REVIEW OF FUNCTION OF JOINTING SAND, BEDDING COURSE SAND AND BASE STRUCTURE IN CONCRETE BLOCK PAVEMENT

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SUMMARY

The concrete block pavement contains the bedding course sand layer, which is not seen in other pavement. The surface layer of the pavement is a kind of discontinuous material composed of a little block and a jointing between the blocks. Consequently, the jointing sand, bedding course sand and the base are very important element, especially when the interlocking concrete block pavement finds its application to the pavements such as yard pavement on which a heavy load works. No reports on the established function of these materials have not yet been available .

We, the authors, intended to investigate the functions of jointing sand, bedding course sand and the base by a loading test in a room by measuring the deflection of the pavement surface and vertical stress in the individual layers.

1. Introduction

Twenty years have elapsed since the introduction of the concrete block pavement in japan, and the area of about 8200 thousand m^2 has been developed by this method. Since the method is excellent for the view and durability of the pavement including excellent follow up and maintenance toward uneven settlement, this method finds its application in the light traffics such as public place park, walking road, and strolling road, which accounts for 80% of its use.

Recently the method is expanding its use year by year for a car road pavement, and the future development is expected in such pavement as airport, harbor bay, and industrial yards where a heavy load works.

Different from other pavement, the concrete block pavement is a pavement in which individual segments are combined and the jointing sand is filled to constrain each block, leading thereby to a load-dispersion. The pavement has an additional characteristic to have a layer of bedding course sand between the base and pavement material.

Therefor, the jointing sand, bedding course sand and the base are important factors which are involved in the durability of the pavement. Particularly in the place such as container yard where a heavy load works, the function of these factors are important to improve the durability of the pavement. In spite of their significance their functions have not yet been elucidated.

As a first step in the application of concrete block to the field of pavement under a heavy load, we focused our attention to its function. By a loading test in a room we investigated the functions of a jointing sand, bedding course sand and base structure in the concrete block pavement.

2. Functions of the base structure and bedding course sand layer

2.1 Outline of the test

Using a testpit placed in a room, function of base structure and a bedding course sand layer were investigated by changing a kind of the base and the thickness of the bedding course sand. The testpit had a size of 2m x 2m, and was equipped with a repeated-loading apparatus which was capable of loading a compressed load 30 times per minute at maximum at 10 tonf at maximum.

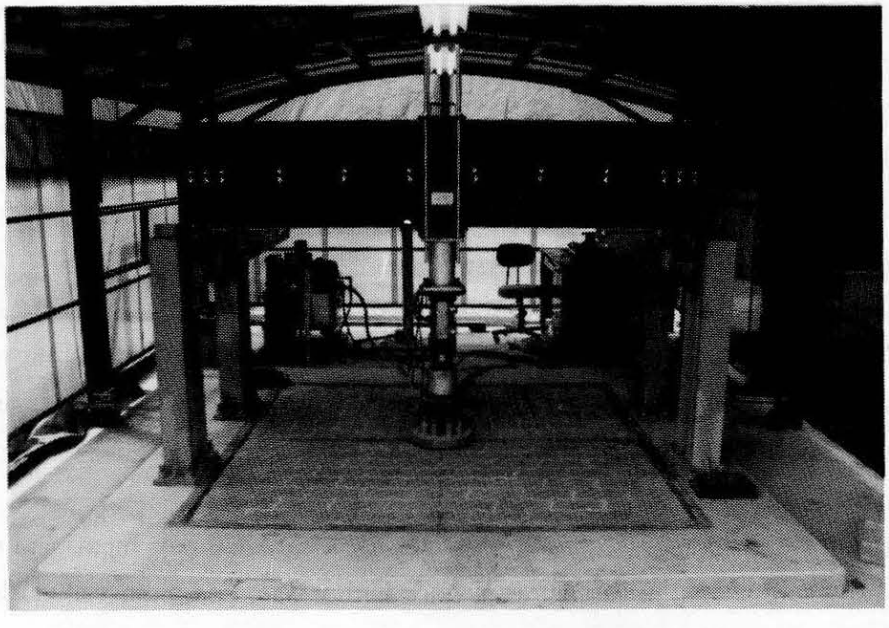

Figure .1 Testpit and loading test machine

The pre-loading 500 times at 4 tonf was followed by the repeated loading at 8 tonf up to 10000 times. The displacement of the block surface at the direction of a long-axis caused by the loading was measured. The vertical stress was measured at the lower face of the block straightly under a load , at the upper face of the base and the upper face of the subgrade.
In addition , the supporting power at the surface of each layer of the pavement materials was measured by the plate-loading test.

