Fact or Fiction

A Review of test methods

for Concrete Small Element Paving

by

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I N T E R P A V E - U.K.

Synopsis

The first question we must ask is :
"Why should we need to test our products"?

The simple answer is - "We need to know".

"What is it we need to know about the product"?
and having found out about the product, by testing, what does that information mean, and how can it be used? Is the information of value to us or indeed to the customer?

Introduction

When testing our products, we need to address the problem by asking ourselves - why are we testing and when we have tested the product - what do the results mean?

Historically, various tests have been used simply because they had been used before on other products, some tests, like the compressive test, are relevant to the use of the product for some aspects relating to the use of concrete.

In the U.K, a variety of tests were performed and from the results of these tests using various production units, the values were taken and a norm set. In the beginning, the researchers did this, considered and guessed at a value of 50 N/mm^2, because it sounded right. Ideas change and instead of a average result, it was felt that we should use the "in vogue" method of characteristic strength, still at this value of 50, not realising that we basically increased the strength by at least 10%. Finally, the statisticians had a go and we ended up with an average value and a minimum strength, because a sufficiently large enough number of results were required before meaningful results could be of value.

Having usefully obtained a strength value, the researchers then set about justifying these values from other properties of the product.

This method of value selection was taking place elsewhere in the world. In holland, following a severe winter, there was failure of the blocks, so some very quick strength analysis was necessary, to establish the pass/fail level. Australia, who do not experience freeze/thaw cycling, lowered the compressive strength and by doing this, ended up with an abrasion failure.

Most people understand, or so they say, a compression test, results and its implications. By changing or indeed not specifying certain parameters then the figure obtained can be

altered. In an experiment the writer found it was possible to change the final strength of a concrete block up to 30% by changing the type of packing piece from European Plywood to European Hardwood. After this evaluation it was observed that, for the proposed split test, if the width of the packing was altered then strength again could be increased.

If we are to test the concrete then surely the test should represent the real world by devising methods of evaluation that are true to life rather then historically perceived ones.

What are the requirements of performance of our blocks?

(1) Not to break under load.
(2) Not to be slippery to cause accidents.
(3) Not wear away.
(4) Resist freezing and thawing cycles.

How do we attempt, in a laboratory, to simulate the requirements listed above? In Europe we have attempted, through meetings, to come to a common test,in order to examine these properties.

Investigation into Strength Methods

In the U.K, we carried out a series of tests to produce data to enable Industry to establish suitable proposals for methods of testing within the forthcoming European Standards. The aim of the series of test was to establish the following :-

(1) Preferred test method.
(2) Pass/fail limits for proposed.
(3) Thickness factors.

In addition to the above, a test was also carried out to establish the effects upon the strength of the block using different widths of the wooden packing pieces between the block and the bearers.Further to this specific evaluation, we investigated the effects on the strength by using alternative packing pieces.

In the investigation, 120 number rectangular blocks were taken from all the members of Interpave, for each thickness 60/65, 80 and 100mm. Each unit was measured, weighed and their density obtained by calculation. The blocks were selected, based upon the mean and standard deviation of their densities, as follows.

80mm

1.0	25 number blocks
1.24	24 number blocks
1.24	12 number blocks

60 & 100mm

1.0	12 number blocks
1.24	6 number blocks
1.24	6 number blocks

Each block was uniquely referenced with the code M for middle density range, H for high density range and L for low density range and to establish the relationship, this family of blocks were further sub-divided for the different testing procedures and the summary table illustrates this.

After selection by densities, the blocks were immersed in water. For those blocks undergoing the present British Standard test, the blocks were placed in water for 24 +/- 4 hours at a temperature of 20 +/- 5°C. When the blocks were removed from the water they were wiped dry and placed in the test rig. A piece of plywood packing was placed between the upper and lower faces of the block and the machine platens.
A load was then applied to the blocks without shock and increased at a rate of 15 +/- 3 N/mm^2 until no greater load could be sustained by the block. The maximum load was recorded and the compressive strength calculated by dividing the load by the plan area of the block and incorporating a thickness and chamfer correction factor (BS 6717 : Part 1 : 1986 Table 1).

