JOINT STABILISATION OF CONCRETE BLOCK PAVING

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ABSTRACT

At previous conferences, the author has been presented many papers on the quality of bedding material and the effects of ingress of water into this layer on the ultimate performance of the pavement.

At the last conference held in Japan, a recommendation was made that if water can be reduced or stopped from entering the bedding sand layer, failures of the pavement would be reduced. Also, the concluding remark was that further research needed to be undertaken to improve the joint performance in respect to water ingress.

The need to address other important issues, which can have an influence on the joint performance, is one of maintenance of the pavement, especially where vacuum sweepers are used. The action of such sweepers is in the need to clean the pavement quickly resulting in some or most of the sand being sucked out of the joints.

This paper reviews the laboratory work carried out on joint stabilisation and will present up-to-date results of the research and development of such systems. The results currently show that certain joint stabilisers greatly reduce the ingress of water and the amount of sand sucked out of the joint.

This research is continuing and the up-to-date findings will be presented at the conference.

1. BACKGROUND

The bedding sand quality has been thoroughly research and recommendations have been made to improve the longevity of pavements constructed with concrete block paving by the author. The principle aim is to minimise water ingress to the bedding layer and to only way the water can enter this layer is through the joints between the blocks. In the UK, BS7533-3, the recommended sand to fill the joints was dry silica sand with the largest particle size no greater than 600µm. This facilitated easy filling of joints and on examination, using the method previously reported by the author, using the Jencons Void meter, the void content was 40 – 45%. This sand could be described as filter bed sand.

In the 1980's, part of the sales promotion used by Interpave was to promote the theory that the joints would quickly silt up with detritus, rendering the pavement impervious. Whilst this statement is generally true, no consideration was given to the use of mechanical sweepers to keep surfaces clean. The use of these types of sweepers have created a reluctance amongst local authorities and other specifiers to specify concrete block paving for roads and pedestrian area because of the sand is removed from the joint making the pavement unstable and liable to failure. An attempt was made by local authorities, machinery suppliers and the block industry to write a code of practice for the use of vacuum sweepers.

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This had minimal effect on the operators of the cleaners and the maintenance departments as monetary restraints were placed on them to clean streets etc as quickly as possible. The only way to achieve this was to use the machines at the highest suction and not the lowest.

Where the non-removal of the sand from joints between blocks is of the utmost priority, e.g. in aircraft hard-standing, chemical solutions were developed, initially by Emery to bind the sand particles together as well as bonding to the side of the blocks. The pavement was required to remain flexible and when cleaned with suction cleaners or subject to down thrust of jet engines, the sand remained in the joint and the integrity of the surface was maintained.

This paper represents part one of a two-stage research programme. Firstly, to evaluate by comparing and contrasting material which have been developed for this purpose in the laboratory and secondly, to carryout full-scale trials on pavements subjected to strict cleaning regimes and traffic.

2. DISCUSSION

The main reasons for stabilising the sand joint in pavements are: -

- to prevent sand erosion due to man made cleaning systems, surface water flow on steep slopes, jet thrust and rotor wash down, building discharge of water and slow moving vehicles resulting in loss of interlock
- to prevent infiltration of water which causes degradation of the lower construction layers.
- to prevent infiltration of hydrocarbons and chemicals resulting in low level explosion hazards
- weed growth and staining

Stabilising the sand joint in concrete block pavements and concrete paving flags areas is not an answer to poor or inadequate workmanship. It is an additional treatment to enhance specific properties in the life of a pavement. Joint stabilisation is not essential for every application. The limitation of Water & Solvent based material is that the surface must be dry, with the minimum working surface temperature required 5 ^{0}C and rain not expected for a minimum of 8 hours but preferably 24 hours.

Types of joint stabilisation solution used in the experiments were a Low viscosity urethane pre polymer and an Acrylic co-polymer emulsion.

3. RESEARCH PROGRAMME

<u>3.1 Desk top study</u>

The first part of the project was to carry out a desktop survey of all the materials, which were commercially available in the UK. The materials fall into two categories, first, a liquid which is poured onto the surface and brushed into the joints and secondly, materials which had chemicals mixed in the sand and then activated by the presence of water. In the first category, this can be further divided into solvent based and water based solutions. Each supplier was claiming that his or her product was the ideal material to use for joint stabilisation and was given a unique number. Table 1 gives the description of material type.

