PAVE 92

BEDDING COURSE SANDS

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SUMMARY

The poor performance of a small number of flexible clay and concrete block pavements receiving heavy channelised traffic and located principally in the North West region of England has led to a number of investigations as to the cause of failure. To date these have proved to be generally inconclusive.

This paper proposes a new solution to the problem. It is considered that sands for the bedding course should be more precisely specified by geological origin and categorised for use in areas receiving specific levels and intensities of vehicular loading.

It is thought that this information will prove to be the catalyst for increased liaison between the sand and block paving industries and also emphasise to specifiers that the sand bedding course must be considered as a designed element of flexible pavement constructions.

INTRODUCTION

The requirement to consider the bedding course of a flexible pavement as a 'designed' element of the pavement became apparent following a series of pavement failures in the North West of England and the failure of a project in Seattle, Washington State, U.S.A. These principally occurred in bus stations or other areas where heavy traffic was channelised. Initially the failures were attributed to inadequacies in design or poor workmanship but subsequent investigations indicated that the choice of bedding course sand could be the possible weak link.

To counter uncertainty as to the suitability of flexible paving for use in areas receiving heavy channelised traffic the Authors have proposed a categorisation system for naturally occurring silica sands linked to the intended application of the pavement. An analysis of sands used in existing pavements that have shown acceptable performance in the long term, the assessment of sands used in pavements that have failed and laboratory investigations have all supported the Authors' assertions.

Failure

Failures of flexible pavements in areas receiving heavy channelised traffic have often necessitated expensive remedial work or have led to a total loss of confidence in this form of construction. In addition as the failures have principally occurred in town centre bus stations the bad press received has made local authorities and transport operators loathe to use the system in less critical areas where its used would be patently suitable.

Failures of flexible pavements in heavy channelised situations has been characterised by the development of ruts and localised settlements for which the name 'elephant footprints' has been coined. This phenomena was first investigated by Lilley and reported in his paper at the 3rd International Concrete Block Paving Conference (Rome) in 1988 (1). In addition it is thought that failure is linked to the fact that the pavements in question typically are constructed over relatively impervious road-bases which 'trap' water in the sand bedding course layer.

Seattle

The project at Pine Street in down town Seattle covered an area of approximately 3,000 sq.m which incorporated two busy road junctions. It was trafficked by a variety of buses including an articulated vehicle with a central axle load of 13,000 kg. 8" x 4" x 4" thick 'sawn' granite paviors were used as the wearing surface and laid in a 45° herringbone pattern on a 2" thick sand bedding course over a reinforced concrete structural slab. Dimensional tolerances for the granite paviors were similar to those for concrete blocks and the project was considered in design terms as though it was a flexible concrete block pavement.

The Seattle Engineering Department had overall responsibility for the project and engaged a local consultant to develop the design. The designer was aware of the requirement to carefully consider the specification for the bedding course layer and took the following precautions. He provided grooves in the surface of the underlying concret slab to encourage the flow of water within the bedding sand and provided a sandwich filter layer between the concrete slab and the sand to create drainage paths. The choice of bedding course sand was based on C.B.R results. The sand which gave the highest results was a crushed rock material.

In its partially saturated condition the sand chosen was very stable as the fine fraction effectively cemented the whole together. When fully saturated, however, the fine material fluidised and the sand lost virtually all of its strength.

Within four hours of Pine Street being opened to traffic visible rutting of the pavement surface could be observed, together with pumping of sand from the joints when heavy traffic passed. After a few days of trafficking the pavement was considered to have failed and an investigation was put in hand to assess the cause of failure. This study eventually focussed on the bedding course sand and made the recommendation that it should be replaced.

The new bedding sand chosen was a naturally occurring silica sand with virtually no material passing a 75 micron sieve. As a precaution and following reconstruction the pavement surface was treated with an acrylic pre-polymer to seal the joints and minimise the amount of water entering the bedding course layer.

The reconstructed pavement has been in service for over two years and has performed satisfactorily despite the passage in some areas of over 2 million standard axles.

The conclusion to be drawn from the Pine Street project is that the bedding sand specification can make the difference between a zero life pavement and one that will perform satisfactorily in the long term. In particular the percentage of fine material, the inability of sand to degrade and the potential for ingress of water to the bedding course layer are considered to be crucial issues. In this case the failure was totally attributable to an inappropriate sand specification. Changing the sand type and nothing else brought the pavement from a condition of failure to one of success.

