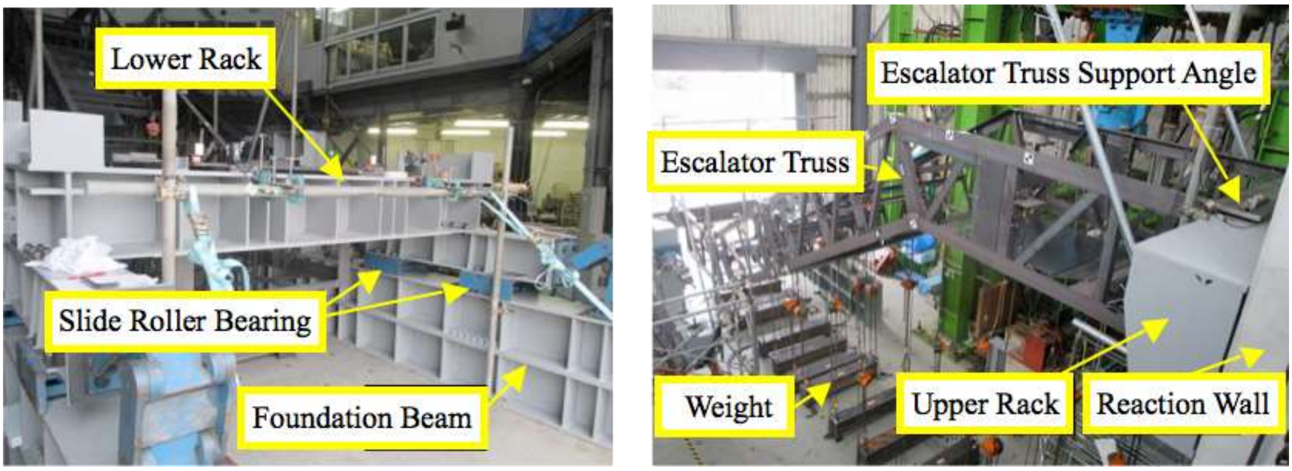

Figure 5 The lower base beam (left), the upper rack and the truss fixed state (right)

3.3 Escalator trusses used for the tests

In a full-scale experiment, tests were conducted using seven truss structures consisting of equilateral angle steels and one with beam structure so that most of the existing escalator truss structures can be covered. The common main specifications of each test specimen are shown in Table 2.

Table 2 Main specifications of the test specimen

Item	Specifications
Floor height	3,000 mm
Step width	Type S1000: 1,330 mm
Slope angle	30 degree
Horizontal step	Standard type
Full length (horizontal projection length)	9,476 mm

Because it is the essential object of this experiment to confirm that the escalator does not cause deformation that would be a hindrance to safety in the case where the escalator underwent forced displacement due to story drift deformation of the building caused by earthquake, only truss structures without any parts such as steps, hand rails and so on were tested instead of using the completed escalator system. In addition, as mentioned above, the escalator internal equipment (Driver Unit, Step, Step Case, Step Rail, Inner Plate, etc.) other than the main body of the truss was not included in the test specimen, and the load of those were loaded by the additional weight and tested. Figure 5 shows test specimen (escalator truss) and installation of additional weight.

