ABRASION TEST METHODS FOR PAVING UNITS COMPARED

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ABSTRACT

European standards for paving products have been prepared by Comité Européen de Normalisation Technical Committee 178 (CEN/TC178). In the specific case of block paving, separate standards have been prepared for clay and concrete block paving units.

CEN Technical Committees were requested to ensure that a specific property should be measured by the same test method regardless of the product material. Although this ideal situation could not be realized in the first generation of European paving standards, it is a requirement of CEN for second generation standards. Against this background, Interpave, the UK trade association for precast concrete paving and the Brick Development Association (BDA) the UK clay paving association entered into a joint research project to evaluate a number of abrasion test methods with the objective of establishing a 'universal' method which would be equally suitable for both clay and concrete paving products.

3 concrete block paver types, 3 concrete flag types and 4 clay paver types were used for the programme. The abrasion tests evaluated were the wide and narrow wheel methods, the Bőhme method called up by European paving standards and additionally the Sydney Council method.

1. INTRODUCTION

The new European block paving standards issued by the Comité Européen de Normalisation(CEN) the European committee for standardization which will replace all conflicting national standards in CEN member countries, in common with other product standards, have taken many years to draft. The time taken is a reflection of both the difficulty in reaching consensus and the drafting guidance and requirements given to CEN Technical Committees.

Although prepared by the same Technical Committee (CEN/TC178) and containing similar requirements, EN 1344 for clay block pavers and EN 1338 for concrete block pavers measure properties using different test methods. During the drafting process there were calls both from CEN and nationally that the same property should be measured by the same test method for both clay and concrete block pavers. However this objective generally could not be achieved in these first generation of European standards . In the specific case of abrasion resistance not only was it not possible to agree on a single test for clay and concrete pavers it was not possible to agree on a single test for concrete pavers. In consequence the concrete block paver standard contains 2 tests for abrasion resistance one of them a reference test and the other a so called alternative test.

The clay paver abrasion resistance tests and the concrete paver abrasion resistance reference test are variations on a single concept and the calls for harmonizing these into a single method are understandable in the light of the many similarities between the 2 methods.

Whilst CEN have agreed, as an expedient, to permit 2 abrasion resistance tests for concrete block pavers in the first generation of European standards it is clear that the rules of having only one test for a property will be strictly enforced in the second generation standards which are due in 5 years time. With the anticipated stricter application of the rules within CEN and the need to try and harmonize test methods across product types, Interpave, the UK trade association for concrete paving in conjunction with the Brick Development Association (BDA), the UK trade association for clay bricks and pavers agreed to collaborate in joint research with the objective of establishing a single method which had the potential of being adopted as the universal test method for abrasion resistance. The test, to meet this objective, would need to give results which were reasonable representations of product performance and which subjectively and objectively did not favour either clay or concrete.

Delays in publishing the European standards led UK industry to drive forward changes to British Standards for both clay and concrete pavers and these revised standards were closely modelled on the then draft European standards. These were both published in 2001. Changes to these British standards meant that European Standard compliant products were available to be selected for the test programme.

3 concrete block paver types, 3 concrete flag types and 4 clay paver types selected as being representative of typical products were selected for the programme. All specimens were tested by the wide and narrow wheel method and the Bőhme method called up by European standards and additionally by the Sydney Council Test.

2. TEST METHODS

2.1 Methods evaluated

EN 1344: 2002 Clay pavers – Requirements and test methods:
Method for the determination of abrasion resistance.
(Narrow wheel method)

EN 1338: 2003 Concrete paving blocks – Requirements and test methods:
Measurement of abrasion resistance.
(Wide wheel method)

EN 1338: 2003 Concrete paving blocks – Requirements and test methods:
Measurement of abrasion according to the Bőhme test.
(Bőhme method)

AS/NZS 4456.9: Masonry units and segmental powers – Methods of test; Method 9:
Determining abrasion resistance.
(Sydney Council method)

2.2 Principles of measurement methods

2.2.1 Narrow wheel method
A steel disc of 200mm diameter and 10mm width is rotated at 75rpm for 2 minutes whilst its perimeter is held in contact with a test specimen. Carborundum (white fused aluminium oxide of grain size F80) is fed between the contact surfaces for the duration of the test.

The contact force between specimen and disc is determined as that required to produce a chord length of 24mm using a reference material (transparent fused silica) after 150 revolutions.

