Erosion of Jointing Sand from Concrete Block Paving

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Summary

In most of its varied applications, block paving relies on the retention of sand in its joints to provide interlock and hence, stability of the pavement surface. It also reduces the ingress of water into the underlying pavement structure. Loss of jointing sand can, if severe, lead to failure of pavements surfaced with block paving, by increasing the moisture content of subgrades and reducing their CBR values. Four causes of erosion of jointing sand have so far been identified. These are:

(i) Action of jet exhaust from aircraft engines.
(ii) Use of vacuum sweepers and high pressure cleaning equipment.
(iii) Turbulent water flow over pavement surfaces.
(iv) Degradation and liquefaction of laying course material due to ingress of water through joints.

Various materials have been used in attempts to stabilise jointing sand, some of which provided a temporary solution to the problem. However, the most effective means of preventing erosion has been by the use of a specially formulated liquid pre-polymer which retains elasticity after polymerisation and is thus able to sustain the essential flexural properties of the block paving surface.

This paper also reports on recent joint investigations by British Aerospace PLC and the author into the effectiveness of the polymer in terms of its erosion protection for block paving subjected to VSTOL aircraft operations. Tests have shown that considerable erosion resistance is provided by the polymer.

Introduction

The stability of a block paving surface is dependent upon the presence of compacted sand in its joints to provide and maintain interlock. Part of the sand, is taken up from the laying course sand as the blocks are vibrated. The remainder of the joint space is filled with fine sand brushed in from the surface and compacted as the blocks are vibrated again.

One of the fundamental requirements of any pavement surface layer is to prevent water penetrating the underlying structure and subgrade. Block paving relies upon a naturally occurring surface 'sealing' process to stabilise the surface jointing sand and to reduce the ingress of water through its joints. Experience has shown however, that this 'sealing' process, which relies upon the presence of materials such as dust, detritus, oil, rubber etc. being in the vicinity of the paved area, is not always effective in meeting these requirements,

Erosion of Jointing Sand

The generally accepted definition of 'interlock', in terms of block paving, is "the development of friction between adjacent and closely spaced blocks". This friction is developed when sand particles have been vibrated into the joints.

Any agent of erosion of jointing sand is therefore a serious problem which may lead to pavement failure. To date, four causes of jointing sand erosion have been identified and investigated. They are:

(i) Jet Blast From Aircraft Engines

Exhaust from Jet aircraft engines provides perhaps the most aggressive form of erosion encountered. In the case of commercial aircraft,jet engine exhaust conditions at the point of impingement onto the pavement surface are: velocities of around 300 m/s and temperatures of up to 300°C. It has previously been reported by the author [1] that more than 1 cm of the jointing sand has been removed by this action. Apart from the problem of potential instability of the block paving there is the added danger that ingestion of sand into engine intakes will cause serious damage to the engines. Erosion problems associated with military aircraft engines are much greater and are discussed later in this paper.

(ii) Use of High Pressure Cleaners & Vacuum Sweepers

Many large areas of block paving are kept clean by the use of powerful cleaners and vacuum sweepers. If these are used before the joints in the block paving have become 'sealed' then there can be a serious loss of jointing sand and hence, loss of 'interlock'. It is difficult to quantify the forces involved in this form of erosion. Although not as severe as jet engine exhaust conditions, they are, nonetheless, substantial. The 'Frimokar' suction sweeper/cleaner shown in Figure 1 has a high pressure water jetting action operating at 40 MPa. and a suction of air velocity of approx. 60 m/s.

Figure 1. "Suction Sweeper/Cleaner"

(iii) High Velocity and Turbulent Water Flow

Where block paving is subject to high velocity and turbulent water flow, e.g. around gullies, in drainage channels and on steep slopes, the action of this water can remove jointing sand and lead to unstable conditions in the laying course. This particular form of erosion has been investigated by Ishai, et al. [2]. Water penetration through the joints in block paving trial areas subject to high velocity water flow was seen to produce unstable conditions in the laying course. By the use of fine aggregate for the laying course rather than the conventional finer grained material, stable conditions were achieved. A trial using a 5% mixture of cement and jointing sand proved to be of only limited success in preventing erosion.

(iv) Degradation and Liquefaction of Laying Sands

A recently recognised problem is that of degradation and liquefaction of certain types of laying sands resulting in failure of a number of block paving areas, particularly on heavy industrial applications. The problem appears to be confined to incidents where poor quality sands or certain crushed rocks were used for the laying course. It is believed that the ingress of water through joints and breakdown of soft granular material into finer particles, forms a slurry which is exuded through the joints under the action of traffic. This loss of fine material by liquefaction, reported by Lilley [3], causes areas of block paving to settle, typically, into elliptical shapes which he describes as "elephant footprints".