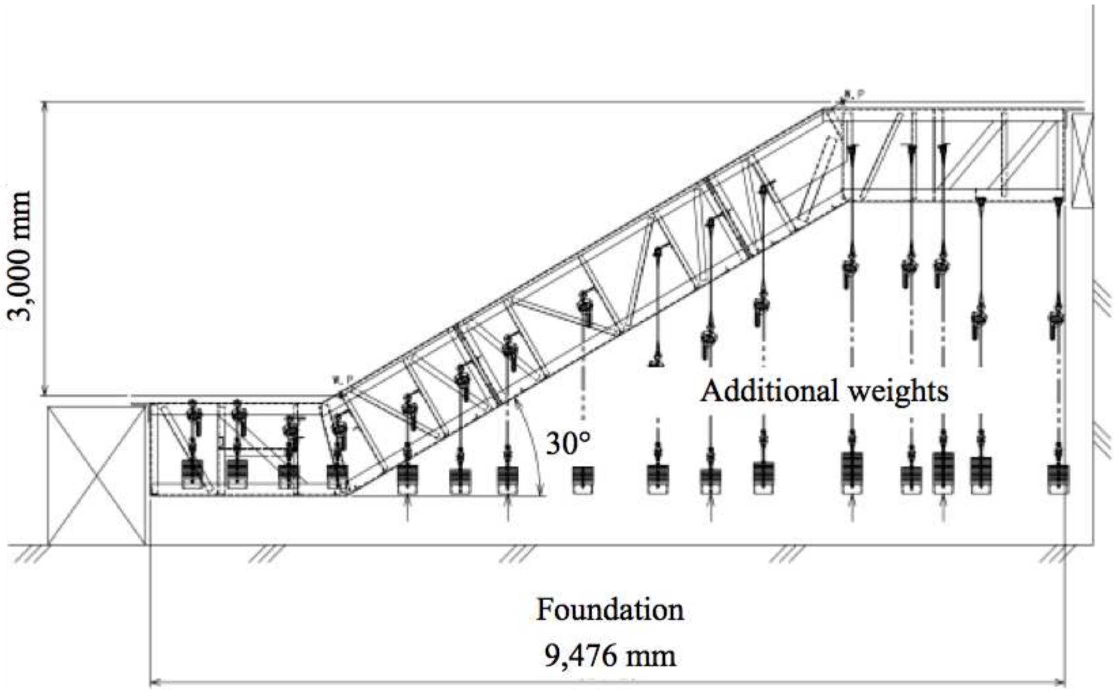

Figure 6 Test specimen and installation of additional weight

3.4 Measurement

Table 3 shows the measurement items and methods in the experimental tests. In addition, in order to observe the behavior of the entire specimen, digital cameras and video cameras were installed and captured.

Table 3 Measurement item list

No.	Item	Measurement method
1	Forced displacement in horizontal axis direction of escalator truss (Compressive deformation)	Forced displacement shall be the value that subtracts the average value of the displacement of the two upper support angles of the specimen from the average value of the displacement of the two support angles at the lower part of the specimen.
2	Horizontal axis direction load	Measure with a load cell attached to each of the right and left hydraulic devices and set it as the total value of the load measured by the left and right load cells.
3	Horizontal displacement	Markers are placed on the part where displacement is measured. Measure the movement of the marker position and determine the displacement by image analysis.
4	Strain induced in the escalator truss	Measure with a strain gauge.

3.5 Loading condition

The vertical load applied to the truss consists of the load of the escalator itself and the internal equipment weight. Since this experiment is carried out only with a truss structure, considering maximum loading load and equipment weight, they are adjusted with additional weight. The loading load was set to 2,600 N/m^2 prescribed in Article 129-12 of the Building Standard Law Enforcement Order and the loading range is assumed to be "step width × total length of the escalator", and the equipment weight was calculated excluding the weight of truss. Additional weights are placed so that the load calculated by these is equivalent to the load distribution of the actual escalator.

3.6 Method of applying force to the specimen

The load applied to the specimen in the horizontal axis direction of escalator truss was not a monotonically increasing load, but the loading and unloading were repeated stepwise several times and compressed until the length in the horizontal axis direction was finally shortened by about 200 mm. This approximately 200 mm corresponds to approximately 1/15 of the story drift deformation angle, which is more severe value than 1/24 of the most severe story drift deformation angle prescribed in Ministry of Land, Infrastructure and Transport Notification No. 1046 as described in Table 1.

The loading plan is as follows and is shown in Figure 7 :

1) After applying a load of 60 kN in the horizontal axis direction, unload it to almost 0 kN.

2) After loading 200kN in the horizontal axis direction, unload it.

3) After forced displacement is applied up to 40 mm, unload it.

4) After 40 mm, forced displacement is applied up to 40 mm to 80 mm, 120 mm, 160 mm in the same way, then unload it.

5) After forced displacement is applied up to the maximum value of 200 mm, then unload it.

