REVIEW OF RESEARCH RELATING TO SETTING STANDARDS FOR CONCRETE PAVING BLOCK IN SOUTH AFRICA

Lane, J.W.[1] and Doulgeris, N.P.[2]

[1]Former Director, Concrete Manufacturers Association
[2]Portland Cement Institute

ABSTRACT

The need to ensure that a fast developing market for the manufacture of concrete paving blocks would remain viable over a long period resulted in manufacturers investigating appropriate standards for the manufacture and use of cpb. Extensive research over a 2 year period, 1979-1980, using a heavy vehicle simulator to test over 50 full-scale pavements resulted in an in-depth appreciation of the significance of compressive strength, thickness, shape and chamfers of cpb. At the same time properties of bedding and jointing sands, thickness of the bedding sand layer and joint widths were investigated.

Industry standards were set covering quality of cpb and their use. These standards (compressive strength mainly) are reviewed in terms of service performance in a number of projects. Abrasion resistance of cpb is discussed.

In a developing African country it is important to set and implement realistic standards to ensure "value for money" based on life costing and to make best use of limited financial resources.

1. INTRODUCTION AND DEVELOPMENT

1.1 Introduction

The acceptance of segmental concrete block paving in South Africa as an apt pavement system arose initially from extensive research of full scale pavements followed by national standards for concrete paving block, and laying. Regular assessment of service performance over 22 years has confirmed standards previously set are appropriate for most uses in a developing country. Higher standards can be set when appropriate depending on service requirements.

The text covers a review and reassessment of research and development to date December 2002.

1.2 National standard

Mass production of SF-type concrete paving blocks (cpb), using German equipment and complying with the then accepted German standards, started in the mid-1960s. A number of large companies subsequently began manufacturing cpb to different strengths, shapes and finishes, with and without chamfers.

In 1978, manufacturers who were members of the then Concrete Block Association (CBA) decided that, for the development and protection of the future market, minimum practical standards for cpb would have to be specified.

In response to this, SABS 1058 Concrete paving blocks was published in 1985. (see Appendix A)

Proceedings of the 7th International Conference on Concrete Block Paving (PAVE AFRICA 2003) 12th – 15th October 2003
ISBN Number: 0-958-46091-4 Sun City, South Africa
Proceedings produced by: Document Transformation Technologies Conference Organised by: Conference Planners

1.3 Research into performance of cpb

In 1979, a research programme involving the Council for Scientific and Industrial Research National Institute for Transport and Road Research (NITRR), Portland Cement Institute (PCI) and CBA (representing cpb manufacturers) was proposed and accepted.

The purpose of the research was to determine the significance of the following in the field performance of cpb:

- compressive strength, thickness, shape, and chamfers of cpb
- properties of bedding and jointing sand
- thickness of bedding sand layer
- width of joints between cpb

For the first two years Dr Brian Shackel, who was at the time on sabbatical leave from the University of New South Wales, together with the staff at the NITRR experimental research centre at Silverton, Pretoria used a heavy vehicle simulator to traffic more than 50 full-scale block pavements.

The result of this research showed that the structural performance of cpb was independent of compressive strength, provided that a minimum compressive strength of 20 MPa was achieved.

No research on resistance to abrasion relating to trafficking, and durability relating to exposure to weather conditions was carried out during this research project, and manufacturers were concerned that:

- the relatively low compressive strength requirement was essentially that of the core strength of the cpb, and did not take the strength of the top surface layer into account
- this low compressive strength might result in inadequate abrasion resistance and durability of the top surface of cpb with no topping layer

2. STRENGTH REQUIREMENTS

2.1 In-service assessment of structural performance

In subsequent assessment of the structural performance in service of cpb, the main consideration was to:

- identify the typical pattern of failure, if any
- assess what this pattern indicated about the quality of concrete used

2.1.1 Spalling

Assessment indicated that lack of sand in joints between contiguous cpb led to tilting, causing a concentration of shear stress at contact points between the cpb. As a result surface edges spalled.

