PAVE 92

ASSESSMENT OF ASTM C944-80 FOR MEASURING THE ABRASION RESISTANCE OF PAVING BLOCKS

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SUMMARY

The poor abrasion resistance of concrete block paving in New Zealand is of particular concern to the local masonry industry. A suitable test method has yet to be established to give a reliable estimation of in-service abrasion performance. Test results from one abrasion test, ASTM C944-80, are presented in this paper. The source of variation of the results and the significance of correlation with parameters such as compressive strength, tensile strength and density is discussed.

Introduction

A problem of particular significance to the concrete masonry industry in New Zealand is the indifferent performance of interlocking concrete block paving in areas subjected to abrasion. There are two environments where this has occurred. Firstly, pedestrian areas where the pedestrian count is high and dominated by high heels, and secondly, industrial areas subjected to heavily loaded turning vehicles.

Measurement of the abrasion resistance of interlocking concrete block paving can be undertaken using a variety of methods. In practice, however, only a few of the countries actively using concrete paving actually specify an abrasion test in their national standards document (1). In many countries there is little or no abrasion resistance problem, and it is thought that the high compressive strength requirements specified to improve freeze-thaw durability has promoted abrasion resistance. The recently revised New Zealand Standard NZS 3116 : 1991 (2) has taken a similar stance and requires a characteristic compressive strength some 15 MPa higher than normal for paving areas subjected to high volumes of pedestrian traffic. However, inferred abrasion performance from strength measurements cannot address options such as topping mixes and surface treatment, so there is still a need to have an accepted test method to demonstrate in-service abrasion performance.

The major thrust towards a suitable abrasion test method for concrete block paving over the last seven years has been assessment of the Australian Concrete Masonry Association MA20 test (3) by the Cement and Concrete Association of New Zealand. This work has highlighted problems with this method in terms of reproducibility and repeatability. Another applicable test method, ASTM C944-80 (4), has been used over a number of years by WORKS Central Laboratories to measure the influence of mix design changes on the abrasion resistance of concrete.

This paper outlines the findings from the first stage of a research programme investigating these two test methods. Only results from the ASTM abrasion test are presented here - it is hoped results from both tests will be available for presentation at the 1992 conference.

Testing

Samples of interlocking concrete blocks were obtained from 11 block plants throughout New Zealand. Ten plants supplied blocks produced for domestic paving applications; one plant supplied blocks produced to meet the abrasion resistance requirements of a municipal application.

The blocks were 60 mm thick, either rectangular or profiled in shape (serrated edge) with length to breadth ratios of approximately 2:1. One sample of red blocks was received, but all other blocks were either grey or black in colour. The blocks were tested using the following methods:

(1) Abrasion resistance according to ASTM C944-80 on a set of 10 blocks from each plant. A new set of cutter wheels were used for each set of 10 blocks, and their positions on the spindle were changed systematically. Each block was abraded for five 2-minute intervals, and at the end of each interval loose material was removed with compressed air and the block weighed. Weight loss (grams/minute) was calculated over the complete 10 minute test interval.

(2) Compressive strength using the test method described in Appendix B of NZS 3116 : 1991.

(3) Tensile splitting strength using the test method described in Appendix C of NZS 3116 : 1991. This method is only suitable for rectangular blocks.

(4) Flexural tensile strength using the test method described in Appendix D of NZS 3116 : 1991. This method is only suitable for rectangular blocks.

(5) Saturated density according to the method outlined in NZS 3112 : Part 3 : 1986.

All blocks were more than 28 days old when tested.

Results

The test results are presented in Table 1.