Analysis

In common with the project in Seattle an analysis of failed pavements in the North West of England revealed that 'crushed rock' sands and not naturally occurring sands had been used. It appeared that under the action of heavy channelised traffic; such as that found in bus stations, the individual grains of crushed rock sands broke down into a fine dust. This, in the presence of water migrating through the bedding course layer, formed a lubricating slurry which was considered to be the principal cause of pavement failure. Micrograph analyses of crushed rock sands revealed that they have sharp features which can become dislodged when individual grains of sand are caused to rub against each other in pavements which receive heavy channelised trafficking (Figure 1). In service the grains break down into smaller and smaller particles and the sand effectively degrades itself.

An assessment of schemes that have performed satisfactorily in critical situations such as bus stations indicated almost exclusively that naturally occurring silica sands had been used.

With reference to the Geological Survey Ten Mile Map of Great Britain, First Edition (Quaternary) 1977 (2) it was found that the principal sources of naturally occurring sands are the 'alluvium' deposits which, geologically speaking, were deposited in relatively recent times and have not been compacted to form solid rock. For this reason the individual grains of sand have retained their structure and are rounded with a smooth and naturally glassy surface (Figure 2). Their intact structure and smoothed surface make it less likely that individual grains will abrade each other and break down into smaller particles. The integrity of the sand is thereby maintained, together with the overall stability of the bedding course layer.

British Standard

Currently the British Standard BS 6717:Part 1:Specification for Concrete Paving Blocks (3) permits the specification of naturally occurring and crushed rock sands for the bedding course of flexible pavements. The Authors research and experience suggests that in this respect its recommendations are flawed and engineers who follow the British Standard specification may have a costly failure on their hands in some circumstances.

Specification Criteria

Drawing on an analysis of sands which have performed successfully in service in a range of applications for a number of years, a categorisation system has been devised based on the fractions that pass the 75 micron and 600 micron sieve sizes. These two sizes were selected to place controls on the percentage of 'fines' and to eliminate single size materials. It is also considered that the sand should be reasonably well graded with no particles being retained on the 6 mm sieve.

Having established that the best bedding course sands for flexible pavements were naturally occurring silica sands and after confirming the scientific reasoning for this, the Authors categorised individual sands for use in different loading applications.

Four categories of sand were determined as shown in Table (1). Pavements subjected to heavy channelised traffic such as bus lanes or bus stations require a sand of high stability designated Category (1). In conditions where the pavement has to perform to a less onerous specification a sand of lower stability, say, Category (3) will suffice. By relating the sand category to the intended usage of a flexible pavement, a designer can maximise the potential for a pavement to perform well in both the short and long term.

Survey

In order to establish the location and availability of the sand types meeting the proposed categories, the Authors carried out a survey of sand suppliers based on the lists of pits contained in the Directory of Quarries and Pits (4). In total 636 No. pits were requested to supply information. The number of respondents to the survey was 108 No. which although low possibly represents those Companies who have greater marketing awareness and have highlighted supply to flexible pavement projects as a major source of potential revenue. Companies were asked to supply details of the sand name, the address of the source pit and the sand grading. From the responses and with recourse to the Geological Survey Ten Mile Map (Quaternary Sheet) it became clear that the same type of sand could be found along the length of the same river valley. This meant that it would be possible to determine the type of sand likely to be found at pits which did not respond to the survey located in the same river valley as other pits which did respond.

Production

The range of sands produced from a particular pit, whilst obviously dependant on the source material, is also related to the production systems operating and the technical and marketing awareness of the management operating the pit. Theoretically most pits could produce a 'sand' to satisfy the requirements of all the four categories. In practice they predominantly produce those sands which can be produced at least cost and which, in a certain area, are the most commercially viable. Some pits are able to produce different grades of sand by 'blending' two or more types or fractions together. This in itself is not a problem if the constituents of the blend are all naturally occurring silica sands. However in some circumstances a 'blend' of crushed rock material and naturally occurring materials is produced. These combined sands have been shown to be the cause of pavement failure in certain heavily trafficked applications as the crushed rock element of the blend can break down under channelised loading.