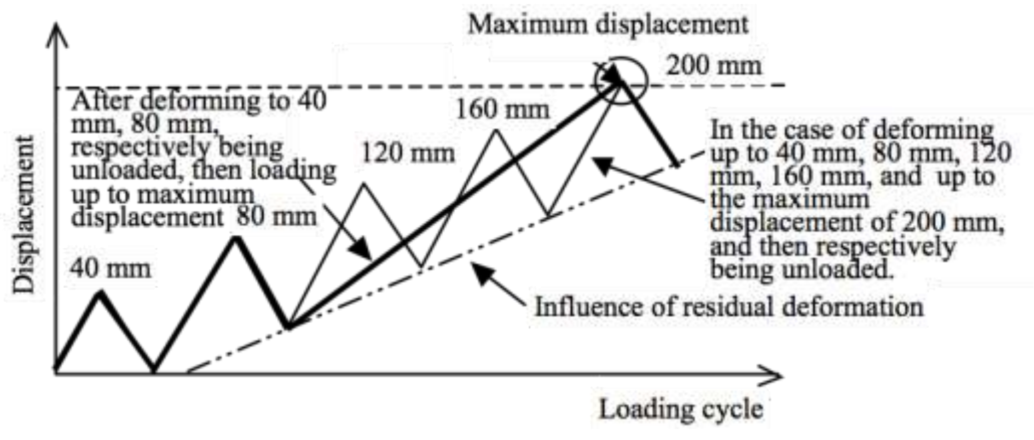

Figure 7 Loading pattern

3.7 Experimental results

In the full-scale experimental tests, a total number of eight truss bodies including a truss structure and a beam structure were carried out. Equipment weight and loading weight other than the weight of the truss structure or beam structure were suspended from the lateral beams of the truss as additional weights with the same weight as each. These additional masses have no effect on suppressing the deformation of the truss structure or the beam structure, so that, in the proof stress assessment after a very large deformation occurred, they do not give the safety side results.

Figure 8 shows restoring force characteristics for all the eight escalator trusses tested. In the beam truss structure, elastic deformation proceeded with increasing forced displacement immediately after the start of applying force and shows the relatively lower stiffness in linear region as compared with the others. When the horizontal axis direction load reached the maximum value, deformation started to occur in the upper chord material of the lower bent portion, and the load in the horizontal axis direction decreased sharply. Because the restoring force characteristics after the stepwise loading started decreasing again on the same hysteretic lines as before unloading, it was confirmed that there was no influence due to repeated loading and unloading.

In the series of experimental tests, the deformation position was the upper chord material located in the lower bent portion or the intermediate part of the diagonal material although the progress of deformation varied depending on each other and on the shape of the section steel used. In addition, in the beam structured escalator truss, deformation occurred at the lower bent portion.

Deformation states of all the types of escalator trusses are respectively shown in Figure 9, 10, 11 and 12.