Spalling was observed even when vertical spacers running from the bottom to approximately halfway up the cpb were cast as part of the cpb. These spacers were inadequate to prevent tilting.

In addition, spalling was exacerbated by:

- inadequate and variable bedding sand and sub-base support
- cpb laid with wide joints ie. not laid tightly with joint widths exceeding 3mm
- joints opening up in service

Chamfering of the cpb obviously reduced spalling.

2.1.2 Transverse cracking

Virtually no transverse cracking of cpb was observed, even in 60mm thickness and 225mm length cpb where flexural stress might be expected to occur.

Transverse cracking observed was related to:

- manufacturing problems, due mainly to green cpb being compacted on joints between the timber planks of the pallets. The pallets move on a rope conveyor over high points at the supports, with green cpb straddling the joints cracked as a result of point loading and movement
- usually large (eg+10 mm) stones in the bedding sand. When the cpb is placed on a large stone at the approximate centre of the block, sufficient flexural stress is induced in the upper surface of the block under load to cause cracking
- in steep slopes using interlocking block where the centre part of the road moves downwards out of line over time. The cpb in the centre move differentially under breaking and sliding to the cpb located near the kerb, inducing shear stress (a rare occurrence, but observed)

2.1.3 Flexural strength

The strength of concrete can be likened to a three-link chain consisting of:

- strength of aggregate
- strength of cement paste (cement, water and admixture, if any)
- bond of cement paste to aggregate

Compressive strength in the range of 20 to 50MPa is primarily related to the ratio of water to cement in the concrete mix.

Flexural strength and indirect tensile strength are more dependent on the paste-to aggregate bond. The geological type, surface texture and particle shape of the aggregate are significant factors. For instance, dolomites from the limestone family have been shown to give concrete of higher flexural strengths than concrete using igneous rocks such as granites.

The test for flexural strength is a single transverse line load on the cpb, which is supported at two points 20mm from each end. Except in 60mm thick cpb, the main stress induced is punching shear, though the eventual failure pattern is a transverse tension crack originating at the bottom of the cpb under test.

2.1.4 Correlation between flexural and compressive strength

An extensive series of tests was organised in 1989 by the Concrete Manufacturers Association (CMA, previously CBA) of cpb from ten manufacturers throughout the country. All tests were carried out in the PCI laboratory in Midrand.

The cpb were sampled from normal production lines, and no attempt was made to subject them to any specialised treatment. All cpb tested complied with SABS 1058 compressive strength requirements but varied in type of cement and aggregate used, and were manufactured on different equipment using different techniques.

No significant statistical correlation was found between compressive strength and indirect tensile strength test results.

2.1.5 Assessment of adequacy of national standard

The development of the concrete block paving industry has been based on the compressive strength of cpb, as a quick, simple and easy test to perform.

However the national specification, in relating quality to compressive strength and allowing no adjustment for the aspect ratio of height to width, penalises thicker cpb.

3. ABRASION RESISTANCE

3.1 Abrasive forces

Fundamental engineering design is aimed at ensuring that structures satisfactorily, safely and economically resist imposed forces. In practice, important main forces cpb should be designed to resist relate to abrasive forces. The severity of abrasive forces in service depends on the intended use, ranging from pedestrian pathways to heavily trafficked industrial pavements. There is no universally accepted abrasion test of cpb (Papenfus in his doctoral thesis reviewed 66 different abrasion tests in use in the world [2]).

Therefore, at the design stage:

- the impact, rolling, and sliding forces that a cpb has to resist cannot be satisfactorily assessed
- a compromise is made by estimating the severity of forces to which the surface of the block may be subjected, relating to intended use

3.2 Industry approach to abrasion resistance

The CMA approach to abrasion resistance has been primarily phenomenalogical, ie how have different cpb performed in service.

This approach was based on in-depth examination of various paved areas, eg.

