STUDY ON THE BEHAVIOUR OF CONCRETE BLOCKS UNDER VEHICULAR LOADS

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SUMMARY

It has become very important to take amenity of pavements into account at the urban roads. The concrete block paving is a method to create such environmental effect on roads by its colors and patterns not only for pedestrian roads but for carriageways. In Japan, concrete block pavings have been constructed mainly on sidewalks, plazas and parks for pedestrians. But, in 1990, "the manual for design, and construction of block pavement (for carriageway)" (1) was published. First, we examined the stress condition in block and subbase by the photoelastic method. Next, we measured the stress distributions directly by reactive paper which is placed between sand laying course and subbase under vehicular load. And the results were compared with the theoretical multi layer elastic analysis.

1.INTRODUCTION

In Japan, concrete block paving for carriageways is designed following the method of "the manual for design and construction of asphalt pavement"(2). But the behavior of block paving is very different from asphalt layers. As the block paving consists of a large number of paving blocks laid on their backs on a prepared foundation, each block can move more freely than the continuously bonded materials in asphalt paving.

We have studied the mechanical reaction of block paving under vehicular loads experimentally and theoretically. First we examined the stress distributions of blocks and subbase by two-dimensional photoelastic experiment. The experiment model was made to have a two-layered or three-layered construction. To get edge restraint, a phenolic resin flame was used. In these experiments, we clarified the stress and strain distributions of block model and subbase model, stress transmission between blocks and blocks,between blocks and subbase. Moreover we clarified the effect of the thin layer (as laying course).

Next we examined a block paving, which had a length of 2m and a width of 2m, at the pit in the laboratory. The blocks were 8cm thick, in the basic rectangular shape. The subbase was well compacted clay. Two type of block patterns, stretcher bond and herringbone bone, were used. We applied the large vehicular load, and measured the displacement of block surface and the stresses under the concrete blocks . To measure the stresses we used a reactive paper (Presscale: Fuji film Co.). This paper catches red color in proportion to the stresses. The results which were obtained from the method mentioned above were compared with the value calculated from the theoretical elastic multi layer analysis.

2.PHOTOELASTIC EXPERIMENT

Experimentation model is made to have a two-layered or three-layered construction using epoxy resin. And these layers are flamed by phenolic resin to get restraint at the edges of the epoxy resin and to prevent lateral movement.(3) Normal temperature-setting epoxy resin board is used as the photoelastic material in the upper layer(as block mod-

el) and lower layer(as subbase model). For laying course, weaker epoxy resin is used. The construction and dimensions of the experimentation model are shown in Fig.l. The block model is of the size 50mm long, 30mm height. The subbase model is of the size 250mm long, 100mm the height. And the thin layer(as laying course model) has 5mm height. The thickness of these models and flame is 10mm. The elastic moduli and photoelastic stress sensitivity of the materials used are shown in Table 1. The interface between each layer is not bonded, lateral movement of each layer is resisted partly by the frictional force and lateral force developed at the edges of the segment and layer. Applied load of 90kgf and loading width of 36mm are taken as standards in the photoelastic experiments. Loading is done in two ways as shown in Fig.l with the center line of the loading plate directly above the joint, with the center line above the center of block segment model. The isochromatic fringe order obtained by photoelastic experiments is proportional to the absolute value of the difference between principal stresses, and is given by the following equation: (4)

$$N=Cd|p-q| \qquad (1)$$

where
N: isochromatic fringe order
C: photoelastic sensitivity
d; thickness of specimen
p,q: principal stresses

As can be seen from Eg.(l), the fringe pattern of the isochromatic lines expresses the distribution condition of shear stresses and principal stress where the specimen is not in contact with other surface.
Photo-1,2 comprise a series of photoelasticity photographs. Photo-2 expresses the model which has not a thin layer between block model and subbase model.