The blocks to be tested in the manner proposed in the European Standards, were immersed in water for 4 +/- 1 hours at a temperature of 20+/- 5 °C. The blocks were removed, wiped dry as previously and placed in the test machine. For this test the machine was composed of two rigid bearers, held in the same vertical plane, whose contact surface had a radius of a) 25mm, or b) 75mm. Between the upper and lower faces of the block and the bearers, two packing pieces of 15mm in width, by 4mm in thickness (subject to allowable tolerances), were placed. A load was then applied through the bearers at 0.05 N/mm^2 /second, until no greater load could be sustained by the block. The maximum load was recorded.

The results were calculated as follows:-

$$T = \frac{0.637 \times t \times p}{80 \times s}$$

Where $S = L \times t$ = area of failure.
t = thickness
p = failure load
L = failure length
T = strength in MPa

SUMMARY OF RESULTS

50mm Blocks

		X	s.d.	C of V
	BS 6717	79.5 N/mm^2	4.19	5.27
(M)	50mm	5.94 MPa	0.63	10.61
	150mm	7.26 MPa	0.74	10.19
	BS 6717	88.6 N/mm^2	0.29	0.33
(H)	50mm	7.04 MPa	0.81	11.51
	150mm	8.27 MPa	0.27	3.26
	BS 6717	73.3 N/mm^2	2.75	3.75
L)	50mm	5.68 MPa	0.60	10.56
	150mm	7.66 MPa	0.40	5.22

60mm Blocks

	BS 6717	66.2 N/mm^2	2.37	3.58
(M)	50mm	5.11 MPa	0.21	4.11
	150mm	7.07 MPa	0.57	8.07
	BS 6717	71.7 N/mm^2	2.28	3.18
(H)	50mm	5.27 MPa	0.15	2.85
	150mm	6.77 MPa	0.37	5.47
	BS 6717	62.2 N/mm^2	0.45	0.72
(L)	50mm	5.21 MPa	0.08	1.54
	150mm	5.72 MPa	0.58	10.14

80mm Blocks

	BS 6717	66.2 N/mm^2	1.92	2.90
(M)	50mm	4.55 MPa	0.20	4.40
	150mm	5.97 MPa	0.49	8.21
	BS 6717	70.1 N/mm^2	1.92	2.74
(H)	50mm	5.11 MPa	0.27	5.28
	150mm	6.20 MPa	0.23	3.71
	BS 6717	58.4 N/mm^2	1.59	2.72
(L)	50mm	4.31 MPa	0.27	6.26
	150mm	5.09 MPa	0.41	8.06

100mm Blocks

	BS 6717	59.1 N/mm^2	1.08	0.18
(M)	50mm	4.67 MPa	0.34	7.28
	150mm	5.47 MPa	0.19	3.47
	BS 6717	64.1 N/mm^2	1.39	2.17
(H)	50mm	5.58 MPa	0.29	3.76
	150mm	5.00 MPa	0.35	7.00
	BS 6717	54.6 N/mm^2	0.99	1.88
(L)	50mm	4.19 MPa	0.50	11.93
	150mm	4.98 MPa	0.25	5.02

It has now been found that the factor due to thickness is not as previously stated as t / 80 but

t	50	60	80	100
k	0.79	0.87	1.00	1.11

when using the 150mm diameter roller.

From previous experiences in testing for strength, the packing pieces influence the result and the table shows how these can effect the results.

Packing Piece	Mean Strength	S D	Characteristic Strength
Hardboard 3.3mm	4.3	0.3	3.7
Neoprene Rubber	3.8	0.5	3.0
European Birch 3.9mm	5.8	0.4	5.1
Far Eastern Soft 3.8mm	4.7	0.5	3.9

An investigation into the width of the packing pieces used in the split test was carried out. The aim was to establish what effect, if any, the width of the plywood had upon the result obtained for strength.

