Escalator Weightless Weight Testing: A Case Study from a UK Metro

Lutfi Al-Sharif

Mechatronics Engineering Department, The University of Jordan
Peters Research Ltd.
The University of Northampton

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Abstract. The escalator braking system is the most important safety component. It is thus necessary to ensure that brakes are tested at regular intervals in order to ensure passenger safety. Carrying out this test using weights is a very complex, risky and expensive procedure, and thus cannot be carried out regularly. For this reason, a model for a weightless brake testing system has been developed for testing the escalator brakes.

This paper describes the work carried out by the author in setting up a weightless brake testing system for testing the escalator brakes at the Tyne & Wear Metro in the United Kingdom.

The first step was to gather escalator type test data on the four escalator models on the Metro. In the second step, the data from the weight tests was used to build a theoretical mathematical model in MS Excel for the different types of escalators. The model allowed the operator to understand the range of acceptable deceleration values that indicate compliant operational brakes. In the third step, all the remaining 28 escalators (out of the full fleet of 32 escalators) were tested and adjusted without the use of weights. They were adjusted in accordance with the outputs of the theoretical model. In the fourth and last test, a training manual was developed for the testing and adjusting the braking systems. On-site training was carried out for the maintenance staff.

1 INTRODUCTION

This paper describes work carried out by the author for the Tyne & Wear Metro in 2002/2003. The work involved carrying out testing on all the Metro’s escalator braking systems, in order to ensure that they meet the European standard requirements.

The Tyne & Wear Metro has 32 escalators that are of four types. They mainly date from the late 70’s/early 80’s and are all manufactured and installed by O&K/KONE.

The testing was planned and carried out in two parts. The first part included weight testing an escalator of each of the four types of escalators. By carrying out the weight test on that type of escalator, not only was that specific escalator tested and adjusted such that it met all the braking requirements, the data was also used to understand the characteristics of the braking system on that type of escalator design.

The data from these tests was then used to extrapolate what the required brake setting on all other escalators of the same type need to be set during light slip tests in order to meet the European standard.

Light slip tests were then carried out on all other escalators. The brakes were tested and then adjusted in accordance with the EN115 braking performance requirements.

This paper describes how the model that was built for the four different types of escalators and the data from the model was used to adjust the remaining escalators in the fleet to meet the requirements of the European standard, EN115.

Section 2 provides some background about escalator brake testing requirements and the concept of weightless brake testing. Section 3 presents an overview of the brake testing performance requirements as stipulated by the European standards EN115. Section 4 discusses the tools used for the measurement of the deceleration of the escalator under the influence of the various braking systems. Section 5 discusses the results from the weight tests that were carried out on the four escalator types. Section 6 discusses the light slip test results for the remaining 28 escalators and presents a table that can be used as a pass/fail criterion for future brake tests of these escalators. Conclusions are drawn in section 7.

2 BACKGROUND

One of the most important safety devices within an escalator is the mechanical braking system [1]. It ensures that the fully loaded escalator is brought safely to a standstill when required to do so following the tripping of a safety device or the activation of the passenger emergency stop switch. Recent developments have introduced the use of electrical braking systems to complement the mechanical braking systems discussed in this paper [2].

It is generally a requirement that full load weight testing be carried out for new, refurbished and partially refurbished escalators to prove that the braking system is capable of (and has been set up to) arresting the fully loaded escalator running in the down direction at rated speed and bringing it to a standstill within the distances stipulated by EN115 [3].

Weight testing is a very lengthy and costly process. It is carried out when an escalator has been replaced or refurbished or where the braking system has been altered. This is especially critical on public service escalators [4]. Public service escalators are subjected to high level of passenger traffic ([5], [6]) which makes the safety of the brakes even more critical.

It is important to note that another paper assumes the value of 150 kg per step in order to calculate the motor or inverter size [7]. The 150 kg is equivalent to two passengers per step each weighing 75 kg, and is over and above the requirement of [3].