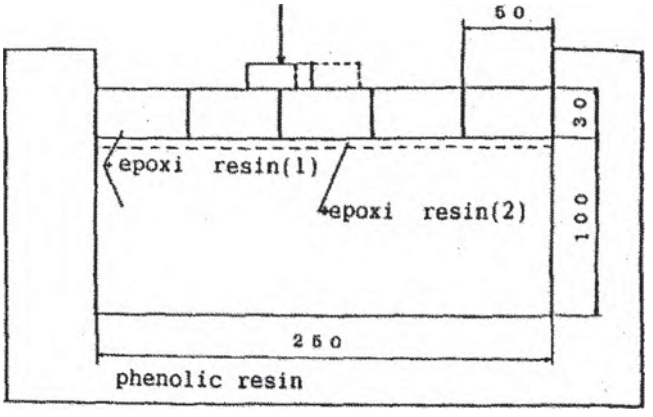
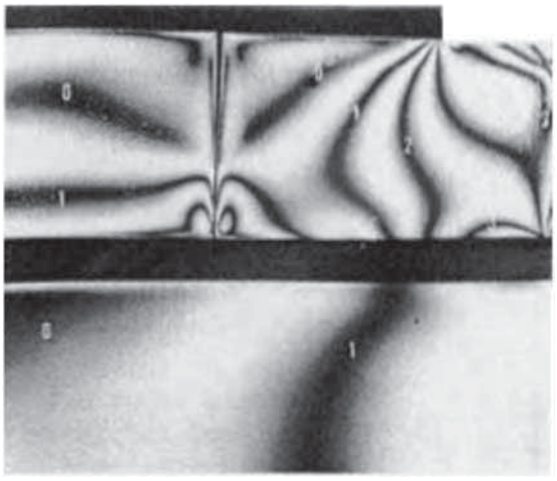


Fig. 1. Two-dimensional experimentation model(mm)

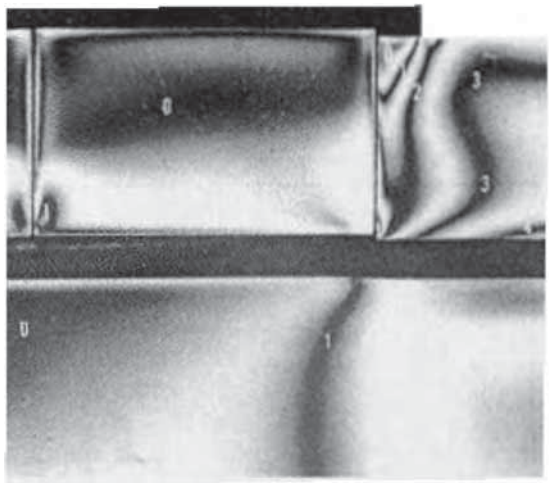
Table 1. Elastic moduli and photoelastic sensitivities

MATERIAL	ELASTIC MODULOUS (Kgf/mm^2)	PHOTOELASTIC STRESS SENSITIVITY (mm/kgf)
EPOXY RESIN (1)	150	1.05
EPOXY RESIN (2)	10	-
PHENOLIC RESIN	1300	-

Photo-1 expresses the model which has a thin layer, (a) shows the results of the photoelsastic experiments with the center line of the loading plate directly above the joint, and (b) shows the result with the center line of the loading on the center of block segment.
Fig.2,3 show the shear stress distributions along the joint and the bottom surface of the block model. Fig.4 shows the shear stress distributions along the surface of subbase model.
According to the photoelasticity photographs, isochromatic lines of high fringe order are produced at the vicinity of the contact points of the edges of the block model and at the vicinity of the contact points under joints of the subbase model especially without a thin layer and in (b) condition.
The conclusions obtained in these experiments are as follows:
(a)When a loading test is performed, the peaks of shear stresses are produced in the edges of concrete block model and in the vicinity of the subbase