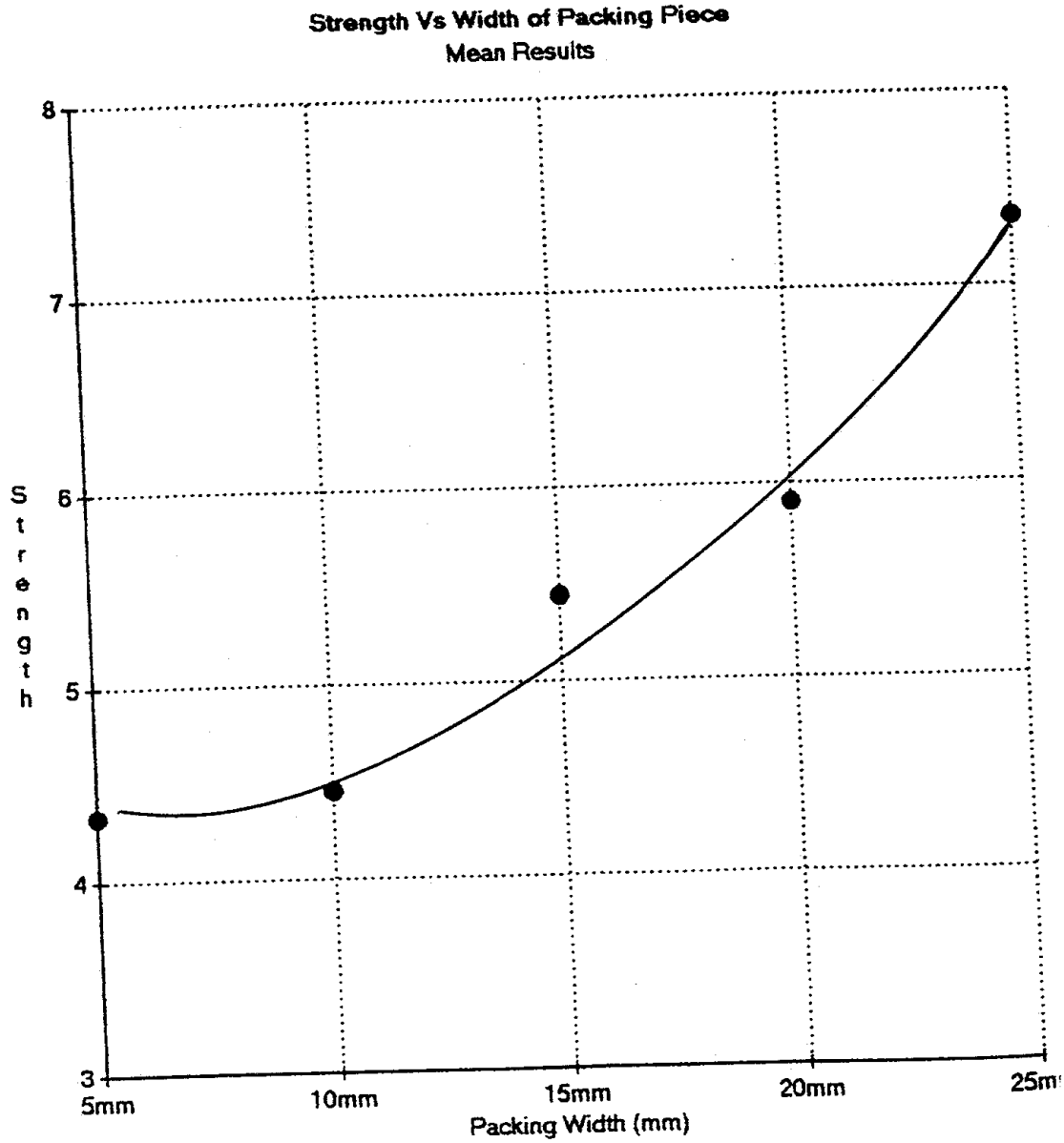
The split test was carried out using 150mm diameter bearers. The densities were not considered as before and therefore the results can only serve as a guide.

The packing pieces used were 4mm thickness European Birch in widths of 5, 10, 15, 20 and 25mm. Five blocks were tested per width of packing piece and the strengths calculated as previously mentioned.

RESULTS

	DENSITY	STRENGTH	
5mm	2356	5.340	
	2372	4.370	X = 4.336
	2362	4.900	s.d = 0.456
	2312	3.630	
	2372	4.340	
10mm	2311	4.520	
	2338	4.570	X = 4.454
	2314	4.830	s.d = 0.260
	2350	4.290	
	2327	4.060	
15mm	2327	5.230	
	2335	5.320	X = 5.442
	2321	5.760	s.d = 0.468
	2341	5.150	
	2320	5.750	
20mm	2341	5.970	
	2325	4.690	X = 5.898
	2352	7.200	s.d = 0.810
	2317	6.050	
	2338	5.580	
25mm	2315	7.210	
	2349	8.050	X = 7.350
	2350	7.000	s.d = 0.630
	2358	8.070	
	2345	6.420	

A graph plotted of these results shows a curve approaching a maximum value as the width of the packing piece becomes equal to the width of the area stressed by the bearer. These results highlight a concern in the new European Standards where the width of the packing piece can be 20mm + - 5mm. It can be seen from the mean results and the graph that the greatest increase in strength obtained is between these limits.