The result of the test is expressed as the mean volume of material removed from 2 measurements on each of 5 specimens.

2.2.2 Wide wheel method
A steel disc of 200mm diameter and 70mm width is rotated at 75rpm for 1 minute whilst its perimeter is held in contact with a test specimen. Carborundum (white fused aluminium oxide of grain size F80) is fed between the contact surfaces for the duration of the test.

The contact force between specimen and disc is determined as that necessary to produce a chord length of 20mm using a reference material (Boulonnais marble) after 75 revolutions.

The result of the test is expressed as the chord length of the groove produced in the specimen adjusted by a calibration factor.

Two tests on a specimen are advised when the largest of the 2 chords produced is taken as the result.

2.2.3 Bőhme method
A dried specimen is held in contact with a standard abrasive spread around the test track of a 750mm diameter cast iron disc. The contact force between the specimen and the disc is 294 $\pm$ 3N. The disc is rotated at 30rpm when loaded and each of the required 16 cycles, during which the specimen is progressively rotated through 90^{o}, consists of 22 revolutions.

2.2.4 Sydney Council method
A square section tumbler box containing steel balls and with test specimens clamped into openings in the opposite faces is rotated at 60rpm for 60 minutes. The long inside edges of the tumbler have fillets to assist the flow of the steel balls during the test.

The abrasion index is calculated by dividing the mass loss of each specimen by its bulk density.

3. PRODUCTS EVALUATED

3.1 Concrete pavers

Ref	*Description*
CBP 1	Gravel aggregate
CBP 3	Granite aggregate
CBP 4	Limestone aggregate

3.2 Concrete flags

Ref	*Description*
F1	Sandstone aggregate
F2	Granite aggregate
F3	Gravel aggregate

3.3 Clay pavers

Ref	*Description*
CL 1	Dense red
CL 2	Blue – Engineering type
CL 3	Medium buff
CL 4	Soft terracotta

4. TEST RESULTS

4.1 Narrow wheel method

There are many similarities between this method and the wide wheel method (egs wheel diameter, speed of rotation, abrasive medium). One of the significant differences between the 2 methods is the required duration of the test. The narrow wheel requires this to be 2 minutes rather than the one minute required for the wide wheel method. To provide a more comprehensive evaluation of the method for the programme and comparison with the wide wheel method additional measurements at 1 minute were carried out for each specimen type.

Table 1. Narrow wheel method results, Contact time 1 minute.

Sample Reference	Chord length (mm)			Material removedV (m^3)
	Groove A	Groove B	Mean (rounded) value	
CB1 4	29.21	29.59	29.5	215
CB1 5	30.01	29.54		
CB1 6	29.60	30.02		
CB3 4	29.97	32.32	31.5	262
CB3 5	30.51	32.64		
CB3 6	32.73	31.58		
CB4 4	41.38	40.81	41.5	603
CB4 5	40.37	41.57		
CB4 6	42.93	40.47		
F1 4	38.65	35.91	37.0	427
F1 5	35.33	36.23		
F1 6	36.37	38.85		
F2 4	38.40	36.67	36.5	409
F2 5	33.04	37.10		
F2 6	35.84	36.50		
F3 4	34.52	33.07	33.0	302
F3 5	34.35	33.13		
F3 6	30.43	33.89		
CL1 4	28.51	28.26	29.0	205
CL1 5	32.58	27.35		
CL1 6	28.12	27.70		
CL2 4	25.93	25.68	26.0	147
CL2 5	25.11	25.99		
CL2 6	25.12	27.01		
CL3 4	26.24	28.27	28.0	184
CL3 5	30.24	23.53		
CL3 6	30.41	30.43		
CL4 4	27.34	40.92	39.0	500
CL4 5	37.07	43.58		
CL4 6	46.76	41.69		

Table 2. Narrow wheel method results Contact time of 2 minutes as specified in EN 1344.