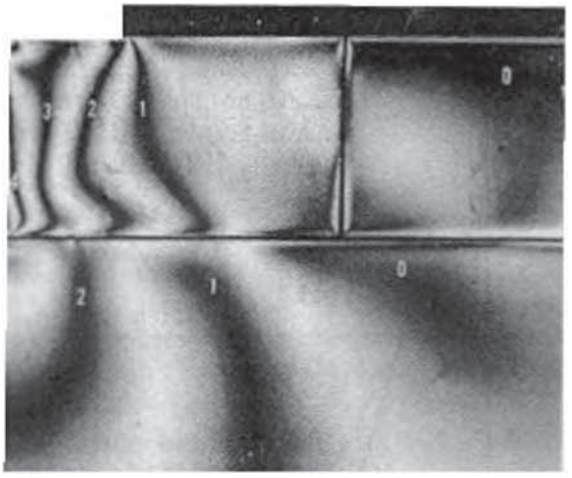


(a)Loading above the joint

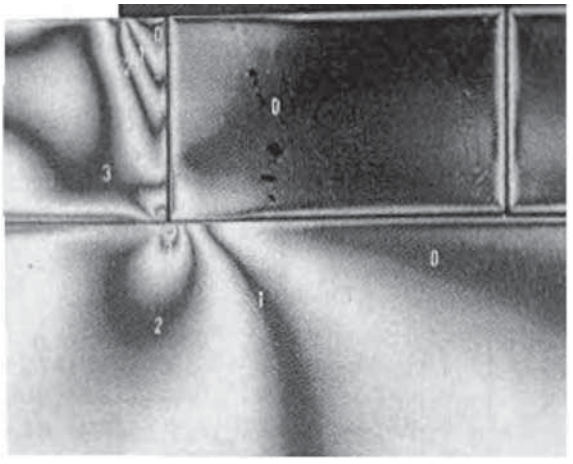


(b)Loading on the center of block

Photo. 1. Isochromatic line (with thin layer)



(a)Loading above the joint



(b)Loading on the center of block

Photo. 2. Isochromatic line (without thin layer)

