ON THIN CONCRETE BLOCKS AND ADHESIVE LAYER

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SUMMARY

This paper is to suggest the method of paving with thin concrete blocks to cover the conventional asphalt pavements which are subjected to damages and rutting due to the increase in recent traffick. Means to prevent skidding in winter are to worsen the damage and the deterioration of the pavements. The thin blocks can enhance the strength and the aesthetic value of the pavements. These are also able to shorten the term of works at the site due to their light weight. This report centers on the overlay method with blocks kept at specific positions with an adhesive layer of asphalt. The thickness of a block can be reduced if the maximum length of the block shortens. The lessened blocks may cause the anxiety of their unstability. For positional stabilization, these blocks have to stick to the underneath asphalt road which governs the bearing capacity. The aptness of adhesive means is a key to the success of the thin block overlay. Mechanical conditions of the adhesive layer are discussed. The maximum tensile stresses in the layer are derived by FEM.
The adhesion of asphalt was obtained by electrical heating in the case studies, in which the adhesive sheets were prefabricated and placed without heating. The blocks were arranged on the sheets, followed by heating. Carbon fibers were in the asphaltic sheets for heating.

1. Introduction

Rapid increase in automobiles in our daily life accelerates the exacerbation of some road-problems. Roads are subjedted to damages due to heavy traffick and other means to prevent skidding on a frozen road in winter. Roads are affected also by the frost heave or the thermal expansion. Being appropriate to bear the weight of automobiles and distribute it underneath in such an environment, the asphalt pavements prevails mostly in a cold region. The asphalt pavements, however, have problems. Especially the rutting one is urgent to be solved. This problem has various causes. Main cause may be that the asphalt is subjected directly to wheels and exposed to the outside air. On the other hand, there are many kinds of concrete which are much stronger and more durable than asphalt. The concrete is particularly resistive to abrasion and high temperatures, although its deformation capacity is limited. Therefore it is suitable to cover asphalt for protection. The overlay with thin blocks of appropriate concrete may be a solution.

2. Concrete Blocks

Each layer between the surface and the base responds to loading differently according to a combination of physical properties and geometrical conditions. When a concrete slab is subjected to wheel loadings and temperature changes, the internal stresses can be given from the ratio between the maximum length and the thickness, particularly when the slab is placed on a soft ground of lower base coefficient (Ref.1).

When the objective of surface concrete is to protect the asphalt underneath, the size of a block can be small only to reduce the internal stress. Then the width of a joint between slabs can be fine for thermal expansion (Ref.2). A thin concrete block is a concrete slab whose maximum length is made as short as possible, so far as the block can function. Blocks are normally prefabricated in a factory. Occasionally these are produced in the site, placing concrete and joint lines are notched in order to avoid the adverse cracks. The surface concrete, which has a thickness less than 20mm and is stabilized by adhesion not by the self weight, is to be analysed as the thin concrete block. In so far as the base condition is identical, the smaller block is stronger to damge due to loading and temperture changes. The smaller the size , the stronger the block mechnically since the internal stress is reduced. On the other hand, the conventional practice has experienced the cost rise with the block size reduced. This is because the size for the mechanical unit cannot be independent from the size for the working unit. Enlarging the size of the working unit, the thin concrete blocks become practicable. Blocks , the size of which are reduced, can be connected to one another in order to attain the objective. There are ways such as connecting blocks with a net and introducing notches in a block like a chocolate bar.

A mechanical problem of small sized blocks is how to stabilize these at desirable positions. In the conventional concrete block practice, the sand has played the key role in joints and on the base. Subjected to pressure and the shear stress, the sand pushed into a joint can transmit the force to the adjacent block. When a block is to be raised, other blocks nearby are also raised in accordance, which can prevent each to be raised independently. The conventional concrete blocks have tendency to move in the repetitive freeze and thaw of water absorbed in the sand underneath .

Two main functions required to concrete blocks as the protective layer are one to reduce the amplitude of temperature variation (Ref.3) and the other to strengthen the surface.

A. ALLEVIATION TO TEMPERATURE VARIATION The maximum amplitude of temperature variation of the surface asphalt can get to 50 degree Celcius in one day cycle in Sapporo. It could be between 20 d. and 70 d. in summer and between -15 d. and 35 d. in winter . Since the highest temperatures in asphalt are found within several milimeters from the exposed surface, the concrete blocks can be protective against the thermal flow and the thermal stress , alleviating the temperature variation thanks to their reflex and the weight. The thicker , the more effective.

B. SURFACE STRENGTHENING Strengthened binders and appropriate

aggregates in any concrete , whether it is of cement or of asphalt, can improve the abrasive resistance and other physical strengthes. Prefabrication in the factories is advantageous for strong binders to improve the concrete. The concrete block overlay in which the joints are filled with asphalt may be taken as the asphaltic concrete of special aggregates of blocks with much less asphalt compared with the ordinary asphalt concrete mixture. Consequently the thickness of the overlay may be added to the thickness of the asphalt pavement.