- observations regarding the performance of cpb in sidewalks and parking areas in central Johannesburg made by two post-graduate civil engineering students at the University of the Witwatersrand in the mid-1980's
- visual examination of 1m wide transverse strips of cbp of different thickness and strength, laid at a large bus station and informal trading area where all vehicles used a single access entrance
- monitoring of pedestrian traffic from a railway and bus station which was channelled in distinct routes

3.3 Wear assessment

In 1989 a CMA committee composed of seven civil engineers specialising in concrete technology, road traffic and manufacture was formed, initially to assess wear from photographs of 11 existing pavements and estimate whether the wear observed resulted from:

- poor manufacture
- particularly rough surface texture in manufacture
- traffic
- a combination of all three of the above factors

The "experts" assessment varied considerably, and it was accepted that a visual study of abraded cpb would not, with any degree of confidence, be able to pinpoint the reason for the abrasion observed.

3.4 Research project

In 1989, the CMA embarked on a major "Abrasion Resistance" research project.

One of the objectives of the research was to define criteria that could be used to assess the durability and abrasion resistance in service of different cpb, by reference to a simple numerical parameter, say between 1 and 5 (refer to Appendix B).

The project utilised ten sites throughout the country where paving using commercial quality cpb would be subjected to a wide range of traffic.

Each manufacturer was required to supply 80 cpb to the PCI for testing, 20 cpb from each manufacturer were stored for possible future tests, and the remaining 60 were subjected to the following tests, each test being done on 10 cpb from each source:

- compressive strength
- indirect tensile strength
- sand blast test (ASTM C418)
- rotating cutter abrasion resistance test (ASTM 779 with slight modification to the cutting wheels)
- PCI wire brush test [3]
- Australian MA20 ball race test

The laboratory test programme attempted to assess the relative merits of the four abrasion tests in terms of their ability to predict the performance of the test pavements.

These predictions would then be correlated against inspection of the ten test sites where the paving had been laid. The test sites were inspected initially by four experienced civil engineers, and were then to be checked after one, three and five years.

The programme monitoring test sites was not completed for a number of reasons, viz:

- a change in attitude by some CMA members to the project
- subsequent changes from the intended use, imposing different "abrasive forces" in a number of pavements:
    - at a primary school all pupils had been channelled to a single entrance, but the traffic authorities changed the entrance position
    - at a large factory the goods-in and goods-out roadway was changed
    - at a pedestrian footpath at a golf club where all golfers had to pass steel-spiked shoes were banned and replaced by plastic spiked shoes..
    - at an upmarket shopping mall the owners placed a carpet over the cbp being monitored

However, an assessment of five of the sites in 2002 after 13 years in service concluded that:

- in general the structural performance of all cbp was excellent; there was virtually no cracking and spalling of cpb
- little horizontal creep (lateral movement between cpb, and kerbing where cpb of interlocking shape were used) was observed
- joint widths were satisfactory, uniform and within acceptable limits

At one of the test sites, and entrance where cars were turning and travelling up an incline, considerable surface wear of cpb was noted There had been a major loss of cement paste and coarse aggregate particles dominated the surface appearance. The extent of wear did not appear to have affected the considerable amount of traffic still using the entrance road and there were no signs of structural failure of the paving.

4. CONCLUSION

In developing countries such as those in southern Africa, the following factors are of prime importance when decisions are made to define parameters for compliance with specifications:

- the use of cpb should be based on "value for money" taking account of life costing (eg. initial, maintenance and salvage costs) and the cost of competing pavements made of materials other than concrete

- costs of pavements using cpb must be kept to a minimum because of the many demands on limited financial resources
- national standards should be appropriate for the intended use in the intended environment, and compliance with requirements of these specifications should be easy to implement
- monitoring of quality of manufacture of production should be appropriate, viz. cost effective and simple

Where high standards of quality are required of cpb, the client, designer and specifier should decided on strength and abrasion resistance requirements to meet quality parameters while taking into account that in many parts of southern Africa, cpb manufacturers do not have access to equipment for making cpb with a high quality topping layer to ensure increased abrasion resistance.