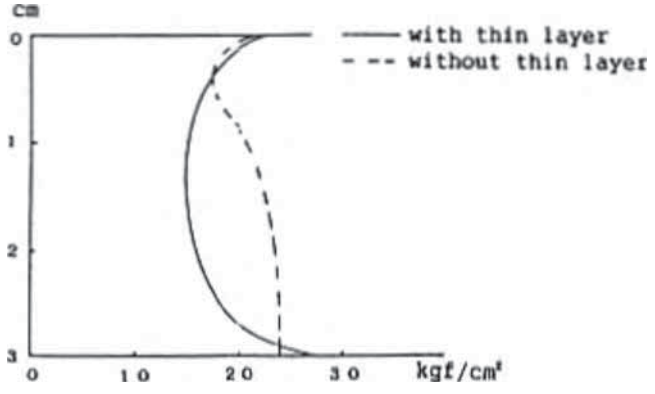


Fig. 2. Stress distribution along the joint

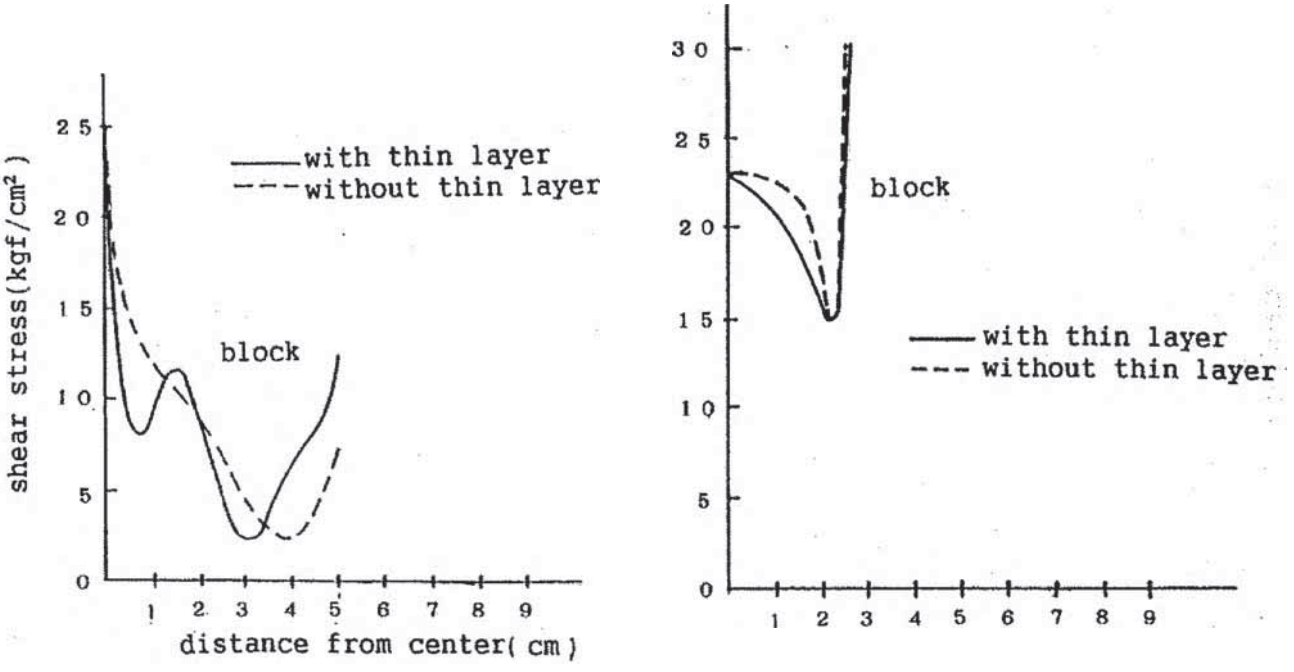


Fig. 3. Stress distribution along the bottom surface of the block model

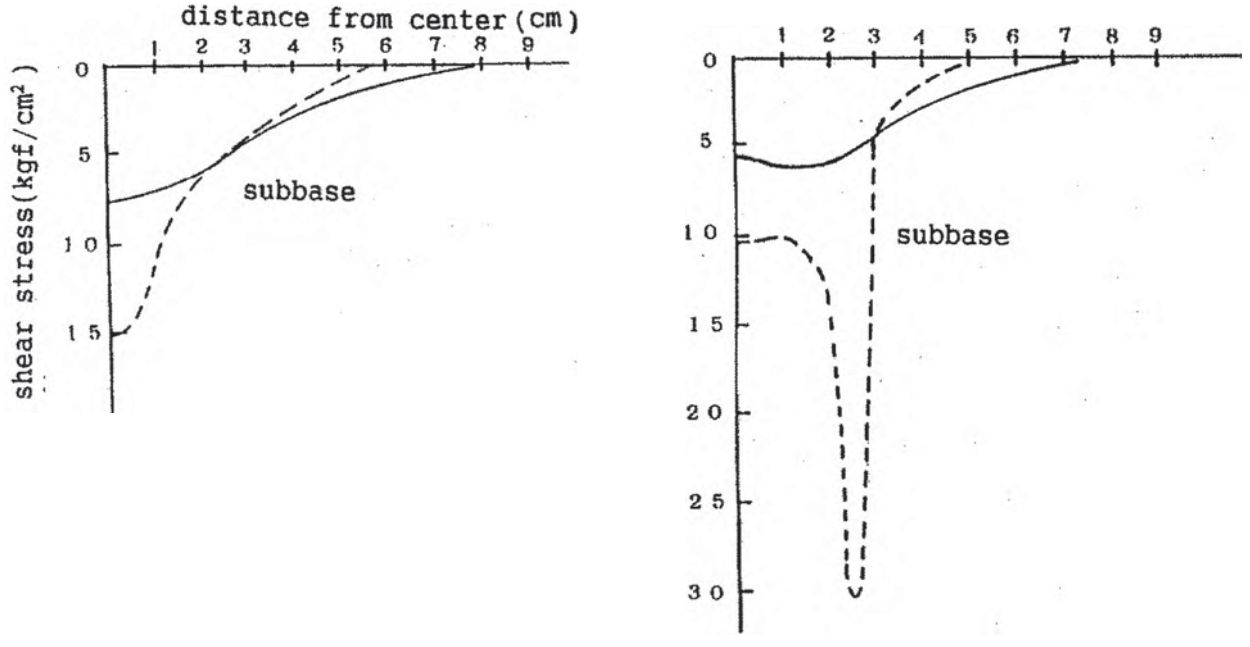


Fig. 4. Stress distribution along the surface of subbase model

model under joint.