In trying to establish any further variation due to age that would effect the result, a small random selection of blocks were taken and the sample sorted into three. One third of the sample was split across its width, the second third along its length and the last third crushed as per normal. Each third was further sub-divided to examine the effect of age on the strength.

Age	Compression	Splitting Width	Length
7	50	4.64	5.37
14	52	4.85	5.59
28	56	5.11	5.25

Slip Skid Testing

It should be made clear that the property of slip is specifically attributed to pedestrian use and skid is specifically for traffic.

SLIP

The same pieces of apparatus is used to evaluate the slip and the skid values. The photographs shows the flat bed polisher and the pendulum tester.

As early as 1974 research began on the development of a suitable test to measure slip resistance to simulate slip in walking. The original work was to use a platform which tilted and the angle at which slipping occurred was recorded. Other work included a shoe mounted on a foot which was then lowered onto the test surface and a load applied. Horizontal forces were applied and the friction measured. It was found that the mechanism by which slip could occur was on the heel or the forepart of the shoe.

In an attempt to simulate the polishing action through the shoe sole and flag surface interface and the wearing through the impact of stiletto heels. Interpave commissioned Dr H Khalid of Liverpool University to study and provide a laboratory test method to evaluate flag performance.

Work had already been concluded for measuring skid on clay products following on investigation into the various test methods. It was decided to use the Flat Bed Accelerating Polish Test Method, which was measured by the TRL Pendulum Machine (universally accepted), after a set polishing regime. The origination of the machine was for pedestrian measurement as the length of the pendulum arm is approximately the distance between the average persons knee and the foot. It has since then, been a norm for measuring road surface performance.

It was of paramount importance that this laboratory test achieved a reasonable correlation with service behaviour as well as possessing adequate repeatability and reproducibility for it to be used with confidence.

Specification limits for polishing and slip characteristics of pedestrian surfaces have been published, taking into account pendulum readings as a recommended criteria by virtue of the extensive use by authorities world wide.