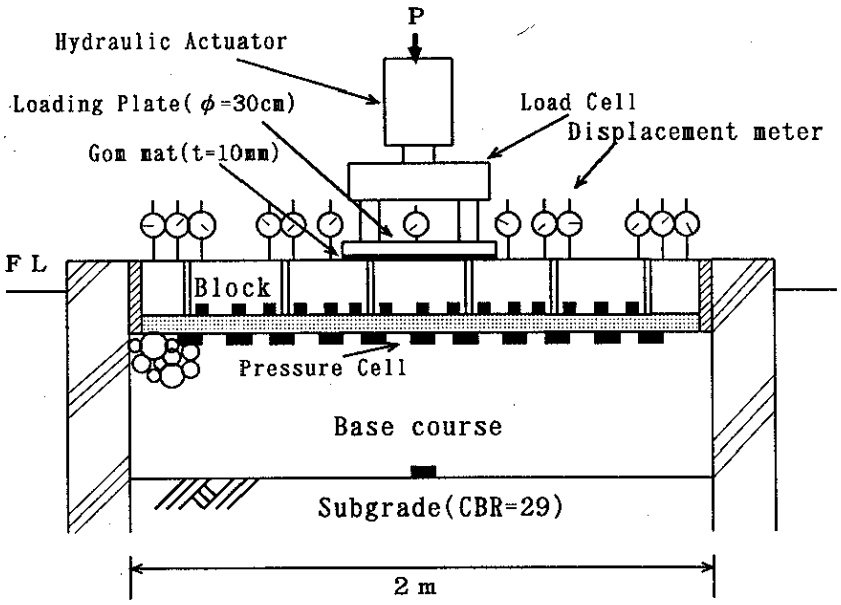

Fig . 1 Repeated-loading test

The blocks used in this study were Uni-system-N type attached with jointing-keep. The settlement-pattern was a stretcher bond. The mean width of the jointing was 3 mm. The testing condition were shown in the Table1. The materials for the base structure were selected from 3 conditions; granular with a controlled particle size as a typical deflection type, concrete as a stiffness type and the material stabilized with cement as the intermediate type of the above 2 conditions. The depth of the bedding course sand layer was investigated according to 2-6 conditions.

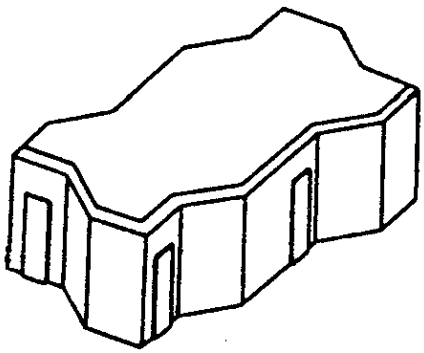

Fig . 2 Uni-system-N block

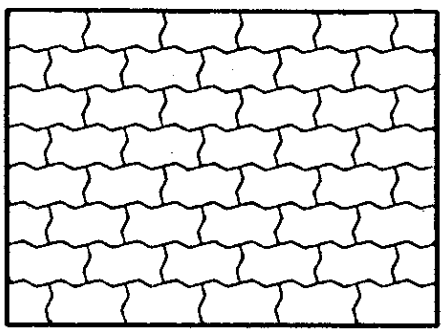

Fig . 3 Settlement-pattern

Table . 1 Test condition

		1	2	3	4	5	6	7	8	9	10
Bedding course	Material	sand (FM=2.84, Dmax=5.0mm, 75 μm under=2.4%)									
	Thickness(cm)	2	5	2	5	1	2	3	4	5	2*
Base course	Material	Granular M-30(Dmax=30mm) CBR=143%		Stabilized with cement E=54,000(kgf/cm^2) qu=35(kgf/cm^2)		Concrete E=280,000(kgf/cm^2) σc=400(kgf/cm^2)					
	Thickness(cm)	50		40		30					
Block	Form	Uni-system-N type(Thickness=10cm, Attached with jointing-keep)									
	Pattern	Stretcher bond (Mean width of the jointing=3mm)									
Jointing sand		Siliceous sand (FM=2.90, Dmax=2.5mm, 75 μm under=0.1%)									
Subgrade		sand (CBR=29%)									