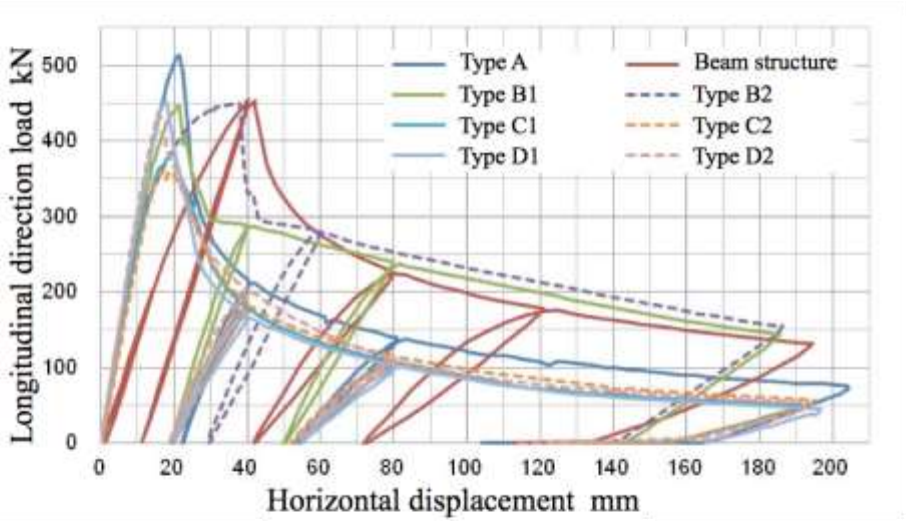

Figure 8 Restoring force characteristics of escalator trusses

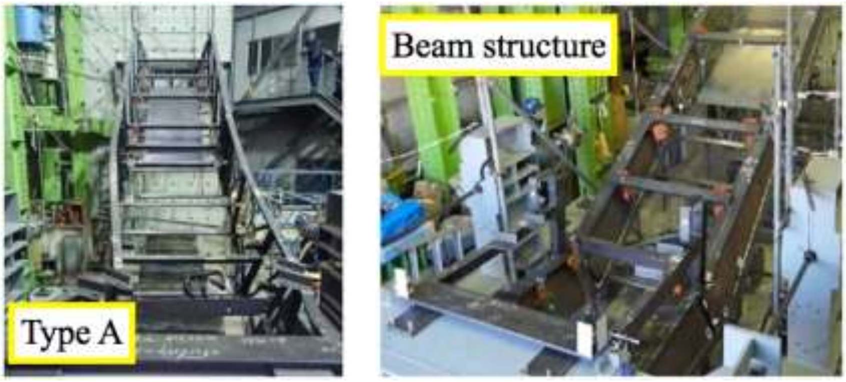

Figure 9 Deformation state of the type A and beam structure escalator truss

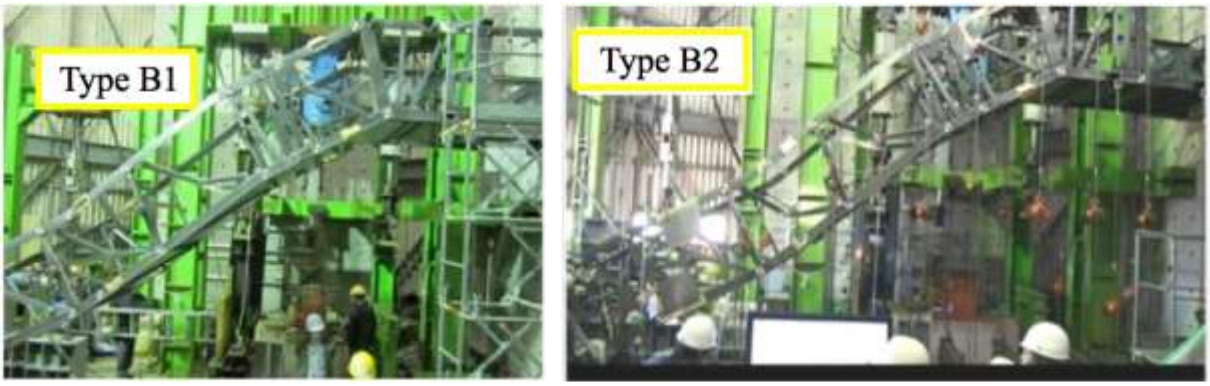

Figure 10 Deformation state of the type B1 and B2 escalator truss

Figure 11 Deformation state of the type C1 and C2 escalator truss

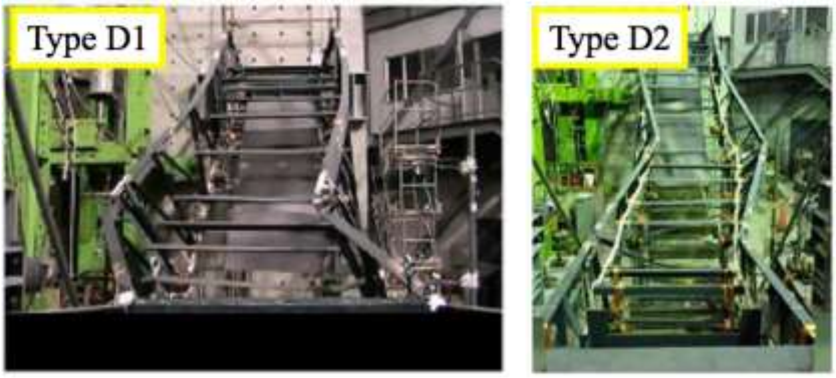

Figure 12 Deformation state of the type D1 and D2 escalator truss

The findings obtained from experimental tests are summarized as follows and all the results obtained in the tests are shown in Table 4;

1) As shown in Figure 8, during the experimental tests, forced displacement amount was given to all specimens up to about 200 mm (equivalent to about 1/15 of story drift angle), but the truss structure and beam structure never dropped. Cracks and fractures in the welds of the parts and large deformation of the lower bent potion other than the upper chord material and the intermediate part diagonal material were not observed. As for the beam structure, the moment generated at the lower bent portion was the maximum, and deformation occurred at the lower bent portion of the escalator.