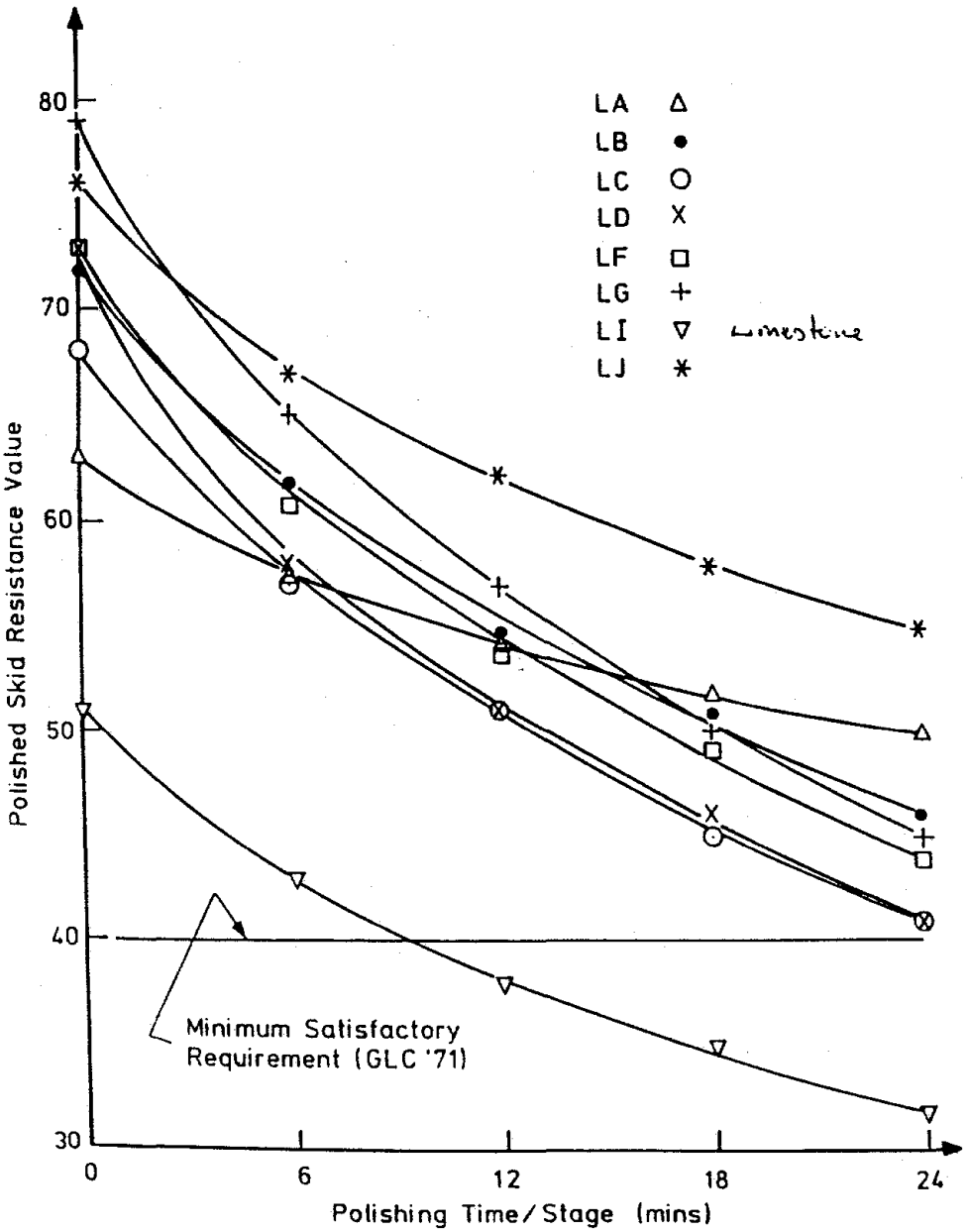
The recommendation issued by the Greater London Council for slip values of various pavement/flooring surfaces are given in the following table:-

CONDITION OF SURFACING	PENDULUM VALUE
DANGEROUS	19
MARGINAL	20 - 39
SATISFACTORY	40 - 74
EXCELLENT	75

BS 5395 Code of Practice for stairs correlated the GLC's values and produced minimum acceptable co-efficient of friction values by using a factor of 100. The DTp memo BE1/78 adopted similar values.

The polishing regime adopted entails polishing the flags with coarse emery for 24minutes, followed by a further 24 minutes with a fine emery. The pendulum test is carried out under wet surface condition and the results compared with GLC values.

In the evaluation of performance, eight different types of aggregates were used in the test. The range of aggregates included limestone, gravel, sandstone granite. It was predicted that the limestone aggregate having a low PSV value would give the lowest polished pavement value (PPV), which was proved to be correct as the diagram below indicates.