※ The block was attached to the concrete base

2.2 Results of the measurement

Fig. 4 shows the ratio of the supporting force at the surface layer of the block (K1) and at the base (K2). For the base made of granular, the supporting force was greater at the surface layer than at the base, whereas for the concrete base it was greater at the base than at the surface layer for the concrete base. For the base stabilized with cement the supporting force showed the intermediate between the above two bases. The results showed that increasing the stiffness of the base does not always lead to the increase of the supporting force on the surface layer. For any of the bases the supporting force at the block layer was the more great, when the bedding course sand layer was made thinner.

The fact that K1/K2 ratio was reduced on repeated loading for the base made of the granular indicated that the supporting force of the base itself was increased by repeated loading.

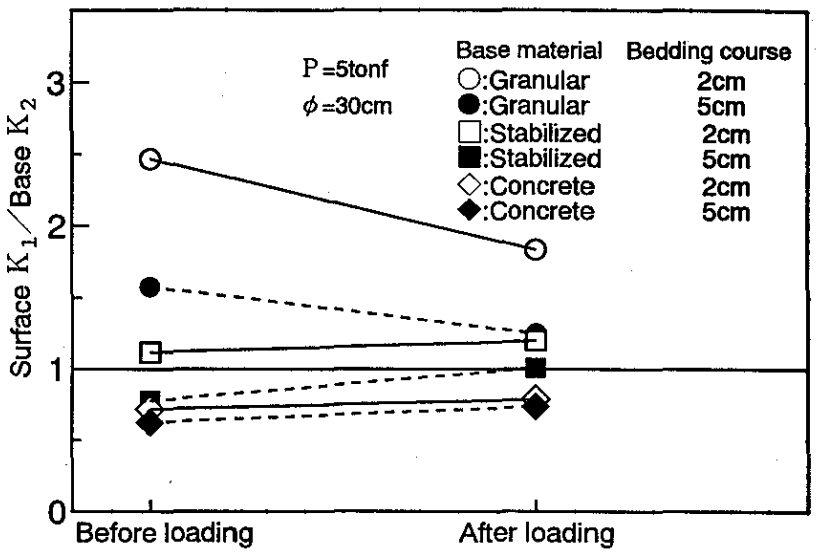

Fig . 4 The ratio of the supporting force

Fig. shows the vertical stress at the direction of the depth at each layer of the pavement material examined straightly under load. The vertical stress at the subgrade face had, naturally, a tendency to be smaller for the base with greater stiffness. However, the vertical stress at the lower face of the block and at the upper face of the base were higher for the concrete base than for the base stabilized with cement. This indicates that increasing the stiffness of the base is not always a bast method to reduce the stress at the base and adding a moderate deflection is favorable.