Stabilisation of Jointing Sand

It is generally anticipated that areas of block paving eventually become 'sealed' with materials such as dust, oil, rubber etc. This process is necessary to the stabilisation of jointing sand and to reduce the ingress of water and other fluids through joints. However, research by Clark [4] concluded that ". . . the amount of rainwater which may penetrate newly laid block paving is sufficient to damage some types of subgrade." It is desirable therefore that the sand in joints should be stabilised and sealed as soon as practicable after block laying has been completed.

Various materials were used by the author at Luton Airport to prevent jointing sand being removed by the action of jet engine blast. Materials tested comprised; lime dust, cement, pulverised fuel ash (PFA), bentonite and commercially available polymers. In most cases a decrease was noted in the permeability of the modified jointing material and an improvement in its stability, but it was apparent that this was only a temporary condition. The lime dust, cement and PFA tended to have insufficient bonding characteristics and were themselves eventually eroded. The addition of bentonite to the jointing sand dramatically reduced the permeability of the jointing material to almost that of the concrete blocks themselves. It was noted however, that after wetting/drying cycles, this material also eventually eroded.

During 1985 a series of trials was made using readily available acrylic and urethane polymers. In all cases the polymer, after combining with the jointing sand, cured to a rigid, high strength matrix. It was also noted that an unacceptable level of shrinkage of the joint matrix had occurred, thus increasing the likelihood of additional water penetrating the joints. These polymers were rejected on the premise that they would in effect convert an essentially flexible form of surfacing into a rigid one.

Formulation of a Polymer Stabiliser

Trials were made using a stabiliser which was formulated specifically for the particular end use. The formulation took into account the requirements for: (a) a reasonable, but not excessive, degree of flexibility; (b) its ability to reduce the permeability of joints and to stabilise jointing sand by bonding particles of sand together and to sides of the blocks, without necessarily completely filling the interstices; (c) non shrinkage of the jointing matrix and (d) ease of application.

The stabiliser formulated is a low viscosity urethane pre-polymer carried in a hydrophobic solvent whose curing is catalysed by moisture in the substrate and in the atmosphere. The final polymer has an amount of cross-linkage present such that it has a degree of resistance to solvents (e.g. Fuels and de-icing fluids).

Performance of Polymer Stabiliser

The polymer stabiliser previously described is performing satisfactorily after being in use for 5 years. Its effectiveness in stabilising jointing sand may be seen in Figure 2, which shows an area of aircraft pavement subject to jet blast, part of which has been treated with the polymer stabiliser. The noticeable absence of sand in the joints makes the untreated area obvious. The method of application of the polymer is indicated in Figure 3. It is applied direct from its container and spread by brooms or squeegees. Any excess material remaining on the surface of blocks is removed by the use of plastic foam rollers.

Figure 2. Aircraft Pavement Partially Treated with Polymer

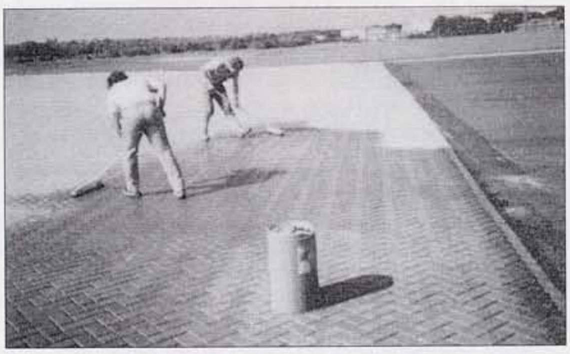

Figure 3. Applying Polymer Stabilisers

Since the initial trials and subsequent full scale use of the polymer stabiliser other benefits provided by the materials have been recognised. These are:

- The appearance of block paving is enhanced by imparting to it a sheen and a more uniform colouring.
- Surface dusting from the blocks is greatly reduced.
- It provides additional resistance to chemicals which might be harmful to concrete products and reduces incidence of efflorescence.
- Inhibits weed growth in the joints of block paving.

There is some reduction in skid resistance of the pavement surface immediately after application of the polymer stabiliser. Tests have been made on concrete blocks using the pendulum test apparatus. The average Skid Resistance Value (SRV) was found to be 52. This is an acceptable value for most needs and will improve as the polymer on the surface of the blocks is abraded by trafficking.

The range of applications for which the polymer stabiliser is proving effective is growing rapidly, varying from heavy industrial pavements, such as bus lanes, busy road intersections and large pedestrianised areas, to small garden patios. The following two examples illustrate this broad range.

Figure 4 shows a turning circle at one of the runway ends at Luton International Airport which is subject to frequent movement of aircraft at full take-off thrust. To date, aircraft pavements surfaced with concrete blocks, have been treated with the polymer stabiliser, at 10 airports in the UK and overseas.