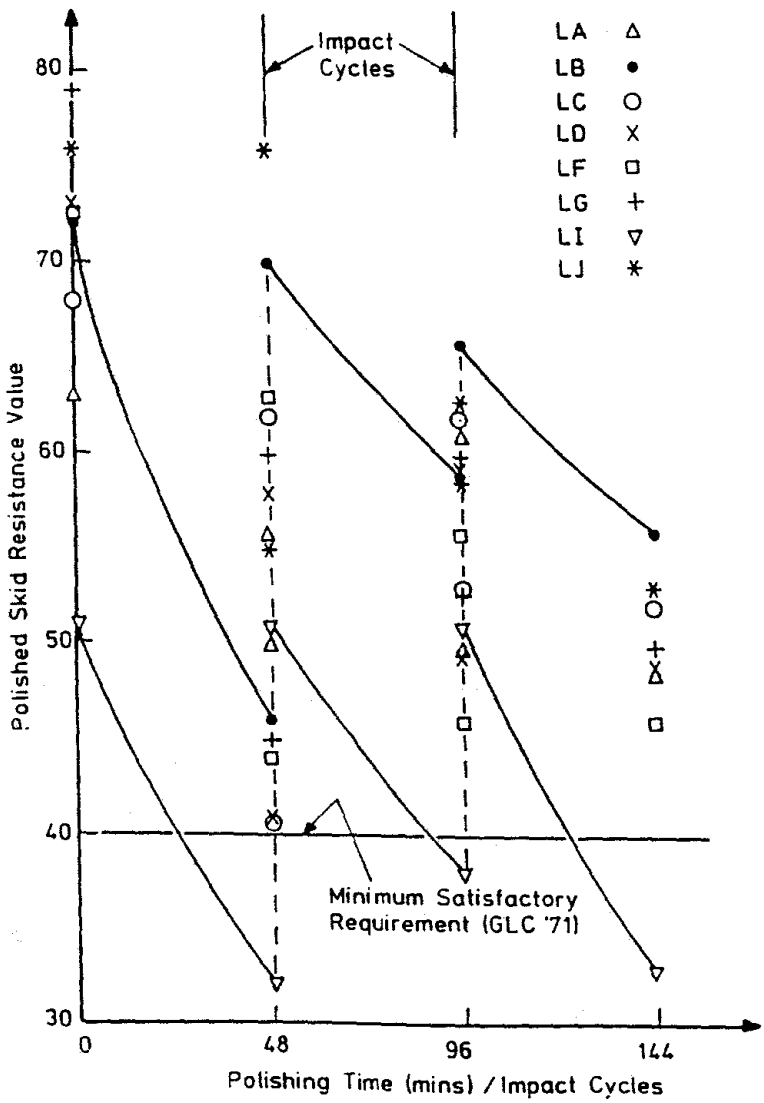


This confirmed that this test method was a suitable laboratory method of evaluating slip resistance.

Further development, following a pilot scheme, in which products were laid and were subjected to foot traffic. It was revealed that the surface underwent a combination of polishing and abrasive action. This was then reproduced by subjecting the unit to polishing and impacting. The impacting was carried out using a test method developed by the Sydney Council, Australia. This test was abrading the surface with a large number of ball bearings contained in a box.

The result of which, was that the sample regained much of its original slip resistance following the impact regime.

The figure below demonstrates the recovering from impact after the polishing phase.



It has been suggested that a pendulum value or friction resistance of 30 or 0.3 respectively, is suitable for pedestrian slip requirement but Interpave, through its precast interest and known performance of the product, would recommend a value of 40 or 0.4, depending on how it is presented. Set against its value of 40 the results are clearly satisfactory with a good margin of safety under both dry and wet conditions.

Skid Resistance

When a vehicle is moving along a road it is subjected to several major factors. These are the properties of the road surface, the vehicle itself, the driver and change in direction.

If the vehicle cannot change direction or slow down in a controlled way then skidding will occur. It is the surface texture and performance of the concrete blocks which is the subject of this article.

The measure of skid resistance in the field can be carried out with a variety of types of vehicles/equipment varying from the TRL Pendulum tester to the SCRIM test machine. What is important to remember is that the block paving is a segmental system with joints very close together and has distance advantages in wet conditions compared with the conventional road surfaces.

In the United Kingdom, the use of blocks has been restricted to roads with speed limits not greater than 40 mph, although in Europe they have been used for roads with much higher speed levels.

At this speed of 40 mph, the important factor in reducing skidding is the micro-texture. Micro texture is measured by a frictional co-efficient between stone and type, which dissipate energy through the generation of heat caused by friction.

As early as 1957, it was concluded that this micro-texture will have a dimension of about 0.25mm and this must be maintained throughout the life of the road. For Concrete Block Paving, the micro-texture will be affected by the method of manufacture and to the extent of the mixture of coarse and fine aggregate, not merely a mortar paste on the surface. To evaluate the performance of the Concrete Block Paving under laboratory conditions and to take account of the polishing of the surface a test was developed.

This test, known as the Flat Bed Polish Test, gives a Polish Pavement Value. By comparing the results of this test and a long term field trial, the typical value for Concrete Block Paving is 50.

This value is controlled indirectly by the limits of acid soluble material in the fine fraction of the aggregate as is clearly defined in BS 6717: Pt 1: 1990.

The micro-texture of the surface is affected by the weather, wet weather will wash out the detritus from the surface.

Work was carried out in 1982, under the supervision of Mr I D Walsh of Kent County Council in co-operation with Interpave and has demonstrated that for Concrete Block Paving there is a significant and rapid increase in skid resistance after a period of wet weather. Tests have been carried out regularly on the trial area and it has been observed that the skid resistance of the blocks have not measurably decreased overtime.