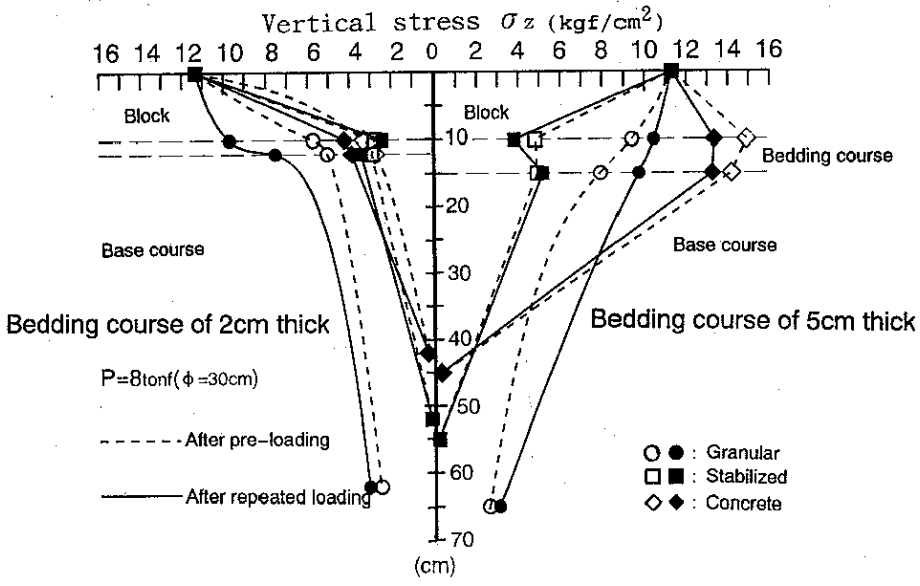

Fig . 5 Vertical stress at the direction of the depth

It was investigated whether it was possible to reduce the stress at the base which had a great stiffness , eg.concrete, if a moderate deflection was given to the base by using the bedding course sand. The results shown in Fig. 6 indicates that the more the bedding course sand layer was thick, the more the settling amount in the pavement surface was high, and the vertical stress at the lower face of the block showed also a tendency to become greater. If the block was attached to the concrete base, settling amount and the vertical stress were the smallest.

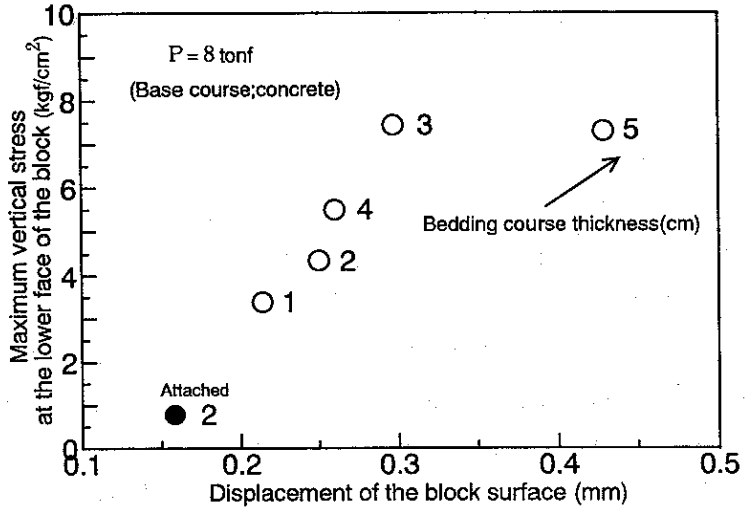

Fig . 6 displacement of the surface and vertical stress at the lower face of the block

Consequently it is considered that if the bedding course sand layer is thick in the block pavement, it did not always contribute to the load-dispersing effect due to block competition , rather resulted in concentration of the stress due to its smaller modulus of elasticity compared to that of the block layer or the base.

After repeated loading, the plastic displacement amount of the surface of interlocking block pavement was smaller for the base stabilized with cement than for other bases, irrespective of the thickness of the bedding course sand. This finding indicates also that the moderate deflection of the base generates a competition between blocks, which prevents the blocks from floating or dropping down locally.

It is considered therefore that a most suitable deflection (stiffness) of the base exists which permits displaying more favorable load-dispersing effect and giving a good durability to the concrete block pavement. Based on the test conditions in this study, it is concluded that, in view of load-dispersing effect of concrete block pavement and settling amount of the block, it is preferable to use the base stabilized with cement, whose structure is characterized by the bedding course sand layer made as thin as possible within the limit at the execution of a work.

3. Function of the jointing sand

3.1 Outline of the test

The function of the jointing sand was evaluated both by the surface displacement amount of the block at the direction of the long axis of the block, as previously mentioned, and by the vertical stress measured with a pressure sell placed on the upper surface of the base and distant at 20 cm pitch from the center of the loading at the direction of the long axis of the block.
The base structure was examined only on the base stabilized with cement (qu=35kgf/cm^2, E=54,000kgf/cm^2).

3.2 Measurement results

Fig. 7 shows the maximum deflection amount examined straightly under loading (8 tonf) and the vertical stress at the face of the base, with and without jointing sand filled . The deflection of the pavement surface and the vertical stress at the face of the base were higher when the jointing sand was not filled than those when the jointing sand was filled. Moreover, when the jointing sand was filled, the deflection and the vertical stress were greater in the block of 10 cm thick than those in the 8 cm thick, whereas, without jointing sand filled, they were smaller in the block of 10cm thick than those in the block of 8 cm thick.