<u>3.2 Material evaluation requirement</u>

As previously stated, the there is a need to reduce the water ingress, this can be measured using an infiltration meter fixed to the pavement to measure the amount of water that enters the joint by simply measuring the drop in water level. The resistance to suction of the joints was measured using vacuum for a set period of time. Bond strength of the joint was measured using a pull out test apparatus and the depth of penetration was measured two ways, one, measuring the bonded sand after the pull out test and secondly, applying the recommended coverage of the stabiliser to a container full of bedding sand. Flexibility was to be measured by saturating jointing sand contained in a steel mould, allowing curing and then on demoulding testing the beam in flexural.

Whenever concrete is treated with a coating or similar material, its properties can change. To measure slip/skid resistance, the test method and description of the TRL Pendulum given in BS 7976 was used, colour change following treatment was measured using a commercial colour meter and weathering resistance, again using the colour meter, readings taken after a time period of external exposure.

Table 1. Details of joint stabiliser.

Reference number	Material description
1	Water based acrylic
2	Water based Styrene Butadiene
3	Water base acrylic
4	Solvent free
5	Solvent based polyurethane/acrylic hydrid
6	Solvent based polyurethane
7	Water based Acrylic
8	Water based Acrylic
9	Aliphatic prepolymer
10	Solvent based Acrylic
11	Solvent based polyurethane
12	Organic admixture

4. SAMPLE PREPARATION AND TEST METHOD

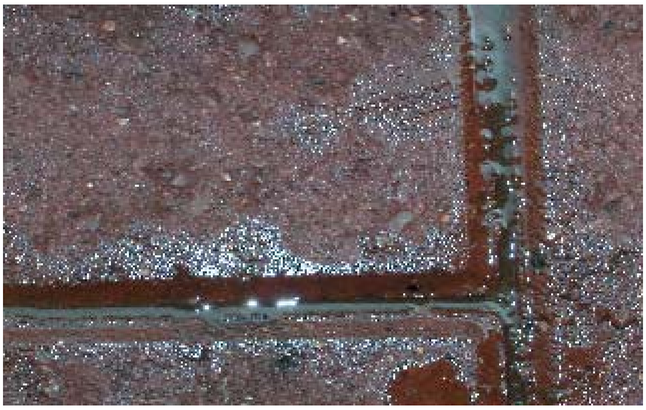
For the entire joint stabilisers used in these tests, the typical coverage rates were between 2.0 m^2 and 2.5 m^2 per litre.

4.1. Suction test

Using the test samples prepared for the absorption test, the nozzle of the vacuum cleaner was sealed on to the blocks at the intersection of the T to give maximum joint area. The vacuum was switch on and left for 20 minutes. After this time the nozzle was removed and the amount of the sand removed was measured. The suction was capable of lifting 9.78kg, this equates to 1.44 MPa.

4.2 Permeability

In a box, block paving was laid on a sand bed, in a configuration so that the joint was in the form of a T, Photograph 1. The joint width was set at 5 mm and this was checked using a gauge. After compacting the blocks down, dry silica sand was poured on the surface, the blocks vibrated again and the surplus sand removed. The joint stabiliser was poured onto the surface of the blocks and a small squeegee was used to wipe across the blocks to remove as much of the material as possible into the joint. The product was allowed to cure for 10 days in a warm environment. After the curing period, a plastic manometer was fixed to the surface using blue tack to ensure a waterproof tight seal, Photograph 2. Water was added to this tube to a height of 34 mm, previously recommended by Emery in his test and dependent of the rate of absorption, the time period for measurement was adjusted. The amount of water that penetrated the joint was measured over the time.



Photograph 1. Illustration of T –joint.

Photograph 2. Permeability apparatus.

4.3. Penetration depths

Having worked out the typical coverage of the various materials known amounts were poured onto the surface of the bedding sand that was contained in clear beakers. The depth was measured at 1 day by noting the colour change of the sand due to the material. After 5 days the jointing sand was removed from the beakers and the crust thickness was measured as a check.

4.4 Slip/skid

The different samples of joint stabilisation material were applied to blocks and using the squeegee the surplus material was removed from the surface. The blocks were allowed to cure for 5 days and each were tested using the pendulum tester. To obtain a pendulum value, the large slider 76 mm wide and the full swing of 126 mm were used under wet conditions.