Sample Reference	Chord length (mm)			Material removedV (m^3)
	Groove A	Groove B	Mean (rounded) value	
CB1-1	28.94	28.11	29.5	215
CB1-2	26.86	30.96		
CB1-3	30.94	30.85		
CB3-1	30.55	28.74	31.0	250
CB3-2	30.53	33.38		
CB3-3	31.23	32.80		
CB4-1	36.07	33.04	35.5	376
CB4-2	34.79	34.81		
CB4-3	35.93	38.90		
F1-1	34.54	33.83	35.5	376
F1-2	33.80	34.37		
F1-3	36.42	39.29		
F2-1	38.37	37.53	37.5	444
F2-2	37.41	36.98		
F2-3	37.81	36.73		
F3-1	36.09	35.28	35.5	376
F3-2	36.03	35.08		
F3-3	34.27	35.14		
CL1-1	33.30	30.00	33.5	316
CL1-2	34.65	35.02		
CL1-3	34.99	32.45		
CL2-1	29.07	29.95	29.5	215
CL2-2	28.13	31.66		
CL2-3	31.61	27.56		
CL3-1	32.54	28.63	31.0	250
CL3-2	31.15	29.79		
CL3-3	32.92	30.15		
CL4-1	27.87	39.66	39.5	520
CL4-2	38.77	43.43		
CL4-3	44.13	43.20		

4.2 Wide wheel method

The specified duration for the test in EN 1338 is 1 minute but to enable better comparison with the narrow wheel method the test was also carried out for 2 minutes on each specimen type. This is the test time required by EN 1344 (Narrow wheel method).

Table 3. Wide wheel method results.

Sample reference	TEST ONE – 1 MINUTE Corrected chord length (mm)	TEST TWO – 2 MINUTES Corrected chord length (mm)
CB1-1	16.3	16.3
CB1-2	15.3	16.7
CB1-3	16	18
MEAN	*15.9*	*17*
CB3-1	16.3	19.3
CB3-2	16.7	17.7
CB3-3	15.7	17.7
MEAN	*16.2*	*18.2*
CB4-1	21.3	25.7
CB4-2	22	28.3
CB4-3	22.7	27.3
MEAN	*22*	*27.1*
F1-1	20.3	24.3
F1-2	20.7	23.7
F1-3	19	24.3
MEAN	*20*	*24.1*
F2-1	17	20.3
F2-2	19.3	23
F2-3	18.3	23.3
MEAN	*18.2*	*22.2*
F3-1	17.7	22.3
F3-2	20.3	22.3
F3-3	18.3	22.3
MEAN	*18.8*	*22.3*
CL1-1	19.3	22.3
CL1-2	18.3	21.3
CL1-3	18.3	22.3
MEAN	*18.6*	*22*
CL2-1	17.7	19
CL2-2	16.6	20.7
CL2-3	19	19.7
MEAN	*17.8*	*19.8*
CL3-1	20.3	21.3
CL3-2	20.3	25
CL3-3	19.7	23.7
MEAN	*20.1*	*23.3*
CL4-1	27	27.7
CL4-2	30.3	36
CL4-3	30.3	36
MEAN	*29.2*	*33.2*

4.3 Bőhme method

This test was carried out as specified in EN 1338. It was noted that no means for keeping the abrasive evenly distributed as directed was specified and the laboratory felt that this could mean that the method was operator sensitive.

Table 4. Bőhme method results.

SAMPLE REFERENCE	Abrasive wear (1000mm^3/5000mm^2)			
	Sample 1	Sample 2	Sample 3	Mean
CB1	5000	6000	5000	5000
CB3	9000	7000	8000	8000
CB4	25000	24000	20000	23000
F1	13000	14000	14000	14000
F2	13000	13000	12000	13000
F3	10000	10000	10000	10000
CL1	8000	10000	8000	9000
CL2	9000	7000	7000	8000
CL3	12000	13000	14000	13000
CL4	22000	23000	25000	23000

4.4 Sydney Council method

The number of specimens available meant that there were insufficient to fill all 4 sides of the tumbler with similar products. Consequently 2 opposite sides of the tumbler were blanked off with steel plates so only the remaining 2 sides were loaded with specimens. The laboratory also had difficulty sourcing 600 ⅝" diameter steel balls and 1000 ½" diameter steel balls were substituted. From earlier work it had been found that this number and size of steel ball resulted in the optimum abrasion.

It was noted by the laboratory that the specimens at the end of the tumbler were only abraded over part of their area. Therefore it was decided to divide the abrasion index by the exposed area of each specimen to take account of the partial abrasion of some of the specimens.

Table 5. Sydney Council method results.

