SPEEDWALK : Development of Accelerating Moving Walk

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Accelerating Moving Walk "SPEEDWALK" has been developed for improved mobility of short (150—1 000 m) and massive pedestrian trips which are hardly covered by conventional means of transportation. This SPEEDWALK is a revolutionary moving walk featured by its speed variation in a continuous loop, i. e. slow at its entrance, then accelerated and again slowed down at its exit. The maximum speed when accelerated is 100 m/min which is 2.5 times faster than that at its entrance and exit.

1. Introduction

With the city development projects, stations and passenger facilities, large-scale public facilities (airports), etc. getting larger and farther away, the distance covered by pedestrians also tends to be longer and longer.

The transportation means for the pedestrians to cover this increasingly long distance of 150 m to 1 000 m is the existing system (new transportation system, constant speed moving walkway, etc.). The new transportation system has the problem of high construction cost against the service distance and the space of introduction; while the constant speed moving walkway takes longer time to cover the long distance (i.e. the speed is excessively low), causing deterioration in service.

The "SPEEDWALK," the accelerating moving walk with the speed 2.5 times as high as that of the constant speed moving walk, gets rid of all the aforesaid problems, provides excellent feeling of speed, and covers the distance that people have resistance in walking on in a short time.

Fig. 1 shows the application areas of various transportation systems.

This figure shows the relation between transportation capacity and transportation distance or traveling time, indicating the need of faster vehicles as the distance gets longer.

The SPEEDWALK is a high-level system of pedestrian transportation, covering a wide range of distance as a short-distance transportation means.

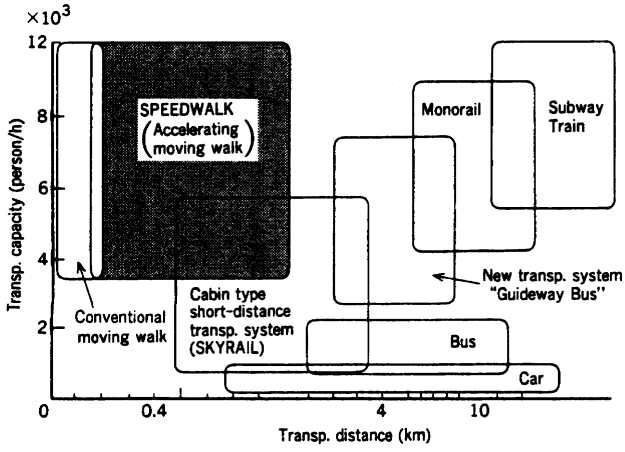

Fig. 1 Application area of transportation system
The relation between transportation capacity and transportation distance or moving time, indicating the need of faster vehicles as the distance gets longer.

2. Development plan

2.1 Aim of development

The constant speed moving walkway is a horizontal moving system as a facility for supporting the pedestrian trips. However, it takes longer time to cover a long distance and leads to the deterioration in service, so that a new high-speed system is currently on demand. The new system has to be acceleration and deceleration type, i.e. a type that gains high speed after acceleration, with the speed at the entrance and exit remaining the same as the conventional type. As for the acceleration and deceleration moving walk, Dunlop Ltd. (including Battele Research Center in Geneva, Switzerland) has developed the obliquely sliding separate treadway type SPEEDWAY, and ACB Co. of France the straight type of slide and shrinkage type TRAX, both of which are not put into practical use yet.

From the standpoint of laws and regulations, the conventional type system has been stipulated in the Building Code, but the acceleration and deceleration type was stipulated as ASME A 17.1-199 APPENDIX-G in 1981 in the U.S.A. However, there is no law applicable to this regard in Japan.

Under such background the development was promoted placing emphasis to simple mechanism and safety at the time of design.

Dunlop aimed at the speed 5 times higher than the conventional type, but the SPEEDWALK set the speed at 2.5 times higher, taking due account of the safety and comfort of the pedestrians.

Table 1 shows comparison of various types of moving walk systems.