4.5 Bond strength

Slices of blocks were cut so that they one moulded side and one sawn side Two moulded sides were placed facing each other and held apart at their ends with a 5 mm diameter doweling rod, jointing sand was placed in and vibrated to consolidate the sand. The sand was saturated with the different solutions and allowed to cure in controlled conditions for 7 days. One sawn face was bonded to a 300 mm square flag using araldite while the pull off bobbin fixed on the other face, Photograph 3. These were allowed to cure for a further 48 hours. The pull off apparatus was set in position, the special screw fixed in the bobbin, the locating head fixed to the top of the screw head and a pull offload applied, Photograph 4. The load was recorded. Each of the sand joints was measured and the mode of failure recorded.

Photograph 3. Bobbin.

Photograph 4. Pull off apparatus.

4.6 Colour changes

Before treating the blocks a colour reading was taken using the Minolta Colour measuring apparatus, the blocks were treated and allowed to cure for 3 days and a further reading of the treated surface was taken. The blocks were then placed facing south and left for 1 month before being brought in allowed to dry and further reading was taken.

4.7 Flexibility

Using the method described by Emery[12] to produce beams, sand was placed into a metal beam mould and saturated with joint stabilising material and allowed to air cure in the laboratory. The beams were demoulded approximately after 10 days.

5. RESULTS

5.1 Suction, permeability, penetration and slip/skid

The results obtained from the tests to evaluate the properties of suction, permeability, penetration and pendulum are given in Table 2.

Table 2. Permeability, suction loss, penetration and slip/skid results on coated blocks.

Reference number	Suction time 20 minutes degree of loss	Permeability ml/min	Penetration depth mm	Pendulum value av of 5 readings
Control	Immediate loss	Not tested	Not tested	64
Water based acrylic	no loss	3	5	55
Styrene butadiene	no loss	3.3	8	50
Water based acrylic	no loss	3.75	9	47
Solvent free acrylic	no loss	1.5	5	51
Solvent base polyurethane/acrylic	no loss(after 40 min)	10	140	53
Solvent polyurethane	no loss	1.5	15	51
Water base acrylic	no loss	0.7	6	56
Water base acrylic	no loss	19	6	51
Aliphatic prepolymer	no loss	3	40	53
Solvent based acrylic	no loss	0.27	8	53
Solvent polyurethane	no loss	0.1	5	60
Organic admixture	after 8 minutes	1	Integral mix	No surface treatment

5.2. Colour change

The colour changes from uncoated to coated blocks are shown in Table 3 as measured with the Minolta Colour meter. The L value measures the degree of lightness with 100 being white and 0 black, ‘a’ value represents the red/green axis and ‘b’ represents the yellow/blue axis. The Delta ‘E’ value is the total colour difference computed from the square root of the summation of the square of each delta value L, a and b. Delta E value indicates deviation or difference, the smaller the value the closer the colour match, the larger the number the greater the colour difference. As a guide, the pigment used in concrete block production is generally supplied with a Delta E value of 1.0 between batches.

Table 3. Colour change of blocks before and after coating.

Reference number	Reading	L	a	b	Delta E
Water based acrylic	before	40.44	13.83	13.22	
	after	40.29	13.24	12.64	0.85
Water based styrene butadiene	before	42.6	13.69	13.1	
	after	41.82	13.13	11.98	1.18
Water based acrylic	before	41.48	14.3	13.58	
	after	40.76	12.77	11.45	2.73
Solvent free	before	42.8	14.85	13.25	
	after	41.73	13.85	13.06	1.48
Solvent based polyurethane/acrylic	before	41.49	15.12	14.51	
	after	34.4	12.34	10.44	8.63
Solvent based polyurethane	before	40.43	13.81	13.91	
	after	39.73	14.7	13.29	3.15
Water based acrylic	before	41.47	14.73	14.3	
	after	39.32	14.87	13.45	2.18
Water based acrylic	before	42.24	14.25	14.48	
	after	39.32	14.19	13.41	2.4
Aliphatic prepolymer	before	42.24	16.3	15.98	
	after	33.12	14.02	12.79	9.92
Solvent based acrylic	before	41.05	15.91	15.75	
	after	36.68	15.69	14.24	3.7
Solvent based polyurethane	before	40.76	17.83	16.05	
	after	34.41	15.42	14.15	6.75

Table 4. Pull off tests to check bond strength.