Sample Ref.	Property	Sample						Mean
		A	B	C	D	E	F	
CB1	Abrasion Index	21.36	25.13	21.73	34.3	25.85	27.33	26.0
	Area (cm^2)	138.6	174.6	174.6	174.6	176.4	140.4	
	Abrasion index. Area	2960	4388	3794	5989	4560	3837	4263
CB3	Abrasion Index	24.64	31.07	29.45	23.63	25.65	15.76	25.0
	Area (cm^2)	144.0	174.6	174.6	174.6	174.6	136.8	
	Abrasion index. Area	3548	5425	5142	4126	4478	2156	4146
CB4	Abrasion Index	38.56	36.81	47.75	37.06	47.59	33.25	40.2
	Area (cm^2)	151.2	183.6	185.4	187.2	183.6	106.2	
	Abrasion index. Area	5830	6758	8853	6938	8738	3531	6775
F1	Abrasion Index	5.97	4.82	3.16	5.02	5.62	4.03	4.9
	Area (cm^2)	138.6	180.0	180.0	181.8	178.2	140.2	
	Abrasion index. Area	827	868	569	910	1001	565	790
F2	Abrasion Index	11.54	10.51	13.08	10.01	18.74	12.86	12.8
	Area (cm^2)	131.4	180.0	185.4	185.4	187.2	131.4	
	Abrasion index. Area	1516	1892	2425	1856	3508	1690	2148

Table 5. continued

F3	Abrasion Index	8.05	11.65	15.07	11.16	9.72	9.39	10.8
	Area (cm^2)	135.0	180.0	180.0	180.0	185.4	129.6	
	Abrasion index. Area	1087	2097	2713	2009	1802	1217	1821
CL1	Abrasion Index	15.77	15.88	16.71	16.15	16.05	16.42	16.2
	Area (cm^2)	142.2	171.0	171.0	171.0	172.8	138.6	
	Abrasion index. Area	2242	2715	2857	2762	2773	2276	2604
CL2	Abrasion Index	10.49	9.78	11.74	10.09	9.37	11.31	10.5
	Area (cm^2)	138.6	178.2	178.2	178.2	172.8	138.6	
	Abrasion index. Area	1454	1743	2092	1798	1619	1568	1712
CL3	Abrasion Index	5.42	7.05	4.93	4.90	4.15	5.57	5.3
	Area (cm^2)	144.0	171.0	171.0	169.2	167.4	142.2	
	Abrasion index. Area	780	1206	843	829	695	792	858
CL4	Abrasion Index	30.32	33.32	29.95	29.11	58.03	33.78	35.8
	Area (cm^2)	144.0	172.8	171.0	172.8	171.0	144.0	
	Abrasion index. Area	4366	5758	5121	5030	9923	4864	5843

4.5 Values plotted

To enable graphical comparison of the values measured by the test methods under consideration, the following multiplication factors were applied to the measured values:

Narrow wheel method x 10^{-1}
Bőhme method x 10^{-3}

The resulting values in table 6 were plotted.

Table 6. Values plotted.

	CB1	CB3	CB4	F1	F2	F3	CL1	CL2	CL3	CL4
Narrow wheel - 1min	21.5	26.2	60.3	42.7	40.9	30.2	20.5	14.7	18.4	50
Narrow wheel - 2min	21.5	25	37.6	37.6	44.4	37.6	31.6	21.5	25	52
Wide wheel - 1min	15.9	16.2	22	19	18.2	18.8	18.6	17.8	20.1	29.2
Wide wheel - 2min	17	18.2	27.1	24.1	22.2	22.3	22	19.8	23.3	33.2
Böhme	5	8	23	14	13	10	9	8	13	23
Sydney Council	26	25	40.2	4.9	12.8	10.8	16.2	10.5	5.3	35.8