Table 1 Specification table of moving walk system

Item \ Machine type	SPEEDWALK	Dunlop product	Conventional moving walk
Speed at entrance/exit	40 m/min	40 m/min	40 m/min
Speed at high-speed zone	100 m/min	200 m/min	40 m/min
Speed ratio	1 : 2.5	1 : 5	1 : 1
Principle	Obliquely sliding separate treadway system	Obliquely and continuously sliding separate treadway system	Continuous linear treadway system
Balustrade	Dividing linear arrangement	Dividing lap arrangement	Single straight line
Laws	On the basis of construction standard of escalator without step thread in Building Code No. 1110	ASME A 17.1-1990 APPENDIX-G	Comformed to construcdion standard of escalator without step thread in Building Code No. 1110

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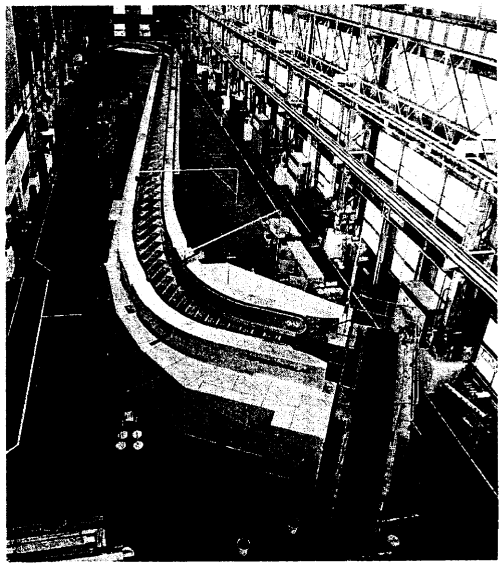

Fig. 2 SPEEDWALK system of model machine
Overall view of the model machine produced as the SPEEDWALK system.

Table 2 Specification of model machine

Item	Capacity and dimensions
Equipment length	60 m (to 300 m)
Speed ratio	2.5
Speed at entrance/exit Speed at high-speed zone	30 to 40 m/min 75 to 100 m/min
Transportation capacity	9 000 to 12 000 persons/h*
Effective width at entry and exit speed zone Effective width at high-speed zone	1 500 mm 990 mm
Platform pitch	About 400 mm
Operating direction	The system can run in either direction.
Entry/Exit direction	Getting on and off for straight forward direction
Power	Electricity
Control system	Invertor
Safety devices	Rubber edged platform Handrails and balustrades Emergency stop device Announcing system

* The transportation capacity is the value when 2 people are riding on each platform at the entrance and exit speed zone of 40 m/min.

3. Outline of development

3.1 Specification for actual-size model machine

The speed of the SPEEDWALK at the entrance is as slow as that of the conventional constant speed moving walkway, but gets gradually accelerated until a constant high speed is attained, which is 2.5 times faster than that of the conventional type.

The speed is again decelerated at the exit to allow the pedestrians to get off safely.

Fig. 2 shows the overall view of the model machine, **Table 2** its specification, and **Fig. 3** the view of entrance or exit.

3.2 Principle of operation for acceleration and deceleration

The SPEEDWALK is a system making use of the principle that the water flowing through a ditch of the same depth runs smoothly at places larger in width and rapidly at places with smaller width.

The system is composed of the quadrilateral platforms forming a continuous path (road), while keeping each other parallel and sliding mutually at the accelerating (or decelerating) zone.

The surface of the platform, designed in Z(S) shape, is composed of a constant low-speed zone, an acceleration (deceleration) zone, and a high-speed zone as shown in **Fig. 4** (a).

The principle of operation of acceleration (deceleration) is shown in Fig. 4 (b). A certain initial low-speed AA′(V_0) is applied to the SPEEDWALK at the constant low-speed zones and acceleration zones, allowing it to travel due to the vector sum-velocity BB′ obtained through the combination of V_0 and slide-velocity that increases gradually in the curved zone. In the high-speed zone, however, the platform does not slide sideways, allowing the SPEEDWALK to move straight forward at a constant speed of max. CC′.

The principle of deceleration is reverse to the aforesaid principle. Moreover, theoretically speaking, the smaller the curve angle α, the higher the speed. So that; the speed ratio

Fig. 3 View of entrance or exit
Entrance or exit of the model machine produced as the SPEEDWALK system.

V_0/V_{max} = AA′/CC′ = sinα. (α= 23.58° when the speed ratio is 1 : 2.5)

3.3 Mechanism

The SPEEDWAY mechanism is shown in **Fig. 5**. The whole system is composed of a constant low-speed zone, an acceleration (deceleration) zone, and a high-speed zone, and is equipped with platforms circulated in a loop form. Compared with the conventional type Moving Walk, which has the platforms linked together and traveled by means of chain etc., the SPEEDWALK does not have the platforms linked with chain, but has a drive unit engaged to the gripper on the bottom of each platform. In other words, the platforms at the entrance are directly pushed up and driven through the engagement of chain and platform gripper, while in high-speed zone, the rack chain and gripper get engaged to drive the platforms.