(b) Thin layer(sand laying course) is effective to reduce the stress in subbase, but the stresses in the block model increase conversely.

(c) When only one block model is loaded downward and frictional forces on the sides of block model are weak like those in this two dimensional photoelastic experiments, high stress concentration occurs at the vicinity under joints. In this case, the thin layer is effective to reduce the stress in subbase , too.

3.MEASUREMENT OF THE STRESSES ON SUBBASE

To make the stress distributions of subbase clear, we construct a concrete block paving, which has a length of 2m and a width of 2m, in the pit in the laboratory, the blocks are 8cm thick, in the basic rectangular shape. The subbase is well compacted clay (CBR25%). The cross-section of the block paving is shown in Fig.5. Two types of block patterns, stretcher bond and herringbone bond, are used. The large vehicular load(lOtf) and a loading plate (30cm:diameter) are applied, and the displacement of block surface and the stresses on the subbase are measured. To measure the stresses, a reactive paper (Presscale: Fuji film Co.), which is placed on a thin polyvinyl chloride plate, is used. This paper catches red color in proportion to the stresses, and the stresses are to be known continuously.

The stresses are expressed as contour lines in Fig.6,7. The former is a case of stretcher bond, and the latter is a case of herringbone bond. The stresses of herringbone bond are distributed coaxially about loading plate, and the stress gradient is steep.

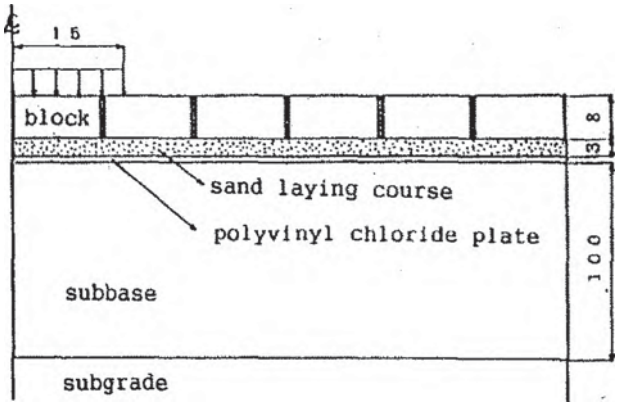


Fig. 5. Cross-section of the block paving

The maximum stress value is 8kgf/cm'. On the contrary, in the case of stretcher bond, the stress gradient is gentle especially in the longitudinal direction of the blocks. The maximum stress value is lOkgf/cm^7, a little bigger than that in herringbone bond.

4,THEORETICAL ANALYSIS

The stress distributions on subbase of the concrete block paving are obtained by the experimental methods mentioned above. The results must be a little different from the stresses produced in the pavements which have cement concrete or asphalt mixture upper