2) From Figure 8, if the deformation in the horizontal axis direction is within 20 mm, it is found that escalator trusses behave elastically, the dimensions are almost restored to the original size after unloading. In addition, as shown in Figure 8 and Table 4, when the forced displacement was given up to 40 mm and then unloaded, the trusses restored about 20 mm in the horizontal axis direction. Moreover, when forced displacement is applied to about 200 mm, they restored from about 31 mm to 45 mm after unloading.

Table 4 Experimental tests results

Item		**Type of escalator truss structure**							
		Type A	**Type B1**	**Type B2**	**Type C1**	**Type C2**	**Type D1**	**Type D2**	**Beam structure**
Maximum deformation member		Upper chord material	Diagonal members		Upper chord material		Upper chord material		-
Maximum deformation point		Lower bent portion	Inclined portion		Lower bent portion		Inclined portion		Lower bent portion
At maximum load	**Load value**	509 kN	446 kN	450 kN	384 kN	361 kN	453 kN	437 kN	455 kN
	Displacement	20.4 mm	21.3 mm	37.7 mm	19.7 mm	18.6 mm	17.8 mm	15.4 mm	40.3 mm
At maximum displacement	**Load value**	76.3 kN	144 kN	155 kN	51.1 kN	57.1 kN	46.0 kN	52.8 kN	131 kN
	Displacement	204 mm	186 mm	186 mm	191 mm	195 mm	197 mm	194 mm	195 mm
Restoration dimension after unloading	**At 40 mm**	18.3 mm	20.8 mm	30.8mm*	19.7 mm	20.0 mm	20.2 mm	20.9 mm	29.1 mm
	At 80 mm	26.5 mm	30.2 mm	———*	25.9 mm	28.6 mm	25.6 mm	26.3 mm	38.5 mm
	At maximum displacement	40.3 mm	42.2 mm	45.3 mm	37.9 mm	39.5 mm	31.5 mm	32.0 mm	60.6 mm

* In the test for Type B2 escalator truss, buckling deformation appeared on the member at the forced displacement around 40 mm, so it was unloaded only when the forced displacement was 60 mm.

4 RELATIONSHIP BETWEEN FORCED DISPLACEMENT AND OVERLAP ALLOWANCE

It was confirmed that some dimensions are elastically restored in the horizontal axis direction after unloading in the full-scale experimental tests using trusses with a rise of 3,000 mm. From this result, considering the restored dimension of the trusses after unloading, we proposed the calculation formula of the margins for clearance and overlapping allowance required to prevent falling off.

(1) Calculation formula of overlapping allowance for one end fixed state

In the fixed state at one end, the forced amount of displacement is expressed by the equation $\sum \gamma \cdot \mathrm{H} - \mathrm{C}$. When the restored dimension δ assumes at least 20 mm from the experimental results, the length of overlapping allowance B is given by the following equations.

In the case of $\Sigma\gamma H - C \leqq \delta = 20$ $\quad \Delta\varepsilon = 0,\ B = \Sigma\gamma H + \beta$

In the case of $\Sigma\gamma H - C > \delta = 20$ $\quad \Delta\varepsilon = \Sigma\gamma H - C - \delta,\quad B = \Sigma\gamma H + \beta + \Delta\varepsilon = 2\Sigma\gamma H - C$

(2) Calculation formula of overlapping allowance for both end non-fixed state

In the non-fixed state at both ends, the amount of forced displacement is expressed by the equation $\sum \boldsymbol{\gamma} \cdot \mathbf{H} - \mathbf{C} - \boldsymbol{D}$. When the restored dimension δ assumes at least 20 mm from the experimental results, the length of overlapping allowance B is given by the following equations.