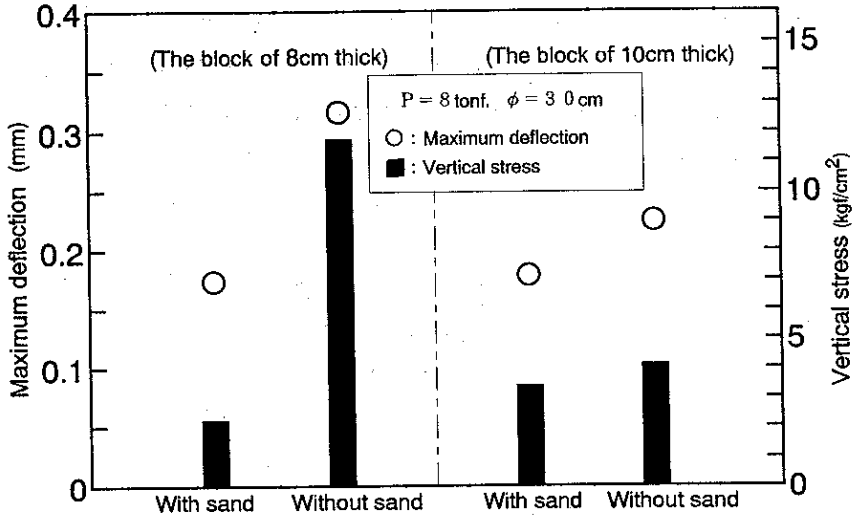

Fig . 7 The maximum deflection and the vertical stress

Fig. 8 shows the deflection of the surface of the pavement under loading of 8 tonf x 10,000 times. When the jointing sand was filled, it causes constrain on the individual blocks, this leading to a mutual biting between the block and sand, which gave a continuous and smooth deflection. When the jointing sand was not filled, only the block adjacent to the loading plate dropped down enormously to give an irregularity of the height among blocks, and even a floating of the block was seen around the loading plate. This tendency was slightly more marked for the block of 8 cm thick in comparison to the block of 10 cm thick.

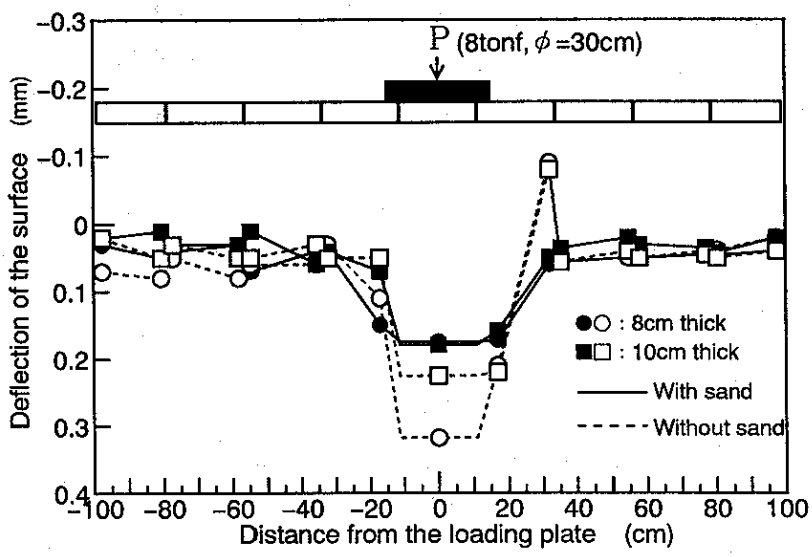

Fig . 8 The deflection of the surface of the pavement

Fig. 9 shows the distribution of the stress on the face of the base caused by the loading at the direction of the long axis of the block. When the jointing sand was filled, the stress was distributed widely on the load, by the transferring effect of the jointing sand, whereas, without jointing sand, the blocks under influence of the loading were so limited that a huge vertical stress was generated straightly under the load.

The tendency was more great in the block of 8 cm thick than in the block of 10 cm thick. This is because, in case of the block of 10 cm thick, the blocks themselves can generate more of less load-dispersing effect by the competition among the blocks themselves or among the laterally attached projections.