The push-out device for each platform is located at the entrance and also in a symmetrical position at the exit.

The platform, pushed out at the entrance, advances in an incurved form in the curved zone to get automatically

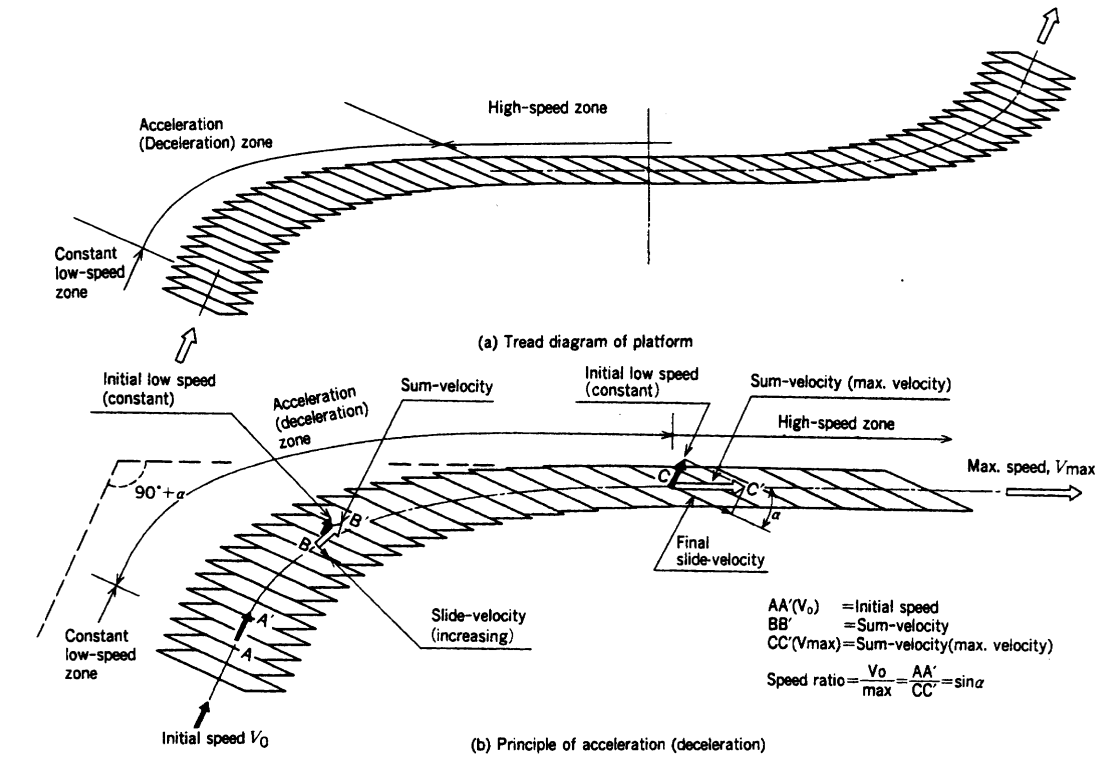

Fig. 4 Treadway and principle of operation
(a) The platform surface, in the shape of Z(S), is composed of an accelerating (decelerating) zone and a high-speed zone.
(b) Indicates the principle of acceleration in the acceleration (deceleration) zone.