In the case of $\Sigma\gamma H - C - D \leqq \delta = 20$ $\Delta\varepsilon = 0$, $B = \Sigma\gamma H + D + \beta$

In the case of $\Sigma\gamma H - C - D > \delta = 20$ $\Delta\varepsilon = \Sigma\gamma H - C - D - \delta$,

$$B = \Sigma\gamma H + D + \beta + \Delta\varepsilon = 2\Sigma\gamma H - C$$

Where,

γ : Story drift deformation angle for design given by building structure designer

H : Rise of escalator

Δ : Restored dimension

Δε : Plastic deformation amount of truss

B : Length of overlapping allowance (margin length)

C : Length of clearance (gap) at one end to be calculated

D : Length of clearance (gap) on the opposite side from the one end to be calculated

5 CONCLUSION

(1) Experimentally examined by using full-size escalator trusses without any internal equipment and so on. Truss structure Type A, Type C and Type D showed deformation of upper chord material, and in the Type B tests, intermediate diagonal member deformed. In addition, in the beam structure, deformation occurred at the lower bent portion. As a result, the truss structure and beam structure never dropped due to breakage of their member or excessive deformation.

(2) Considering the reinforcement effect by the internal equipment of the escalator, it can be expected that the truss structure and beam structure has sufficient strength against escalator falling off from the support angle of the building by compression effect during severe earthquakes.

(3) In order to prevent the escalator from coming off against severe earthquakes, even when the calculated lateral displacement of the beam of the building supporting the escalator becomes the maximum value, the length of overlapping allowance is necessary to have a sufficient length that the escalator's support angle does not release from building structure beam.

(4) When the clearance between escalator and building beams supporting the escalator is the minimum, a clearance must be provided so that the escalator and the building beam do not collide. In case of collision, it is necessary to verify the strength of the truss of the escalator.

Since there was little technical knowledge about the deformation of the truss when the escalator collides with the building beam, there were technical problems in the strength evaluation method by the time of this investigation were carried out. Based on the results obtained in this full-scale experiment, it was conceivable to examine more detailed strength evaluation method. As a result, based on the results obtained in this experiment, we add that August 3, 2016 announcement of revised Notification No. 1046 of Ministry of Land, Infrastructure and Transport Notification No. 1046 was promulgated.

6 ACKNOWLEDGMENTS

With the support of the Ministry of Land, Infrastructure and Transport, Tokyo Denki University and the Japan Elevator Association organized a committee. In this committee, experts in construction and mechanical systems, Housing Bureau of the Ministry of Land, Infrastructure and Transport, National Institute for Land and Infrastructure Management and Building Research Institute of the Ministry of Land, Infrastructure and Transport, and Japan Building equipment and Elevator Center (BEEC) attended. Especially, authors greatly appreciate the cooperation of the Building Research Institute that provided useful technical guidance. Finally, authors thank Mr. Nariya and Mr. Tanaka of the former Tokyo Denki University graduate students for their dedicated cooperation in carrying out the experimental tests.

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BIOGRAPHICAL DETAILS

Prof. Satoshi Fujita, a JSME (Japan Society of Mechanical Engineers) Fellow, has ten years of management experience as a director, a dean of school of engineering and a vice-president of Tokyo Denki University. He has been engaged in engineering research and development of seismic isolation systems and vibration control systems for buildings or key industrial facilities for over 35 years at both University of Tokyo and Tokyo Denki University. In recent ten years, he has been a committee member of the Panel on Infrastructure Development of Japanese ministry of land, infrastructure and transport (MLIT), and a chair of the Special Committee on Analysis and Evaluation of Lifts, Escalators and Amusement Facilities Accidents and Failures held in MLIT. In addition, he has been a chair of the ISO TC178 Japanese committee.

Mr. Motoo Shimoaki was a managing director of the Japan Elevator Association (JEA) about ten years from 2008 to May 2018. In JEA, he served as a member of the ISO/TC 178 Japanese committee and the lifts and escalators committee to develop a Japanese industrial standard (JIS) that is consistent with international standards. And with prof. Satoshi Fujita of Tokyo Denki University, JEA carried out several projects of MLIT. In addition, as one of the activities of JEA, when a large earthquake occurs in Japan, the damage situation of the lifts and escalators is investigated each time, and it is reflected in the seismic design guideline of the lifts and escalators. Before JEA, he has extensive experience at Mitsubishi Electric Corporation as a mechanical engineer and experience as a president of the Mitsubishi Elevator Company Asia in Thailand.