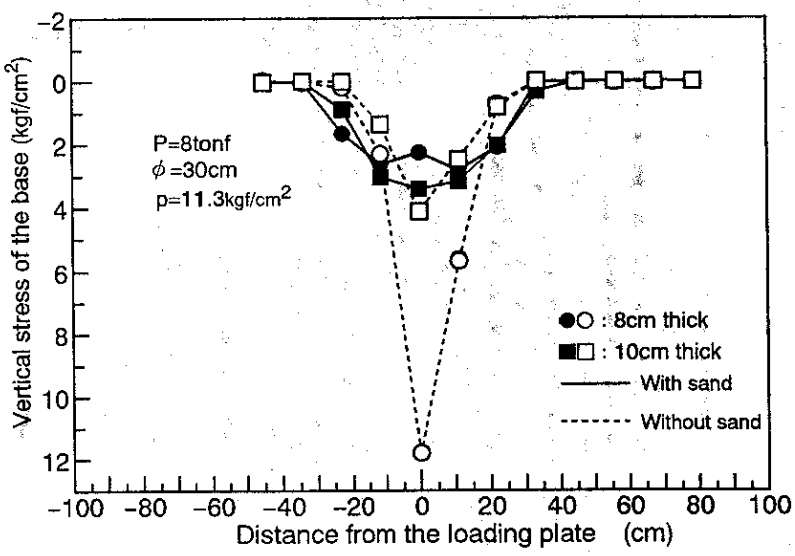

Fig. 9 The distribution of the stress on the face of the base

Fig 10 shows the relationship of the loading weight to the vertical stress examined straightly under the face of the base. As the loading weight was increased, the vertical stress under the face of the base was increased. However, if the block was filled with the jointing sand, the increment of the vertical stress was less pronounced under the face of the base where the loading weight was great, compared to the block without jointing sand.

This suggests that the base may be gradually deflected by the load and, if the load reached a certain level, the deflection may generate, in the presence of the jointing sand, a competition among blocks, thus yieding a load-dispersing function.

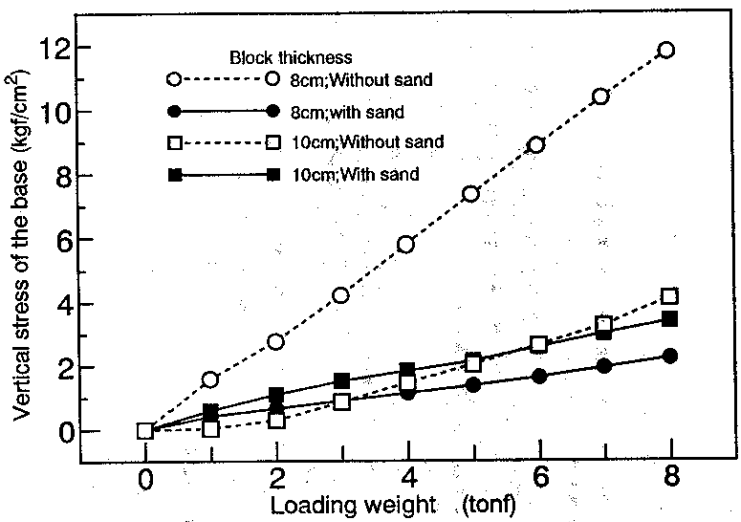

Fig . 10 The loading weight and vertical stress of the face of the base

The results based on the these testing conditions may suggest the following hypothesis;

A. When the whole block pavement is deflected by the loading, the jointing sands existing among blocks are compressed to constrain the individual blocks, thus generating a competition between blocks.

B. The generated competition between blocks causes mutual biting among blocks, thus permitting the block layer to function as a load-dispersing layer.

C. The block layer, now working as a load dispersing layer, reduces the concentration of the stress on the base as well as prevents the blocks from giving an irregularity of the block height or floating.

4. Conclusion

This study showed a) depending on the deflection of the block pavement caused by the load, the jointing sand works as a constraining material of the blocks, thus generating the competition between blocks, and permitting the block layer functioning as a load-dispersing layer, b)increasing the thickness of the bedding course sand layer does not contribute to the load-dispersing effect, c)a base with a great stiffness does not always lead to decreasing the stress on the base, and the base should be deflected moderately, if it is expected for the block layer to display fully its load-dispersing function.

In order to find further application of the concrete block to the field of heavy load pavement, our future study will be focused on finding the most suitable pavement structure and on elucidating the physical required to the bedding course sand and joint sand for the ideal pavement structure.