Much research has been carried out on the energy drawn by escalators ([8], [9], [10] and [11]) that have shown that that the power drawn by an escalator in kW can be calculated as follows:

$$P_{NL} = 0.47 \cdot r + 1.74 \tag{1}$$

where:

P_{NL} is the power drawn by the escalator at rated speed and no load in kW

r is the escalator rise in m

A previous paper [12] has presented a measurement-based-model that allows the prediction of the stopping distance of an escalator under loaded conditions in order to obviate the need for the full load weight testing. Such a model will enhance the level of safety in escalators and allow a more scientific approach to the subject of weight testing and proofing of the brakes.

3 BRAKE PERFORMANCE REQUIREMENTS

The brake performance requirements as set out in the European Standard EN115 only stipulate maximum and minimum stopping distance. The maximum stopping distance relate to the fully loaded escalator running in the down direction. The minimum stopping distance relates to empty stopping escalator (see Table 1).

The rationale for this is that the escalator should not stop too abruptly when empty, so that it does not cause passengers to fall when travelling on it. When fully loaded it should be able to stop within a reasonable distance to protect passengers from a runaway situation.

Table 1 Stopping distance in accordance with EN115

Rated speed	Stopping distance
0.50 m/s	min. 0.20 m; max. 1.00 m
0.65 m/s	min. 0.30 m; max. 1.30 m
0.75 m/s	min. 0.35 m; max. 1.50 m

The American Standard ASME A17.1 specifies the maximum value of deceleration of the escalator, as 0.91 m/s^2.

There is strong evidence to suggest that the maximum value of deceleration is a very good indicator of the passenger stopping comfort [11]. It is believed that the maximum value of the deceleration during an escalator stop is inversely proportional to the risk of passenger falls. EN115 has been re-drafted to specify an additional maximum deceleration requirement of 1 m/s^2 in addition to the stopping distances.

The stopping distance on its own is a poor indicator of brake performance. For these reasons, the tests in this document use the maximum value of deceleration as the indicator of the brake performance. The maximum value of deceleration has been used during the tests as the basis for adjusting the brakes and is also used in the results section later as a pass/fail criterion for the braking system.

4 TOOLS USED FOR MEASUREMENT

The main tool used for measuring the brake performance is the EVA-625 unit from a company called PMT (Physical Measurement Technologies). Although the unit was originally developed to measure vibration in lifts, it has been adapted with a handheld tacho-wheel to carry out direct speed measurements on both lifts and escalators.

The handheld tacho-wheel is held against the handrail while the escalator is running. The escalator is then stopped by pressing the passenger emergency stop switch on the escalator using a switch supplied by PMT. The switch has a contact that is connected to the EVA625 unit. This triggers the start of speed recording by the unit. The point at which the switch is pressed is denoted as the ‘trigger point’ and placed at zero time on the time axis.

The data can then be downloaded from the unit via a serial cable connected to an RS232 serial port on a laptop. A software supplied by PMT is then run on the laptop to analyse the data. An example of the analysis is shown in Figure 1. Three variables are shown against time: Velocity (m/s), Acceleration (m/s^2) and Distance traveled (m). the point at which the switch was pressed is denoted as the trigger point (time=0 s). Data logged 0.5 seconds before the trigger point is also shown in the plot. When the escalator gets to zero speed that point is denoted as the ‘Rest Point’.

The maximum value of velocity, maximum value of acceleration and the distance traveled following the trigger point are all shown on the plot.