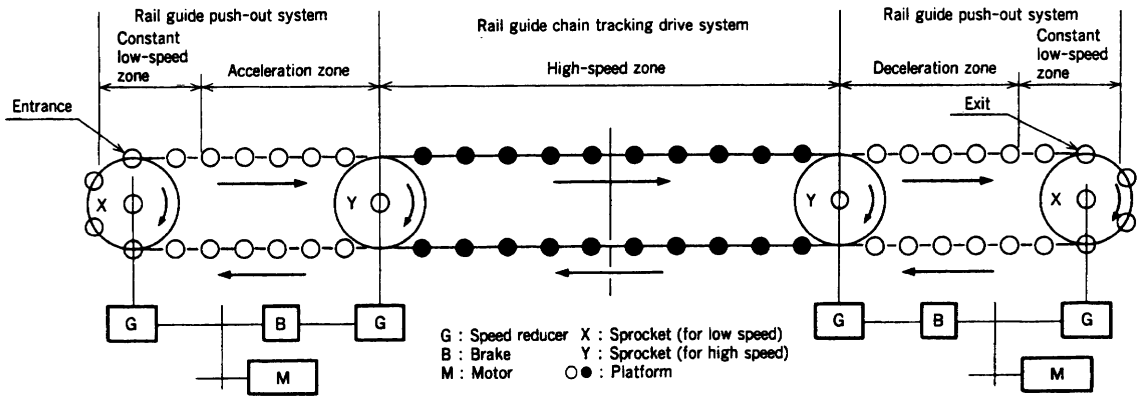

Fig. 5 Mechanism

accelerated and then run at a high speed.

Thus, the combination of foward and sideways movement produces an acceleration at the end of which the platforms merge smoothly into the main high-speed transport zone, where they are travelling at up to 2.5 times their entrance speed. The high-speed zone is straight and the platforms are driven by the shafts connected to the Y sprockets. The X sprockets are driven by the motor as the Y sprockets but through a reduction gearbox.

3.4 Development program

The SPEEDWALK is an unprecedented new transportation system that moves at a low speed at the entrance, gets accelerated after the pedestrians ride on it, and then picks up speed. The prime importance during the process of development was given to the safety of the system, and therefore, the simplification of the machine itself and the balustrades was taken due account of.

3.4.1 Study on the safety of the system (including the human engineering)

(1) In the first stage, the acceleration of platform due to slide-velocity was studied, using human technology with due attention paid to the following points.

① The SPEEDWALK should ensure safe riding whether the pedestrian is an elderly person or a child. In order to provide an experience closely similar to that of an actual machine, two types of alignment of S-shape curve were prepared and the accelerating (decelerating) speed of max. 0.015 G (about one-seventh of the new transportation system, subway or train) was selected by way of mock-up.

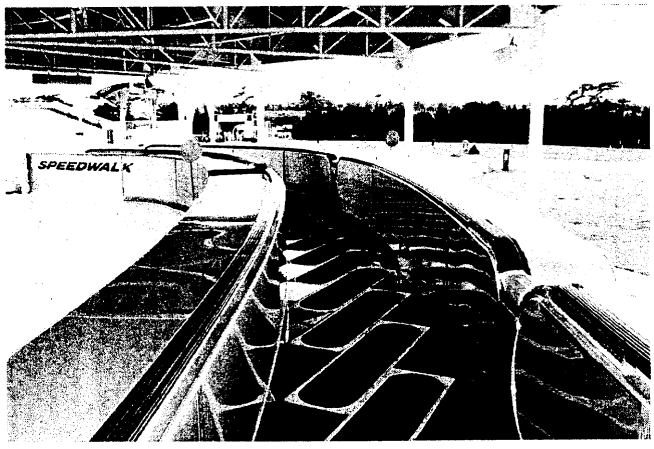

Fig. 6 Figure of divided handrail
The handrail and junction stand allowing smooth hand movement and safe riding at junction of divided balustrades.

Fig. 7 Test of handicapped people
A handicapped person riding the system.

(2) In the second stage, study was made on balustrades. It is ideal for the balustrades to move at the same speed as the acceleration (deceleration) zone curve. However, at the present stage there are no materials of expansion/shrinkage and mechanism to match with the 2.5 times faster speed from low speed to high speed, so that the balustrades (handrails) were divided and set to constant speed at the acceleration (deceleration) zone.

Therefore the handrails in the acceleration (deceleration) zone do not agree with the platforms in terms of speed change, causing the pedestrian's hand to move back and forth. In this respect due attention was paid to the following point.

① What will be the ideal distance of the hand moving to and fro due to the speed difference between platform and handrail to allow even the elderly person to catch up with the speed difference.

Study was made from the standpoint of human engineering, and taking into consideration the height and hand length of average Japanese men, the physiological data regarding the hand position against the handrail, i.e. the limit of comfortable position of hand was set in the following manner: the hand should be lifted no more than once in every 2 seconds, and the relative hand position should not exceed 0.3 m.

$|V_p - V_h| \cdot \Delta t \leqq 0.3$ m

where,

V_p : platform speed

V_h : handrail speed

Δt : time difference

(3) In the third stage, study was made on the junction of divided balustrades, with due consideration paid to the following point.