Whilst there is good correlation on a homogeneous surface with SCRIM, for concrete blocks it is more difficult but the use of the portable pendulum tester has proved more than satisfactory. From the values obtained the typical values of PPV are in the range of 50-55 making them suitable for categories A B C roads and/or risk rating 2 and 3 of up to 1000 commercial vehicles per day and risk rating 4 and 5 roads of up to 250 commercial vehicles per day. On roads with speeds greater than 40 mph the mirco-texture measured by texture depth becomes important.

Concrete block pavements have been successfully laid and trafficked in the public highway using Concrete Block Paving providing they comply with BS 6717 and the PPV is greater than 50.

The skid resistance of blocks is rapidly restored to it equilibrium value after rainfall and after 6 years there is no evidence that this value will decrease and that the surface characteristics will last indefinitely.

Abrasion

This is an important factor in the long term acceptance of small element paving and the longest known laboratory test, is the "Capon Tester". This was originally used on ceramic tiles, then clay and was modified to test concrete. The major differences between the two tests, are the width of the wheel, the rate of feed for the abrasive and the type of abrasive.

The diagram illustrates the test method principle. In developing the test, the original abrasive was Fontainbleau Sand, for it to be a universal test a more acceptable abrasive should be used. The table below gives a summary of the first evaluation range results using the same volume of abrasive based on the Capon Test.

FUSED ALUMINA	FONTAINBLEAU SAND	
	WIDE WHEEL	NARROW WHEEL
24 - 35mm	25 - 28.5mm	23 - 28mm

When using the proposed rate of 3 litres per minutes the value reduces to between 17 and 24.5mm.

Because, the abrasive is costly, an investigation was carried out to see the effects of using the abrasive more than the specified time at the 3 litre rate and comparing this with a 1 litre rate.

TEST NUMBER	1	2	3	4	5	6
3 Litre	18	23	20	22	12	19
1 Litre	16	16	16	16	-	

Obtaining a range of small units from members of Interpave, the proposed test was carried out and the table below gives the results.

SAMPLE REF No/TYPE			AVERAGE ABRASION (mm)
A	1	block	12.0 13.0 14.0
B	1	block	18.0; 17.3; 15.3;
	2	block	17.0; 15.0; 15.3;
	3	block	16.0; 15.0;
D		block	16.0; 18.0; 17.0;
E		block	17.0; 16.0; 16.0;
F		block	14.0; 16.0; 15.0;
G		block	14.0; 16.0; 15.0;
K	1	flag pimple	15.0; 16.0; 15.0;
	2	flag ground	19.0; 18.0; 16.0;
	3	flag gravel	15.0; 17.0;
L		flag	