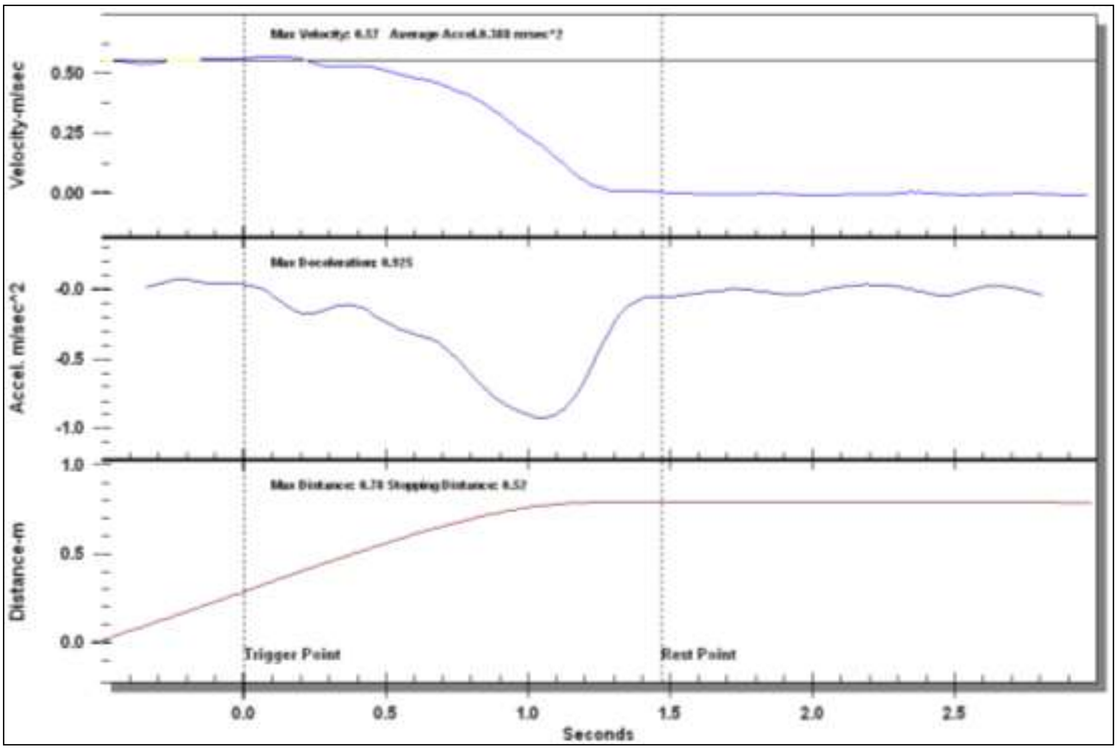

Figure 1 Graphical display on the EVA625 software

It is the maximum deceleration value taken from the software that has been used during the tests as the basis for adjusting the braking system.

5 THE FOUR WEIGHT TESTS

As mentioned in earlier, four weight tests were carried out on four escalator types. A weight tests involves loading the escalator steps with steel weights, running the escalator in the down direction, stopping it and measuring the stopping distance and the maximum deceleration.

The brake load testing is done based on a brake load of 120 kg per step (in accordance with EN115) as the step width is 1 m. The full brake load can be found by using the following formula:

$$L_b = m_s \times \frac{r}{r_s} \tag{2}$$

where:
L_b is the total brake load (kg)
r is the rise of the escalator (m)
r_s is the step rise (0.2 m)
m_s is the applied load per step (120 kg/step)

Prior to placing the weights on the escalator, tests were done with 0% brake load. Then the weight tests were started by gradually loading the escalator with weights in the following sequence: 25% of brake load, 50% of brake load, 75% of brake load and then 100% of brake load and then down in the reverse sequence. A 0% brake load test would then be carried out. Thus the full sequence of tests is:

0%, 25%, 50%, 75%, 100% and then 0%

A 0% brake load test is referred to informally as a “light-slip” test. Each step was loaded with around 180 kg, such that the full load filled around 2/3 of the incline (equivalent to a load per step of 120 kg). The weight tests were carried out on the following four escalator types as follows:

HDM10	18/3/2003
RTV-HD	19/3/2003
HDMS	21/3/2003
Compact	22/3/2003

In order to protect the escalator from the risk of runaway during a weight test the weights are progressively increased and the stopping distance monitored. If a concern arises regarding the capability of the brakes, they are adjusted in order to increase the braking torque.

The results of the weight tests have been summarized as speed versus time plots for the stopping escalator with various loads. The plots have been shown for HDM10 type (Figure 2), RTV-HD type (Figure 3), HDMS type (Figure 4) and the Compact type (Figure 5).