Sand Survey

In June 1991 the Authors published the results of their sands survey in a document sponsored by Blockleys Brick Limited. The survey lists sands by name, Category and by the location of the pit from which they are derived. Each sand source has also been referenced and plotted on a map of the United Kingdom to give the specifier an overview of sand categories available in the vicinity of a particular project.

The Future

Until the publication of the bedding course sands survey, the designers of flexible pavements have generally been unaware of the importance of specifying the correct type and grading of bedding course sand. Conversely, sand suppliers have been unaware of the limitations of their own materials or indeed the advantages of specific sand types over others.

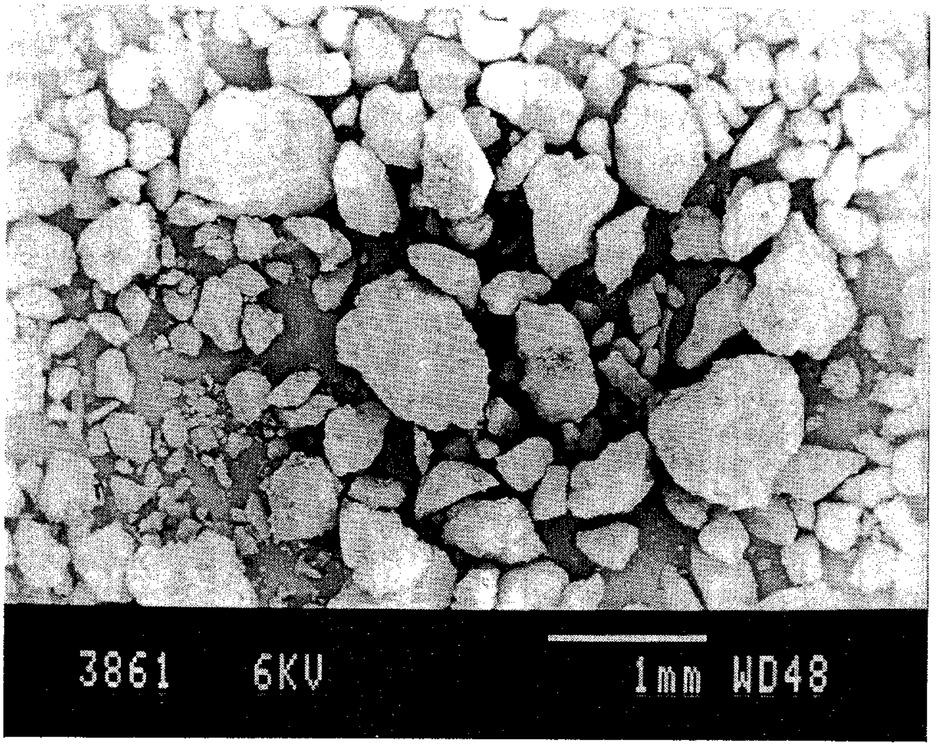
As far as the Authors are aware, their survey was the first time that the block paving industry had seriously communicated the importance of correct specification of bedding course sands in the overall design of flexible pavements to the sand industry.

The current usage of bedding course sand in the U.K is approximately 1.3 million tonnes per annum. This amount is increasing each year as interest and confidence in flexible pavement construction grows. It is surprising therefore that until the authors began their investigation there was little or no contact between the two industries and that the bedding sand layer had not been considered as a 'designed' element in the overall pavement construction.

It has been demonstrated that the wrong sands used in the wrong circumstances can create a requirement for expensive remedial measures in the short term which in turn generates a loss of confidence in the effectiveness of flexible paving systems.

The Authors hope that the Bedding Sands Survey will make suppliers and specifiers more awarė of each others problems and requirements and form the catalyst for future effective growth for the block paving and sand supply industries.