The characteristic compressive strength results range from 19.0 MPa to 68.5 MPa, and four samples failed to meet the 40 MPa requirement of NZS 3116 : 1991. The blocks with the lowest compressive strength

TABLE 1: TEST RESULTS

Sample	Date of Manufacture	Abrasion Loss (g/min)	Abrasion Loss/ Coefficient of Variation (%)	Characteristic[1] Compressive Strength (MPa)	Characteristic[1] Tensile Splitting Strength (MPa)	Characteristic[1] Flexural Tensile Strength (MPa)	Saturated Density (kg/m^3)
4-91/34	31/10/89 or 8/5/90	0.50	22.2	48.5	-	-	2240
4-91/35	19/10/90	0.56	33.2	50.5	3.9	6.1	2330
4-91/36	14/3/91	0.52	38.8	46.5	2.7	5.7	2310
4-91/37	20/2/91	0.26	24.0	68.5	5.1	7.0	2360
4-91/40	22/2/91	1.15	38.4	44.5	2.6	4.9	2230
4-91/46	Oct 1990	1.57	18.0	29.5	-	-	2140
4-91/47	Jan 1991	0.69	14.7	52.0	-	-	2240
4-91/50	4/4/91	1.07	29.8	35.0	2.0	4.2	2240
4-91/52	1988	0.76	33.2	53.5	-	-	2220
4-91/56	10/12/90	1.21	58.5	19.0	1.8	3.3	2220
4-91/57	23/10/90	0.71	17.4	35.5	3.6	5.1	2250

(1) "Characteristic" strengths (NZS 3116 : 1991) include a correction for the range of individual results, hence these results are lower than the average strength.

(4-91/56) show highly variable individual results for saturated density and compressive strength, which suggests compaction of these blocks was inconsistent. Significant voids present in the surface of these blocks support this theory. The blocks produced for municipal paving (4-91/37) show the highest compressive strength and saturated density, and are the only blocks which meet the standard's 55 MPa requirement for abrasion resistance.

Tensile strength requirements have been included in NZS 3116 : 1991 as an option to specifiers as this property more truly represents the block failure mode in service, particularly for heavy duty uses. Characteristic tensile splitting strength of 4.5 MPa and characteristic flexural tensile strength of 6.0 MPa are specified. Only the municipal pavers (4-91/37) meet both the tensile strength requirements - sample 4-91/35 exceeds the requirements for flexural tensile strength.

The ASTM abrasion loss results vary between 0.26 g/min for the municipal pavers and 1.57 g/min (4-91/46). The coefficient of variation averages 29.8% and ranges between 14.7% and 58.5%. This variation is not solely a feature of the test method and is clearly influenced by variability in the paving blocks. The block sample showing the highest coefficient of variation (4-91/56) shows correspondingly high variability of all other parameters measured. The ASTM quotes a single operator coefficient of variation of 21% for this test method under normal test conditions and 12.6% under severe test conditions. Recent abrasion results from a range of concretes made in the laboratory show an average coefficient of variation of 14.4% for five samples. In this particular testing the test method should have a coefficient of variation of less than 20% for a 10 sample test, and any addition variation can be attributed to material variability in the paving blocks.

The ability of this test method to quantify the in-service abrasion performance of paving blocks has not been established, although the low abrasion loss recorded by a specifically designed municipal paver suggests a useful correlation exists. However, some comment can be made on its ability to replicate the abrasion induced by pedestrian traffic. The main cause of paving block abrasion in pedestrian areas is thought to be high heels which apply very high point loads along with some shear. The dressing wheels used in this test method apply a point load over a 1 mm x 0.5 mm (approximately) metal tip which then rotates off the surface. This mechanism appears to apply a similar, although scaled down, stress to the surface of the block as a high heel and superficially seems more applicable than the tests incorporating rotating ball bearings.

An abrasion test with proven correlation to in-service abrasion performance is the best method of quantifying abrasion resistance. It is also one of the only applicable methods for use where topping mixes or surface hardening treatments have been used to enhance abrasion performance. However, the New Zealand paving industry would prefer a quick and simple quality control test to indicate likely abrasion resistance. A level of compressive strength has been incorporated into NZS 3116 : 1991 above which "reasonable confidence" can be expected in a block's ability to resist abrasion. The correlation between abrasion resistance and other simply measured parameters such as density and tensile strength is also worthy of consideration. ASTM abrasion loss is plotted against characteristic compressive strength, characteristic tensile splitting strength, characteristic flexural tensile strength, and saturated density in Figures 1, 2, 3 and 4 respectively.