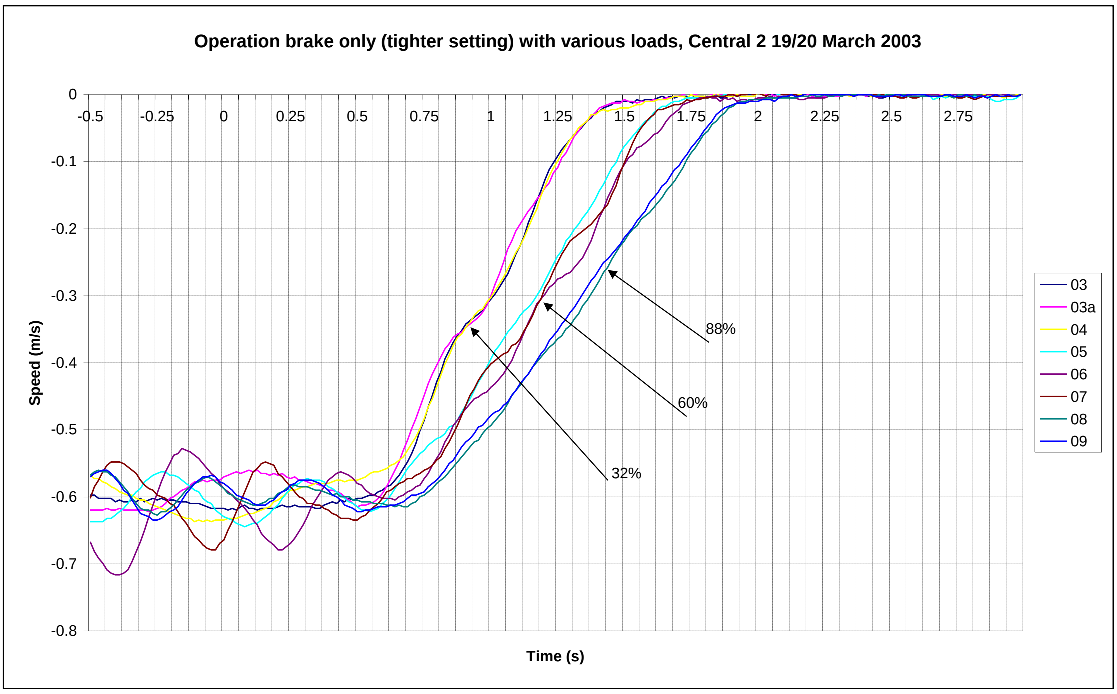

Figure 2 Weight test results for HDM10

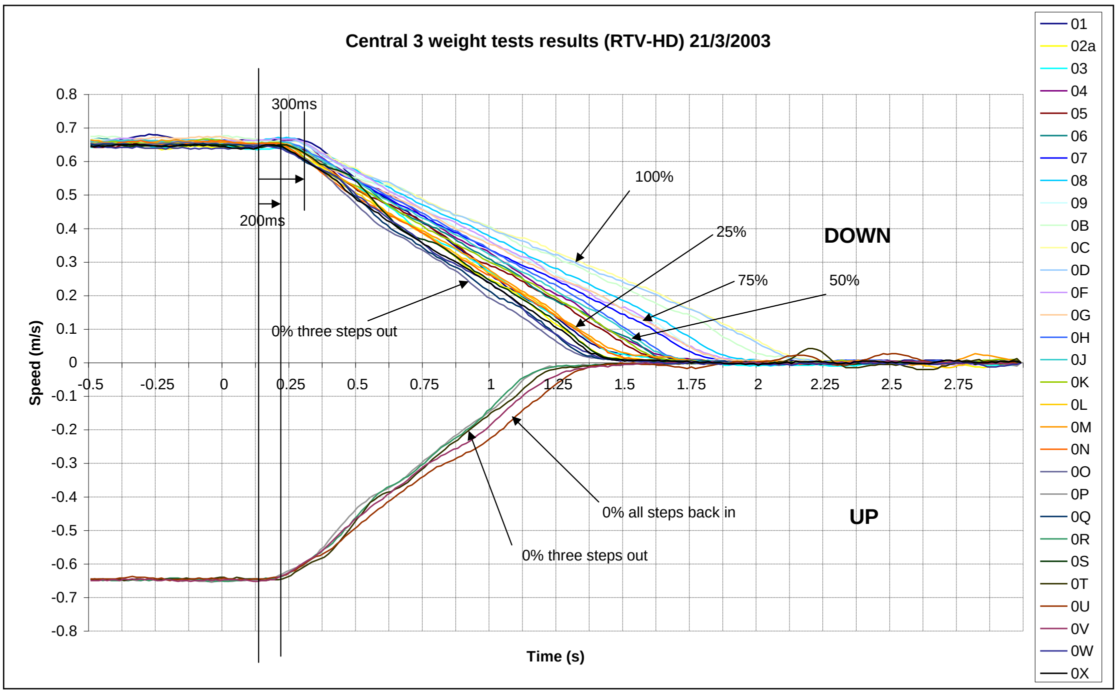

Figure 3 Weight test results for RTV-HD Type

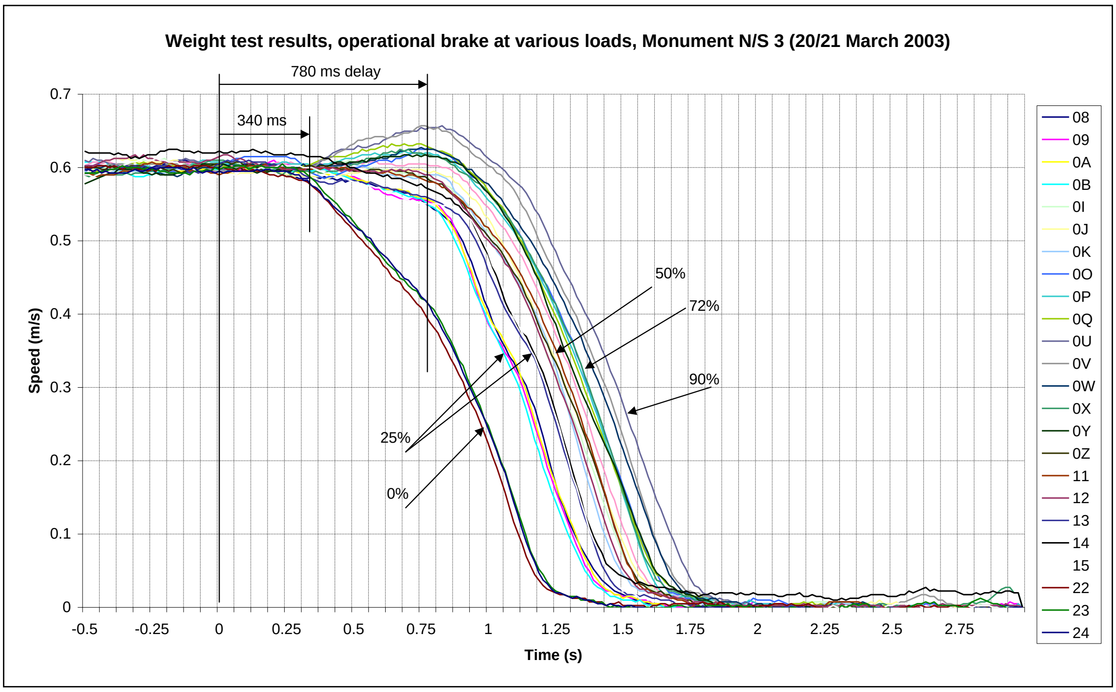

Figure 4 Weight test results for the HDMS Type

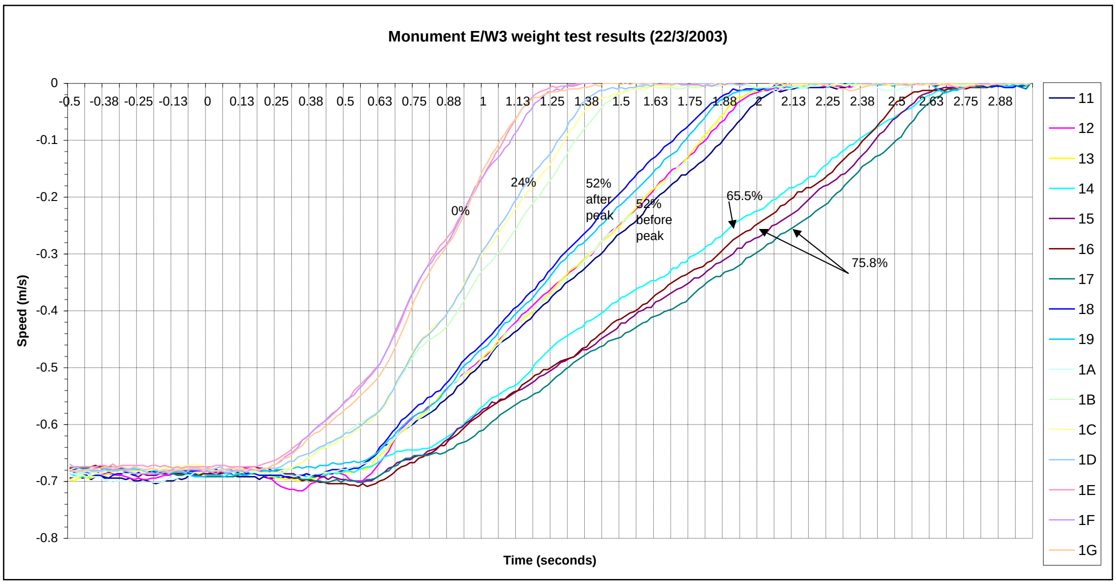

Figure 5 Weight tests results for the Compact Type

6 LIGHT SLIP TESTS AND ADJUSTMENTS

Based on the results from the weight tests, mathematical models were constructed for each of the four types of escalators. Then, light slip tests were then carried out on all other escalators. The operational brakes and the auxiliary brakes were adjusted on these escalators in order to achieve the required deceleration.

The philosophy of the light slip tests is based on isolating each brake and carrying out the tests on it separately to evaluate its efficiency. The light slip tests comprised the following tests:

1. Operational brake only: For this type of stop, the escalator is set up to stop under the influence of the operational brake. The controller must be set up such that it delays the application of the auxiliary brake long enough to ensure that the escalator has come to a full stop.
2. Auxiliary brake only: For this type of stop, the escalator is set up to stop under the influence of the auxiliary brake only. Usually, wiring is introduced into the controller to keep the operational brake lifted such that it does not contribute to the stopping braking performance. From a safety point of view, it is important to remember to remember any wiring that was introduced during the test.
3. Frictional stop: In a frictional stop, both brakes are kept lifted such that the escalator comes to rest under the influence of friction only.
4. Both brakes: Under this type of stop, both brakes are applied immediately and simultaneously (with any delay that is usually applied to the auxiliary brake bypassed).

A guidance table has been produced that can be used to adjust all the escalator during light slip tests. The guidance table is shown in Table 2 below.

Table 2 Table that shows the recommended values of deceleration under light slip tests