Reference number	Pull off load N/mm^2	Type of failure
Water based acrylic	9.9	unit cracked
	1.6	from side of block
Styrene butadiene	1.5	from side of block
Water base acrylic	1	from side of block
	2.1	from side of block
Acrylic emulsion	7.3	sand failed
	12.6	pulled off base
Solvent based	13.7	pulled off base
	12.9	pulled off base
Solvent based polyurethane/acrylic	1.4	from side of block/sand
	1	from side of block
Water based acrylic	0.5	from side of block
	0.3	from side of block
Water based Acrylic	10.5	bond broken at bobbin
	7.6	pulled off base
Aliphatic prepolymer	3.2	from side of block
	3.8	from side of block
Solvent based acrylic	6.5	through sand
	5.1	through sand
Solvent based polyurethane	2.2	from side of block
Organic mixture	0.2	through sand

5.3 Flexibility tests

On demoulding the beams for the flexibility test, even on the repeat attempts to produce beams, it was impossible. This was due to the upper exposed surface hardening under natural curing and entrapping the remainder of the sand jointing stabilising material in the sand being unable to cure. This exercise was repeated three times without any success, subsequently there are no results available.

5.4 Bond strength.

The bond strength was determined by dividing the load required to pull the specimens apart by the contact area of the hardened sand joint. The results are shown in Table 4.

6. OBSERVATIONS FROM THE DIFFERENT TESTS

6.1 Permeability test

In the permeability test, water had passed into the block and the water head had forced some water to bounce back up onto the surface away from the test area as shown in Photograph 5.

Photograph 5. Bouncing effect.

6.2 Suction test

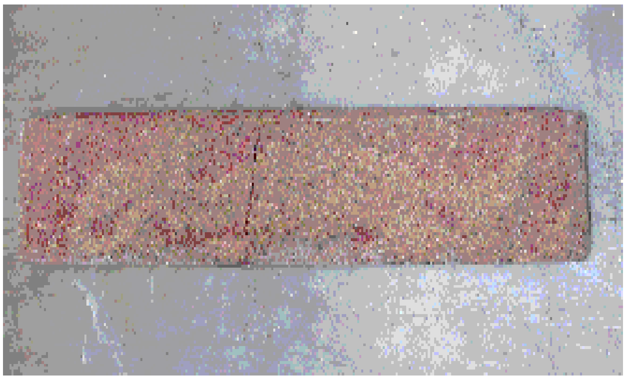
Following the permeability test, the same test specimens were used and following the suction period water and some of the uncured joint stabiliser was sucked up back through the sand and this effect is shown in Photograph 6. Following the suction period, sand was removed from the joint and this phenomena is shown in Photograph 7.

Photograph 6. Water and uncured stabiliser.

Photograph 7. Joints sucked out.

6.3. Bond strength test
The different types of failure experienced in this test are illustrated in Photograph 8 where the bond was broken at the interface of the stabilised joint and the block side. Photograph 9 illustrates failure in the stabilised jointing sand.

Photograph 8. Bond failure.



Photograph 9. Sand Joint failure.

6.4. Flexibility test
Photograph 10 and Photograph 11 illustrates the problem of producing a beam, where the upper surface is cured and beneath this layer is the uncured stabilised sand.

Photograph 10. Cured and uncured sand

Photograph 11. Cured and uncured sand.

7. CONCLUSIONS

From this first phase of experimental work, it is shown that there is no one material that is superior to another for all types of applications. The type of material to be chosen for any given application is dependent on the properties required. The bonded sand could not be sucked out when using either the acrylic or polyurethane based material, with the exception of the organic admixture, however this material had a low bond strength with a relatively low permeability and had no effect on the slip/skid performance or colour change.

Some of the joint stabilising material is used to enhance the colour of the surface of the blocks. The colour change of the treated blocks when compared with the untreated block, produce a high Delta E figure. The effectiveness of the treatment is dependant on the type and volume of traffic

Assuming that block pavements are flexible, some joint stabilising material could have a detrimental effect on pavement performance, by being too rigid with high bond strength. This observation will be addressed on the full-scale trials to be undertaken next year to measure the increase stiffness of the pavement.

All stabilising material affects the slip/skid of the blocks to some degree and this must be taken into consideration when selecting any of the materials for road applications. The experiments will continue to monitor any changes in the surface of the blocks for colour and slip/skid.

The benefits of stabilising the joints include reduction of maintenance costs and therefore the whole cost of pavement is less, limits the surface staining, reduces weed growth in the joints and helps to stabilise pavements and minimise trips

Joint stabilisation application can be used in heavy and light duty port areas, airports, public areas to prevent sand erosion from cleaning systems, to stop hydrocarbons entering the underlying layers in petrol stations and storage areas or for general maintenance to keep areas clean.