A linear regression line is plotted on each graph and the closeness of fit to this straight line is indicated by the correlation coefficient (r). The negative sign of the correlation coefficients indicate the abrasion loss results decrease as the other parameters increase. The magnitude of the r values confirm a linear correlation exists between abrasion and all the other parameters. The best-fit correlation is shown by the flexural tensile strength ($r = -0.923$) followed by the tensile splitting strength

FIGURE 1: CHARACTERISTIC COMPRESSIVE STRENGTH v. ASTM ABRASION LOSS

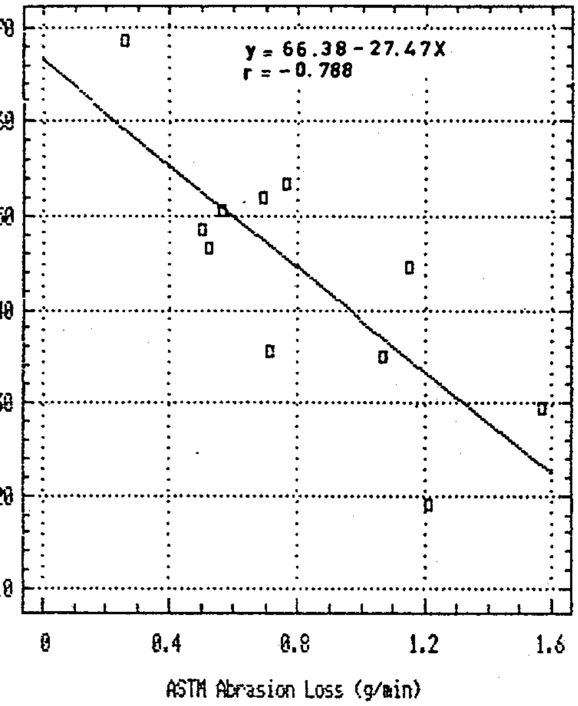


FIGURE 2: CHARACTERISTIC TENSILE SPLITTING STRENGTH v. ASTM ABRASION LOSS

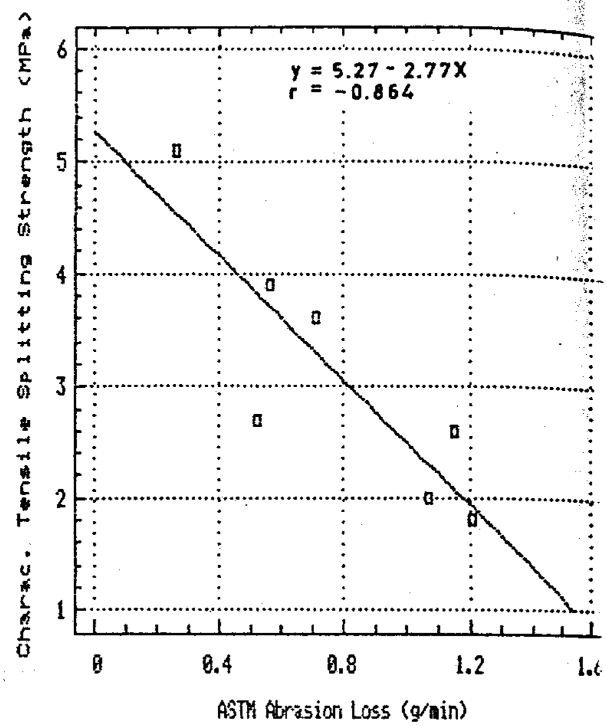


FIGURE 3: CHARACTERISTIC FLEXURAL TENSILE STRENGTH v. ASTM ABRASION LOSS

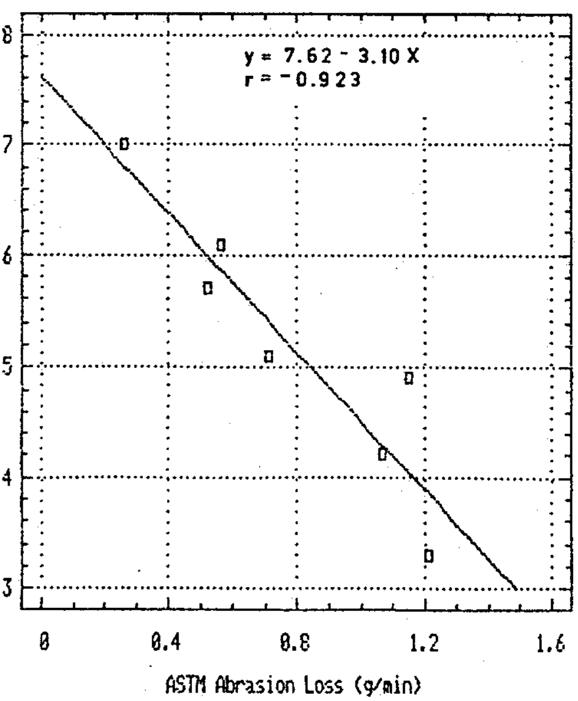
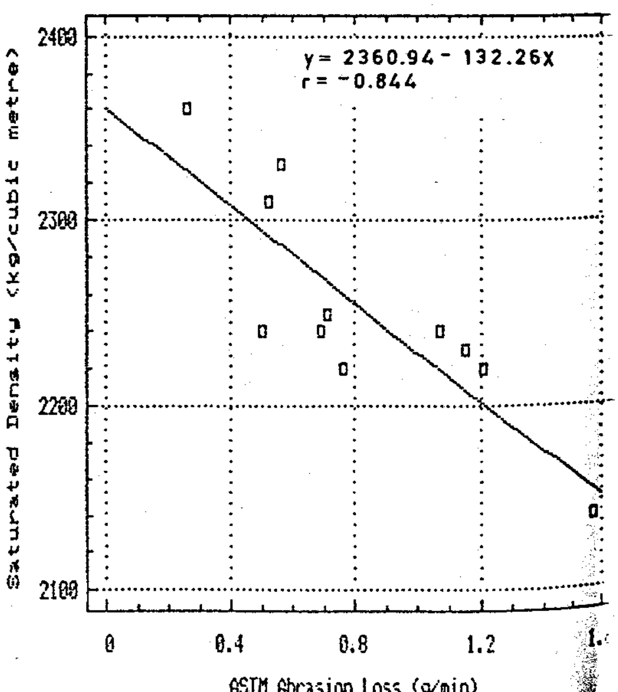


FIGURE 4: SATURATED DENSITY v. ASTM ABRASION LOSS



(r = -0.864), saturated density (r = -0.844) and compressive strength (r = -0.788). So, the best parameter of the four tested with which to estimate abrasion resistance as measured by ASTM 944-80 is flexural tensile strength, and the worst is compressive strength. Tensile strength may be a better parameter with which to estimate in-service abrasion performance, although further testing is required to confirm this.

Conclusions