Figure 4. Aircraft Pavement – Runway Turning and Take-off Area

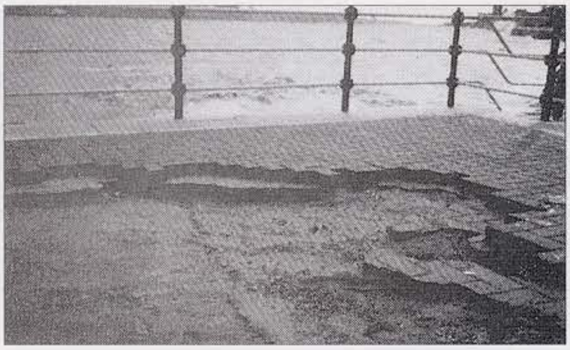

Figure 5. Egremont – Damage to Block Paving by Flooding

Figure 5 shows a promenade area adjacent to the River Mersey at Egremont in north-west England. Clearly visible is the damage resulting from high tides and severe storms. Repairs were made later and the jointing sand stabilised with the polymer despite being inundated by tidal water to a depth of approximately 1m there has been no subsequent damage.

Effect of VSTOL Aircraft on Block Paving

The development of Vertical Short Take Off and Landing (VSTOL) aircraft has increased concern about possible operational limitations being imposed on these aircraft due to their greater Jet Pressure Ratios (JPS's) and higher exhaust temperatures presenting potentially serious ground erosion problems. Typical present VSTOL aircraft efflux values, during vertical lift operations, are JPR 1.5 to 2 and temperatures at ground level of up to 500°C. Indications are that future VSTOL aircraft could increase these values in the region of, JPR 4 and 800°-900°C.

Investigations into block paving erosion problems were made by British Aerospace PLC [5], at their Hot Gas Laboratory (HGL). This unique facility enabled tests to be carried out at full scale jet pressure and temperature values. Although the individual blocks were generally found to be resilient to jet blast, dependent on temperature, the jointing sand was found to be easily removed by the pressure of the jet. This occurred at JPR's well below present VSTOL operating conditions. Also it was noted that loss of jointing sand allowed air to penetrate under the blocks, creating 'ballooning' of the block pavement surface, thus destroying the integrity of the pavement and causing serious Foreign Object Damage (FOD) risk in operational applications.

A combined study of British Aerospace (Military Aircraft) Ltd., and the author [6] has been made to investigate the effects of direct jet impingement on block paving treated with the polymer. Sample trays, measuring 600mm x 600mm, containing 80 mm thick rectangular blocks laid in the modified herringbone pattern shown in Figure 6, were mounted on the Ground Erosion Rig at the British Aerospace HGL. The results indicated that considerable erosion resistance is provided by the polymer. An untreated block paving panel showed extensive loss of jointing sand under increasing ambient temperature pressures, up to JPR 2.0. At this pressure the laying course was penetrated and fluidised' and blocks were lifted. Polymer treated samples were unaffected by high pressure ambient temperature jets, up to JPR = 4, when subjected to runs of up to 60 seconds duration. The maximum operational limit obtained for the treated blocks when subjected to jets of JPR 1.8, nozzle temperature 527°C, was a residence time of 5 seconds. This exceeds the results obtained from previous studies.

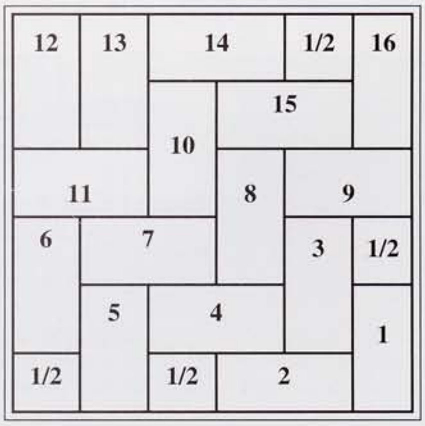

Figure 6. Test Sample – Layout of Blocks

Conclusions

A polymer stabiliser, formulated specifically to control; jointing sand erosion problems associated with aircraft pavements surfaced with concrete block paving being used by commercial jet aircraft, has now been performing satisfactorily over a period of 5 years. As a result of further trials the polymer has also proved to be capable of resisting the four forms of erosion identified in this paper.

It is considered that this polymer will prove useful in extending the range of pavements which may be surfaced with blocks to those having moisture susceptible sub-bases and/or subgrades by virtue of its ability to reduce greatly the ingress of water through joints. It should also reduce the ingress and accumulation of combustible liquids in the laying course sand, e.g., at petrol station forecourts.

Further studies have shown that erosion resistance is possible for aircraft pavements surfaced with block paving and subject to VSTOL aircraft, limited to Jet Pressure Ratios of up to 1.8 and nozzle temperatures not exceeding 527ºC.

Acknowledgments

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