8. REFERENCES

Dowson A. J. and Lilley A. A. 1988. Laying Course Sand for Concrete Block Paving.Proceedings 3rd Int. Conf. on Concrete Block Paving, Rome, pp. 457 – 462

Dowson A. J. 1993. Bedding Sand Durability. Proceedings BIBM'93, 14th International Congress of the Precast Concrete Industry, Washington, pp. 127 – 134

Dowson A. J. 1996. Further Investigation into Saturated Bedding Sand - Interim Report. Proceedings 4th Int. Conf. Concrete Block Paving, Tel Aviv, pp. 151 – 160

Dowson A. J. 1998. Investigation and evaluation of test methods for sand for laying course. Proceedings 5th Int. Conf. Concrete Block Paving, Colombia, pp. 35 1-10

Dowson A. J. 2000. The influence and effects of water in laying course material in concrete block paving construction. Proceedings 6th Int. Conf. Concrete Block Paving, Japan, pp. 151-158

British Standards BS 7533 Pavement constructed with clay, natural stone or concrete pavers."Part 3. Code of practice for laying precast concrete paving blocks and clay pavers for flexible pavements

Dowson A. J. 1980. Mix design for concrete block paving. Proceeding of 1st international Conference Newcastle pp121 –127

Interlocking Paving Association. Block paving brochure Leicester UK

Scottish Local Authority Group. 1990 Use of Vacuum Sweeper on Pavements.

Emery J. 1993. Stabilization of jointing sand in block paving. American Society of Civil Engineers Journal of Transportation. Engineering Vol. 119 No 1.

British Standards. BS7963 Pendulum testers. " Part 2. Method of operation.

Emery J. 1994. Infiltration of fuel through paver joints. Proceeding 2nd International workshop on concrete block paving. Oslo

JOINT STABILISATION OF CONCRETE BLOCK PAVING

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Biography

Dr Allan J. Dowson began his career in 1956, working for the British Precast Concrete Federation at their laboratories located at the Cement and Concrete Association at Wexham Springs, Stoke Poges. Among the research areas was the developments of waterproof cements, freeze thaw testing, crazing of Cast Stone and the development of the ISAT test method.

After eight years, was appointed as Head of Technical Research and Development with Marshalls PLC, the largest producer of these products in the UK, a position held for 36 years. During this time was responsible for all quality aspects of concrete products, the development of new products including the introduction of concrete block paving and vehicle over-run flags and the technical advice given to all types of customers for the complete range of the company's products. Also, he specialising in concrete block paving and paving flags design, construction and maintenance.

Throughout this period has been involved with several national working parties related to concrete block paving and paving flags. Has been President of the British Precast Concrete Federation, Chairman of Interpave Main committee and Technical committee, National Paving and Kerb Association and a member of Stone Federation Technical Committee, Concrete Society Technical Executive Committee and Chairman of the Joint Concrete and Clay Industry Committee.

Currently a member of B507 Precast Concrete, Stone and Clay Products, Chairman of B507/1 Precast concrete products, Chairman of B507/2 Natural Stone, Secretary to B507/4 Slip/skid group and B507/5 Tactile paving. Responsible for writing standards on concrete block paving, concrete flags and natural stone.

Is a UK expert on European Committees CEN 178 (main committee), CEN 178/WG1 Concrete products, TC 178/WG2 Natural Stone, TC 178/WG4 Slip/Skid Group, and was a member of TC 229/WG3/TG4 Linear Drainage and the European Standards committee for Pigments.

Is the Chairman of TC178/WG5 -Tactile paving committee.

Obtained Doctor of Philosophy Degree at Newcastle by researching construction methods and laying course and jointing sands for use in block paving construction.

In September 2001, he established 'Allan Dowson Consulting' as an organisation to provide a service to producers and users in all aspects of design, construction and maintenance of precast, clay and natural stone pavements. He is also a Consultant to Interpave and a Visiting Industrial Lecturer at the University of Leeds, where he lectures on concrete block paving to MSc students.

Has presented over forty papers at different international conferences, ranging from mix design, construction methods, materials and product standards, pigmentation, development of urban areas, designing for the disabled, bedding sand quality, maintenance to slid skid properties. Also made many company and trade association presentations.