① To prevent the fingers, clothes, etc. from getting trapped the comb configuration was adopted to eliminate the gap between handrail and junction stand, and the specialists of human engineering were consulted before deciding the height. (**Fig. 6**)

3.4.2 Development of the machine main body

(1) Development of platform acceleration mechanism

Due attention is paid to the following points.

① Smooth running and excellent ride quality of the platform.

② Reduction in noise through simplification of the drive mechanism of the acceleration zone. Compared with the conventional moving walkway with the platforms fixed to the chain and driven at low speed, the SPEEDWALK uses speed changing system, so that instead of adopting the expansion/shrinkage mechanism due to chain, the platforms are independently installed and are driven without being fixed to the chain. Furthermore, the divided $\sin^{-1}\alpha$ of acceleration equivalent to the transition curve is adopted in the guide zone to the acceleration (deceleration) zone, and such speed pattern was adopted so as to allow the platforms to move sideways smoothly and to get accelerated without leaving any gap.

(2) Delivery of platforms from accelerating zone to high-speed zone

Due attention is paid to the following points.

① The delivery of platforms from the acceleration zone should be carried out in a good timing with the same velocity of high-speed zone.

② Because of the high speed, due measures should be taken against noise, abrasion, etc. Hence, the low-speed and high-speed zones are mechanically connected with line shafts to provide the same velocity of high-speed zone.

3.4.3 Development of balustrades

(1) Development of curved handrail of horizontal

Due attention is paid to the following point.

① The handrail should have sufficient tension and strength, with the difference of stretch of inside and outside duly preserved.

For this, the core wire is carefully and skillfully inserted into the handrail of the balustrade to provide the difference of stretch of inside and outside as well as the tensile strength.

(2) Development of high-speed balustrade

Due attention is paid to the following point.

① Since the balustrade speed has to be improved to 100 m/min from the conventional speed 40 m/min, the structure should be designed to have less abrasion to prevent heat generation.

For this, the roller rotating structure with bearing is adopted in the internal guide to reduce the friction.

4. Result

Since there are several inexperienced and unprecedented items (fields) in the "SPEEDWALK," acceleration and deceleration moving walkway such as slide slipping speed of the walkway due to accelerating mechanism, higher speed, failure of the acceleration (deceleration) zone in slightly having the same velocity of high-speed zone due to the adoption of fixed-speed division of balustrades, etc., the verification was carried out by using the actual machine to get real experience. About 1 400 people [including 5 elderly people, 6 people using wheelchairs (**Fig. 7**), 2 people with poor eyesight, 50 elementary school pupils and 6 kindergarten pupils] were requested to take part in the test riding.

In case of the verification of acceleration 0.015 G, studied for the safety of the system, about 6 people had monitor electrocardiographs capable of taking the electrocardiogram attached to their bodies to read the change in heartbeat, which was found to be slightly higher than the normal heartbeat. The heartbeat was found to be the normal level in high-speed zone, indicating that the acceleration is slow, safe, and comfortable for the pedestrians.

Tests of 0.1 G and 0.05 G for emergency stop at high speed clarified that people can stand the acceleration of 0.05 without tumbling in somesthesia test.

As for the movement of hand due to the speed difference between platform and balustrade, most of the participants replied "excellent," which was verified also by the specialists of human engineering. Two types of balustrade mechanism were successfully developed: one with speed 2.5 times higher than the conventional one and the other matching with the curve of the acceleration (deceleration) zone.

5. Conclusion

The status of development of the new short-distance SPEEDWALK as a supporting system for pedestrian trips has been introduced.

The authors would like to extend their thanks to the specialists from the Ministry of Construction, corporations, academic fields, and transportation system for their cooperation and guidance throughout the process of development. The authors believe the newly developed system could be safely put into practical use.

With the acquisition of individual conference approval from the Building Center of Japan Foundation, the public operation of the system started in Uminonakamichi Kaihin Park in Fukuoka City in July 1995, and a large number of users confirmed the safety and verified the comfort of the system. The authors hope that the SPEEDWALK will be introduced all over Japan (areas of urban development, between stations, access to recreation facilities, airports, etc.) as a new means of transportation.

The authors determined to make further studies on the safety based on the result of public operation, because the SPEEDWALK (accelerating moving walk) is a completely new system to be put into practical use.