5. REFERENCES

South African Bureau of Standards, SABS 1058: 1985 Concrete paving blocks

Papenfus, NJ, 2002, Doctoral thesis University of the Witwatersrand, Abrasion wear, abrasion resistance and related strength characteristics in concrete, with special reference to concrete pavers

The Cement and Concrete Institute, 1985 Test method TM7.11, Methods for assessing the abrasion resistance of concrete using a wire brush or silicon carbide grit

APPENDIX A

GUIDELINESS ON RATING WEAR

It is likely that the various signs of wear detailed below may appear at overlapping times:

Rating	Observation	Surface similar to
5	Perfectly smooth and plane surface	Glass
4.8	Loss of laitance	Rough steel-trowel finish
4.7	Minor loss or absence of cement: sand matrix	Fine sand paper
4.4	Some loss or absence of cement: sand matrix	Wood float finish
4	Major loss or absence of cement: sand matrix	Very coarse sand paper
3.7	A few coarse aggregate particles observed on surface	Deep pitting
3.5	Some coarse aggregate particles exposed	
3	Considerable number of coarse aggregate particles exposed	
2.5	Exposed coarse aggregate particles rounded and polished	
2	Aggregate particles plucked out	
1	Loss of surface layers	
0.5	Major loss of surface layers	
0	Disintegration of surface and cpb	

Note:

- A surface rating 5 may be pitted with smooth plane surfaces between the pits/holes/depressions
- It is intended that photographs taken during the various test stages will be used to illustrate ratings

APPENDIX B

SABS 1058: 1985 CONCRETE PAVING BLOCKS EXTRACTS OF SOME PROPERTIES SPECIFIED

Compressive strength

Class of block	Compressive strength, MPa, min	
	Average	Individual
25	25	20
35	35	30

Compressive strength is based on blocks immersed in water for 24h, tested between 3mm thick plywood sheets and calculated on the wearing surface of the blocks. ie. area between chamfers

Type (shape)

Block type S-A allows geometrical interlock between all faces of adjacent blocks:

Block type S-B allows geometrical interlock between some faces of adjacent blocks.

Block type S-C allows no geometrical interlock between adjacent faces of blocks.

REVIEW OF RESEARCH RELATING TO SETTING STANDARDS FOR CONCRETE PAVING BLOCK IN SOUTH AFRICA

Lane, J.W.[1] and Doulgeris, N.P.[2]

[1]Former Director, Concrete Manufacturers Association
[2]Portland Cement Institute

Biography

J W Lane
B.SC (ENG) DIP TP MSAICE FICE FISTRUCT E

Re:Involvement in development and research concrete block paving

In 1978 requested, and addressed, a meeting of South African Bureau of Standards and paving block manufacturers on need to control manufacturing quality and use of concrete paving blocks.

From 1979 to 1980 while Deputy Director Portland Cement Institute elected chairman of ad-hoc committee consisting of representatives of CSIR National Institute for Transport and Road Research, Concrete Masonry Association and Portland Cement Institute to advise and supervise research on concrete block paving at NITRR Silverton Test Site. This involved the full scale testing of 75 test sections using a Heavy Vehicle Simulator. Dr Brian Shackel was the NITRR officer in charge of this research.

In 1979 was chief organiser of, and speaker at, two day Concrete Society Southern African and Concrete Masonry Association symposium on "Concrete block paving" in Johannesburg with overseas speakers from Australia, England and West Germany. In the international field this is regarded as the "first international conference" on concrete block paving.

From 1982-1986 was a member of SABS Technical Committee drafting SABS 1058 Concrete Paving Blocks.

Presented papers at the 2nd and 3rd International Conferences on concrete block paving (Delft 1984 and Rome 1988).

1989 et seq: Initiated a 5 year research programme on abrasion of concrete paving blocks under the auspices of Professor Mark Alexander of the University of the Witwatersrand and the CMA.

Author of Concrete Masonry Association Paving Block Manual. (Now out of date)

In 1991 elected Concrete Man of the Year by the Transvaal Concrete Society Southern Africa partly for contributions to research and development in concrete block paving.

John Lane is now a consultant on concrete block paving and concrete masonry.