CRUSHED ROCK MICROGRAPH



SILICA SAND MICROGRAPH

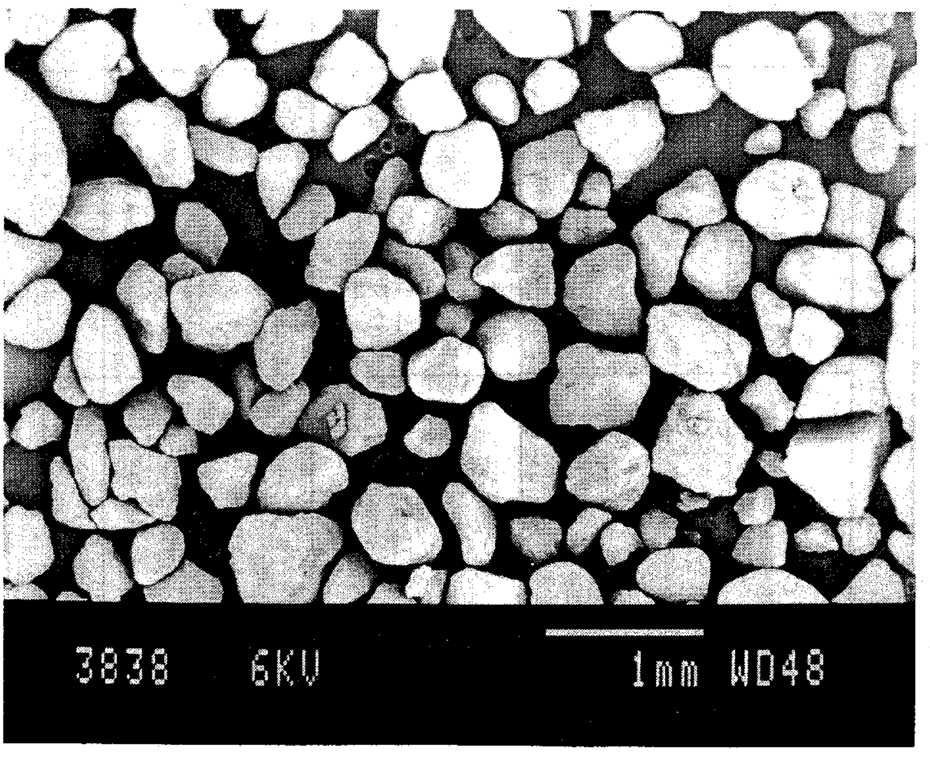


TABLE (1)

BEDDING COURSE SAND CATEGORIES AND APPLICATIONS

CATEGORY	% OF SAND PASSING 75 MICRON STEVE	% OF SAND PASSING 600 MICRON SIEVE	APPLICATION
I	LESS THAN 0.1%	LESS THAN 60%	: PAVEMENTS RECEIVING SEVERELY CHANNELISED TRAFFIC : INDUSTRIAL PAVEMENTS (DOCKS AND HARBOURS) : BUS STATIONS : LOADING BAYS
II	0.1 TO 1.0%	LESS THAN 60%	: ADOPTED HIGHWAYS : PETROL STATION FORECOURTS : PEDESTRIANISATION PROJECTS RECEIVING REGULAR HEAVY TRAFFICKING : CAR PARKS RECEIVING SOME HEAVY TRAFFIC : AIRCRAFT PAVEMENTS
III	1.0 TO 3.0%	LESS THAN 70%	: PEDESTRIANISATION PROJECTS RECEIVING OCCASIONAL HEAVY TRAFFICKING : CAR PARKS RECEIVING NO HEAVY VEHICLES : PRIVATE DRIVEWAYS : PUBLIC AREAS RECEIVING PEDESTRIAN TRAFFIC ONLY : FOOTPATHS LIKELY TO BE OVERRIDEN BY VEHICULAR TRAFFIC
IV	3% AND ABOVE	LESS THAN 70%	: FOOTPATHS NOT LIKELY TO BE OVERRIDDEN BY VEHICULAR TRAFFIC : PRIVATE AREAS RECEIVING PEDESTRIAN TRAFFIC ONLY

NOTE: WHERE THERE IS DOUBT AS TO WHICH CATEGORY A PROJECT FITS INTO, DESIGN FOR THE MORE ONEROUS SITUATION

REFERENCES

1. Lilley A A and Dowse A J : Laying Course Sand for Concrete Block Paving. Proceedings of the 3rd International Conference on Concrete Block Paving, Rome, 1988. pp 457-462

2. British Geological Survey : Geological Survey Ten Mile Map (North Sheet and South Sheet) - First Edition (Quaternary) 1977. London.

3. Quarry Managers Journal Limited : Quarry Management & Directory of Quarries and Pits (22nd Edition), Nottingham 1988.

4. British Standards Institution : Precast Concrete Paving Blocks : Part 1: Specification for Paving Blocks. BS 6717: Part 1 : 1986. London