Three letter code	Escalator number	Rise (m)	Speed (m/s)	EN115 min. stopping distance as no load (mm)	EN115 max. stopping distance at full load down (mm)	min. no load stopping deceleration to prevent runaway (m/s^2)	min. no load stopping deceleration to comply with EN115 (m/s^2)	Ideal value of no load stopping deceleration (m/s^2)	Deceleration should not ever exceed (m/s^2)
AAA	1	7.830	0.60	267	1200	0.41	0.68	0.78	1.00
AAA	2	7.830	0.60	267	1200	0.41	0.68	0.78	1.00
AAA	3	5.950	0.75	350	1500	0.38	0.71	0.81	1.00
BBB	1	4.580	0.60	267	1200	0.34	0.61	0.71	1.00
BBB	2	4.580	0.60	267	1200	0.34	0.61	0.71	1.00
CCC	1	5.740	0.65	300	1300	0.37	0.66	0.76	1.00
CCC	2	5.740	0.65	300	1300	0.37	0.66	0.76	1.00
CCC	3	6.240	0.60	267	1200	0.38	0.65	0.75	1.00
CCC	4	6.240	0.60	267	1200	0.38	0.65	0.75	1.00
CCC	5	4.240	0.60	267	1200	0.33	0.60	0.70	1.00
CCC	6	4.240	0.60	267	1200	0.33	0.60	0.70	1.00
CCC	7	3.895	0.50	267	1000	0.32	0.54	0.64	1.00
DDD	1	17.920	0.60	267	1200	0.49	0.77	0.87	1.00
DDD	2	17.920	0.60	267	1200	0.49	0.77	0.87	1.00
EEE	1	5.070	0.60	267	1200	0.35	0.62	0.72	1.00
EEE	2	5.070	0.60	267	1200	0.35	0.62	0.72	1.00
FFF	1	6.400	0.60	267	1200	0.38	0.66	0.76	1.00
FFF	2	6.400	0.60	267	1200	0.38	0.66	0.76	1.00
GGG	1	15.644	0.60	267	1200	0.48	0.76	0.86	1.00
GGG	2	15.644	0.60	267	1200	0.48	0.76	0.86	1.00
GGG	3	15.644	0.60	267	1200	0.48	0.76	0.86	1.00
HHH	1	8.440	0.65	300	1300	0.42	0.71	0.81	1.00
HHH	2	8.440	0.65	300	1300	0.42	0.71	0.81	1.00
HHH	3	8.440	0.65	300	1300	0.42	0.71	0.81	1.00
III	1	8.148	0.65	300	1300	0.42	0.71	0.81	1.00
III	2	4.656	0.65	300	1300	0.34	0.63	0.73	1.00
III	3	3.492	0.65	300	1300	0.30	0.59	0.69	1.00
JJJ	1	4.580	0.60	267	1200	0.34	0.61	0.71	1.00
JJJ	2	4.580	0.60	267	1200	0.34	0.61	0.71	1.00
KKK	1	10.930	0.60	267	1200	0.45	0.72	0.82	1.00
KKK	2	10.930	0.60	267	1200	0.45	0.72	0.82	1.00
KKK	3	10.930	0.60	267	1200	0.45	0.72	0.82	1.00
KKK	4	10.930	0.60	267	1200	0.45	0.72	0.82	1.00

7 CONCLUSIONS

Due to the strict requirements of setting the escalator braking systems, it is necessary ensure that they are able to stop the fully loaded escalator running at rated speed within predefined distances. Traditionally, this has been done by using weights placed on the escalator steps and measuring the stopping distances.

A previous paper presented a mathematical model [12] that was developed for the Tyne & Wear Metro in order to allow testing to be carried on the escalator braking systems without the use of weights. A type test was carried out on each of the four types of escalators and mathematical models developed. Using the results from the mathematical model, recommended values for the deceleration under no load conditions were tabulated for each escalator on the network.

These recommended deceleration values have been compiled into a table that contains the maximum and minimum allowable deceleration values. The maximum limit ensure that the escalator stop is not too abrupt (and thus cause passenger falls). The minimum limit ensures that the escalator does stop within the stipulated distance (and thus comply with the requirements of the European standard EN115:2008).

A running test schedule for all escalators was then setup to ensure that every escalator has such a test carried out at least once a year (and adjusted accordingly if needed). Training was also carried out for the Metro staff on the method of measurement and adjustment.

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BIOGRAPHICAL DETAILS

Lutfi Al-Sharif is currently Professor of Building Transportation Systems at of the Department of Mechatronics Engineering, The University of Jordan. He received his Ph.D. in lift traffic analysis in 1992 from UMIST (Manchester, U.K.). He worked for 9 years for London Underground, London, United Kingdom in the area of lifts and escalators. He has over 20 papers published in peer reviewed journals the area of vertical transportation systems and is co-inventor of four patents and co-author of the 2nd edition of the Elevator Traffic Handbook. He is also a visiting professor at the University of Northampton (UK), member of the scientific committee of the annual Symposium on Lift & Escalator Technologies and a member of the editorial board of the journal Transportation Systems in Buildings.