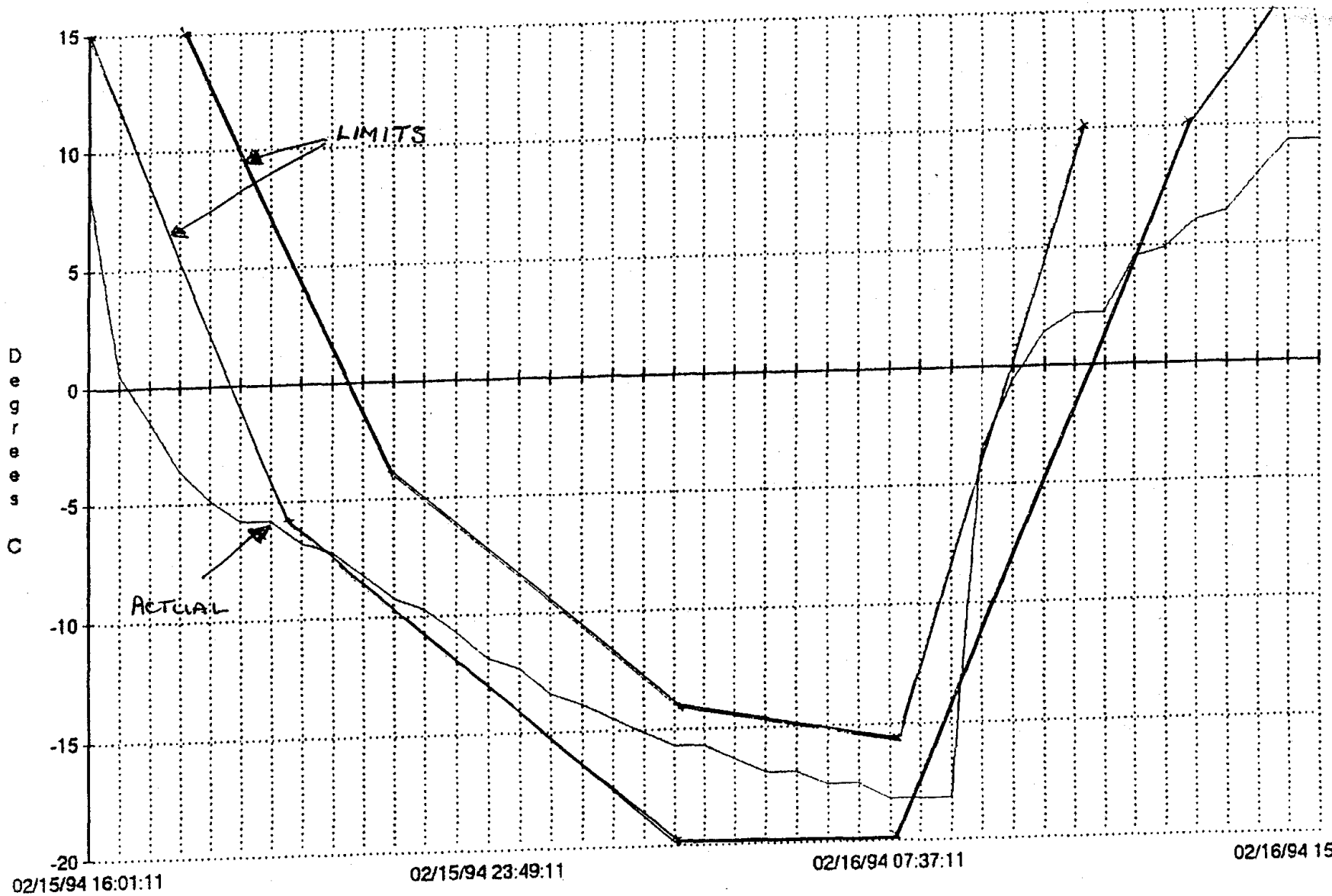
Durability

Everyone requires durability, but in essence what they mean is resistance to freeze thaw cycles with de-icing salts.

This subject has been debated long and hard, and, still after 30 years no real laboratory test has been developed to simulate the "real world". The BRITE project has now been completed and in my opinion, we are no further forward in our understanding of the mechanism of de-icing salt failure.

The original test was developed by RILEM and most test have a similar approach. For European Harmonisation, we are investigating the Scandinavian method as it seems to be one of the most documented one for Concrete Block Paving. As with all evaluations, a wide spectrum of products are used and the table below gives the results. From the graph, the equipment used did not meet the proposed rates of freezing and thawing but this was consistent throughout the test.

REF NUMBER	WEIGHT LOSS RANGE (kg/sq m)
3 (facing mix)	0.01
7	0.3 to 1.5
13	0.09 to 0.5
17	0.13 to 0.21


15
10
5
0
-5
-10
-15
-20
Degrees C
LIMITS
ACTUAL
02/15/94 16:01:11
02/15/94 23:49:11
02/16/94 07:37:11
02/16/94 15:

Conclusions

From the foregoing information it is possible that by making minor changes to a test procedure, you can alter or influence the results obtain. It is of the utmost importance, that we minimise any variation and this paper highlights the possible variation.

All the tests illustrated, form part of the European Standard Harmonisation process and hopefully we shall when each countries comments have been received, be able to have an integrated standard, with the minimum of variation.

As manufacturers and users alike, we need to know whether our product will be suitable for specific applications by judging its performance against historic data. This data is base on "in service" performance allied to laboratory testing.

To answer my original question - SHOULD WE TEST?

The response must be yes. We need to be able to judge for ourselves that the values set for the product are achieved in production. The customer, when looking at our results or indeed his own, can satisfy himself that the product will perform to his satisfaction.

The ultimate test for our product is, will it perform its function, without failure, for the requisite life span? Only time will tell.