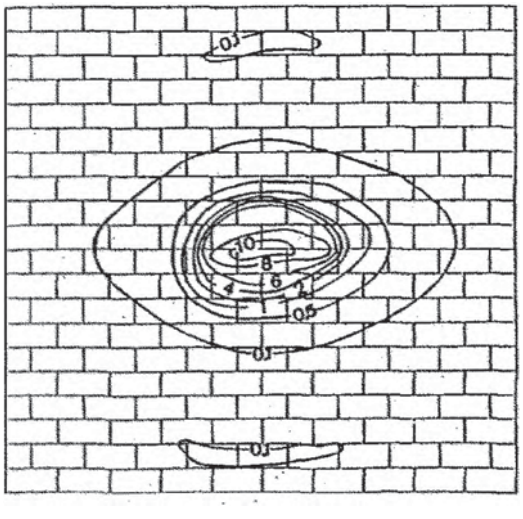


Fig. 6. Stress of the stretcher bond

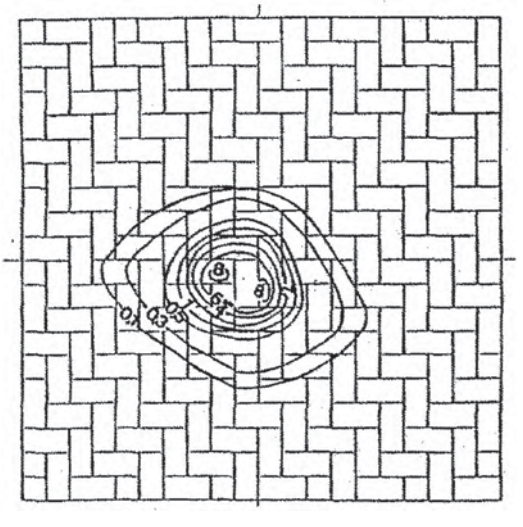


Fig. 7. Stress of the herringbone bond

layers. But it is very difficult to know the stress values under such layers by experiments. Therefore, we calculate them based on theoretical elastic layer system(ELSA), developed by Dr.K. Himeno, and compared them with the experimental results. The results are expressed in Fig.8. Two layer structures are used to calculate the stresses on the subbases. The compared experimental stress values are the maximum one which is obtained from the contour lines of herringbone bond pattern. In calculation, the elastic moduli are assumed to take the calculated values close to the experimental values. But in the reasonable range, which the elastic moduli can take, all experimental values are bigger than theoretical values. Practically, they are not so different much on subgrades. But care must be necessary in the vicinitiy on the subbases.

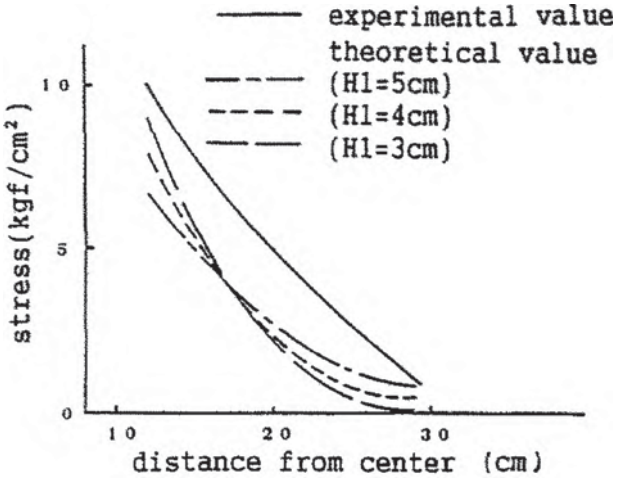


Fig. 8. Experimental value and theoretical value

5.CONCLUSION

The findings of this research are summarized as follows;

(1) The stress distributions in concrete blocks and subbases were expressed by photoelastic method. And the mechanism of stress transmission in the models was clarified.

(2) The stress distributions under concrete blocks were measured continuously by reactive paper under vehicular load.

(3) The anisotropic stress distributions in stretcher bond were measured.Especially, when the load became heavier, at a little distance some of concrete blocks came off the laying course and rose up from the surface.

(4) The stress distributions in pavements were calculated according to elastic multi layer theory, and were compared with the experimental results.

REFERENCE

1) Interlocking Block Association, Civil Engineering Research Center: Manual for Design and Construction of Interlocking Block Pavement (for carriage way),1990.(in Japanese)

2) Japan Road Association: Manual for Design and Construction of Asphalt Pavement,1988.(in Japanese)

3) J.P. Watson: Highway Construction & Maintenance, Longman Scientific & Technical.1989.

4) Photoelasticity:M.M. Frocht,John Wiley & Sons,1941.