(1) The characteristic compressive strength of the block samples tested ranges between 19.0 MPa and 68.5 MPa. Paving blocks from four plants fail to meet the 40 MPa requirement of NZS 3116 : 1991.

(2) The coefficient of variation of abrasion loss measured according to ASTM 944-80 ranges between 14.7% and 58.5%, and much of this variability can be attributed to the paving blocks themselves. The best abrasion performance was recorded by blocks specifically designed for abrasion resistance which suggests this test method may be useful in predicting in-service abrasion resistance.

(3) Tensile strength, particularly flexural tensile strength, shows a better linear correlation with abrasion loss than compressive strength, and may be a better simple test with which to estimate abrasion performance of paving blocks.

References

(1) Houben, L.J.M., van der Kreeft, S.G., Lewis, M. (1984): "Specifications and Standards for Concrete Paving Blocks, A Worldwide Survey Based on an Inquiry by the Programme Committee CBP", Second International Conference on Concrete Block Paving, Delft, 10-12 April 1984.

(2) Standards Association of New Zealand (1991): "Interlocking Concrete Block Paving", NZS 3116.

(3) Concrete Masonry Association of Australia (1986): "Specification for Concrete Segmental Paving Units", Test Method MA20.

(4) American Society of Testing and Materials (1980): "Standard Test Method for Abrasion Resistance of Concrete or Mortar Surfaces by the Rotating-Cutter Method", ASTM C944-80 (reapproved 1985).

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