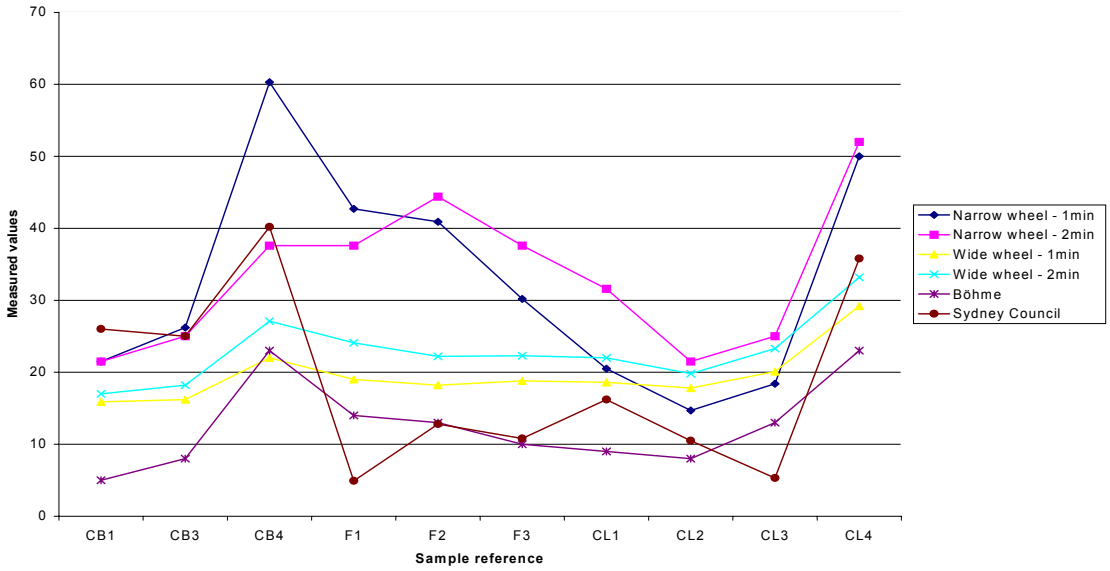

Figure 1. Comparison of Results.

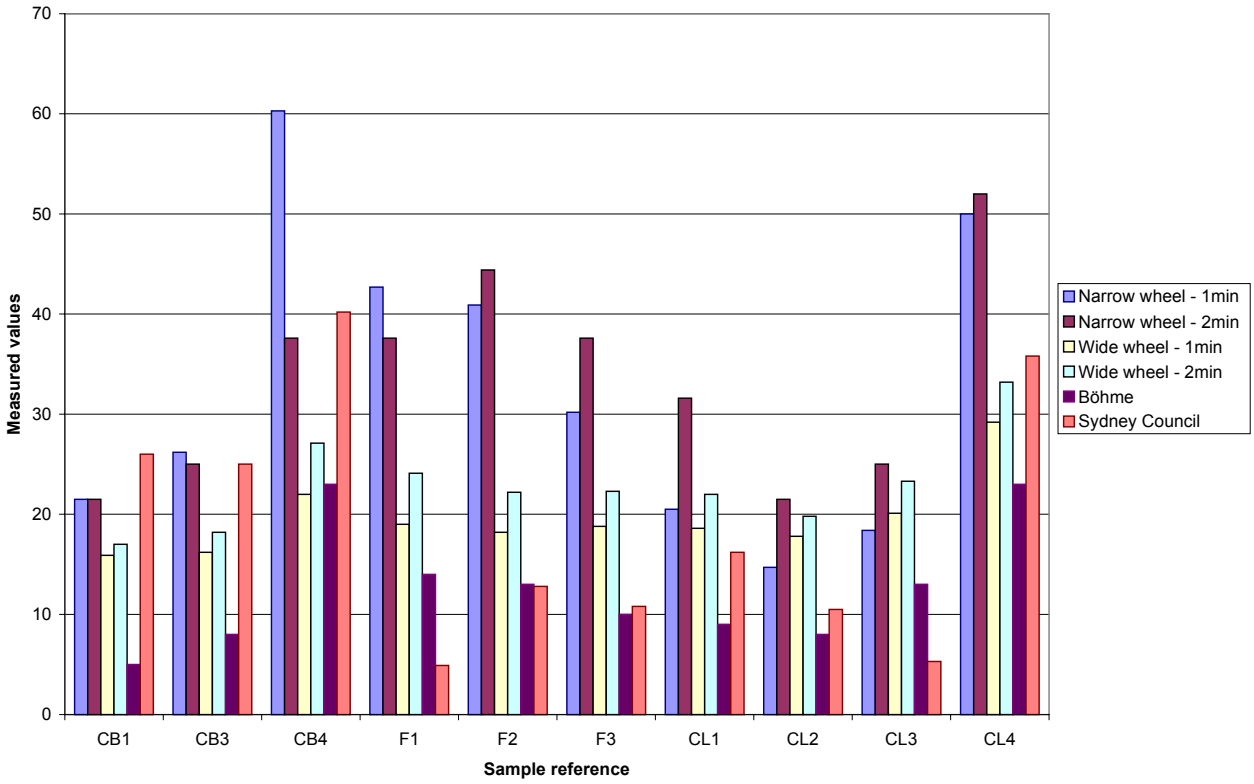

Figure 2. Comparison of Results.

5. COMMENTARY

5.1 Comparison of results

Plots of the results given in table 6 are shown in the line graph in figure 1. The results are repeated in the bar chart in Figure 2.

5.2 Narrow wheel method

CB4 and F1 results for 2 minutes seemed not to follow the trend of the 1 minute results or the trends of the other tests. On the basis of these anomalies it would seem that a test duration of 1 minute was preferable to the 2 minutes specified in EN 1344. The 1 minute test did detect the 2 distinctly 'softer' materials CB4 and CL4 although it emphasized the differences.

5.3 Wide wheel method

The two sets of results clearly followed the same trend and with all the 2 minute results being higher than the 1 minute results. Therefore it would not matter whether 1 minute or 2 minutes duration was the standard time used.

An argument for the 1 minute duration as specified in EN 1338 would be less wear on the wheel and therefore it would have a longer service life if the specified 1 minute is used.

5.4 Bőhme method

The results followed the general trend and identified the 2 'softest' materials. The method emphasizes the differences between materials more than the wide wheel but less than the narrow wheel. The fears of the laboratory that the test could be operator sensitive appear not to have been realized during this series of measurements.

5.5 Sydney Council method

Although the results followed the general trend there were a few materials which gave unexpected measurements (F1, CL1 and CL3). It is not clear whether these were as a result of the modifications to the method, to operator inexperience or because the principle of the method is different to the other 3 methods evaluated.

As with the narrow wheel it emphasized the 'harder' and 'softer' materials.

6. CONCLUSIONS

6.1 Ranking of results

To a greater or lesser extent, all the methods assessed ranked the abrasion resistance of the specimens tested as anticipated.

The narrow wheel and Sydney Council methods both gave results which showed the differences between the harder and softer materials in significantly greater relief than the other methods assessed. Whilst this is acceptable technically it is generally unhelpful commercially if manufacturers have to declare seemingly excessive differences in performance across a product range unless this spread of results is a true reflection of the relative abrasion resistances.

The wide wheel results for 1 minute and 2 minutes were very consistent and the Bőhme method results followed the same trend but showed the harder and softer materials in greater relief, but far less so than either the wide wheel or Sydney Council methods.

The highest and lowest values obtained by both the wide wheel and Bőhme methods represented reasonable comparisons of abrasion resistance yet did not over emphasize the extremities.

6.2 Apparatus comparisons

The Sydney Council method requires a relatively large number of specimens to carry out one test and equipment (steel balls) of a specification which proved difficult to obtain in the size specified in the standard.

The narrow wheel and wide wheel methods both specified materials which were relatively easy to obtain. The abrasive specified by the Bőhme method was not described generically but rather as being available from a single specific source. There were concerns about the rate of wear of the cast iron disc used for the Bőhme method and the cost of replacing this when worn.

6.3 Universal abrasion method

Both the wide wheel and Bőhme methods have the potential of becoming the universal a method suitable for both concrete and clay paving products. Neither method gave unduly wide differences in abrasion resistance for the materials tested. Both gave values which reflected the relative abrasion resistance of the specimens tested.

The simplicity of the apparatus and cost and availability of consumable materials favour the wide wheel method with a test duration of 1 minute as the universal method.

ABRASION TEST METHODS FOR PAVING UNITS COMPARED

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Biography

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Gerry Pettit is Standards Manager for Tarmac Topblock Ltd (manufacturers of concrete masonry units) and Tarmac TopPave Ltd (manufacturers of concrete paving units). He has held advisory and research positions in the building materials industry for over 25years and chairs the technical committees of the UK Concrete Block Association (for concrete masonry units) and Interpave (for concrete paving units). He also chairs the Masonry Industry Alliance Regulatory Issues Task Group.

He directs the preparation of industry comments on standards, codes, Building Regulations and other legislative issues. He also leads research programmes on construction product performance.

He is an active member of BSI, CEN and ISO committees dealing with construction products and building physics.