3. Stress Analysis of Adhesive Layer

The stresses of adhesive layer varies with the wheel moving over each block. Pig.1 shows the assumption made for FEM analysis for the elements of concrete block and adhesive asphalt. Since the uniform pressure p of a wheel advances from the left hand side, the maximum tensile stresses of the adhesive layer are found near the right hand edge. The progression of fracture of blocks depends on conditions of the adhesive layer, site conditions and the construction procedures. The block length is 100mm. The stresses of all elements are computed for three thicknesses, 6mm,12mm and 13mm. The unit loads are applied to the surface nodes. Young's modulus of concrete block is 200,000 kg/sq.cm. That of the adhesive is 5,000 kg/sq.cm.
The layer thickness tis either 3mm or 6mm. The element 10 of the layer is the key to keep the block stable when a wheel is passing by from the left. The maximum tensile stress, of the element 10 takes place when the foremost load of travelling ones gets to the specific node such as No.49 of block surface. These nodes are close to the centre of No.50. Fig.2 shows the maximum tensile stresses of No.10 with the node number to which the foremost load gets. The absolute maximum values decrease with the block height h reduced. Fig.3 is obtained by the similar computation for the 6mm thick layer. The values would increase about 20 % . Consequently , the blocks can stay at the placed locations if the tensile strength of the layer is over a quarter of wheel pressure value p. This value is roughly in agrrement with the value 1/3 which is calculated under the assumption that the modulus of the layer is equal to that of a block and the layer thickness is zero (Ref.5).

4. Case Studies of Adhesive Laye

Experimental blocks of 20mm thick were placed on a road in 1983 (see Ref.1). The thickness of original layer was 3mm. The over lay was applied to the roads which suffered from severe abrasion due to the studded tires forming two troughs on the roads. No damages were found for five years after the construction. Yearly abrasion depth is between 0.5mm and 3mm. The tensile strength of asphalt adhesive was from 1.0 kg/sq.cm to 8.0 kg/sq.cm depending on pulling rate and temperatures. The lowest value was in reality in midsummer. Plate 1 shows the present conditions of the blocks. Hair cracks began to appear in 1988 as shown in Plate 2 and Plate 3. Once cracking started, cracks incresed rather quickly. Advancing rate is in accordance with the gradation of

abrasion. When the block height became less than 5mm or the maximum size of fine aggregates, it crumbled into pieces and seemed stripped out of the layer. This is because the crumbled blocks begin to move horizontally, losing the restriction and widening the joint gaps. Without crumbling, the blocks were stable throughout. In the plates, the hexagon blocks and square ones are of resin concrete which has been developped by HOKKO. Resin Development Engineering Co. Ltd.(Sapporo City). Although the adhesive strength to the layer is equal to that of Poltland cement ones, the bending strength of the concrete is 80 kg/sq.cm and showed little abrasion in the last eight years. The shape of blocks seemed less effect for their deterioration than the size. Since the objective of the overlay was to reduce the abrasion as well as the closing time of the roads under construction, the electrical heating was used with carbon fibres made of coal pitch and covered rather small area. A kerosene generator on a truck was employed for the electricity source.

5. Conclusi

a) The adhesion required to sustain thin concrete blocks can be reduced with the block thickness reduced.

b) The adhesion will increase with the adhesive layer thickness increased.

c) The adhesion can be secured by asphaltic mixtures over 2 kg/sq.cm tensile strength for the positional stability of blocks under current traffick in Japan.

d) When blocks are thined up to crumbling level , these are to be stripped off leaving the adhesive on the road surface.

e) The original size of blocks is to be minimized, in so far as the horizontal movement can be restricted.

f) The thickness of the adhesive layer is to be minimized in so far as the whole area of underneath block surface sticks to it.

g) It is possible to take the thin block surface as a concrete slab which is fully processed with cracks which are unform and of a specific shape in order to prevent the serious destruction. A larger working unit is compatible with a smaller mechanical unit, as a chocolate bar shows it.

h) The destruction of blocks is also due to cavities in the adhesive layer, followed by stripping, since the blocks above the cavities are subjected to the bending moment and the punching shear.

i) The sizable undulation on the block surface will cause the impact loading against the salients of a block. Adhesive asphalt will be evacuated on account of the impact, moving to other locations. When the motion is accompanied with the layer undulation, it will enlarged only to destruct the salients by a wheel.

j) Block stripping takes place mostly in winter, although the tensile strength of the adhesive asphalt is higher at colder temperatures. The rate of stripped blocks seems higher at colder temperatures. One of the advantages of adhesive asphalt used at higher temperatures is the recuperability in summer.

k) The electrical method was able to produce a reliable adhesion even by unskilled workers. The heating has caused no deterioration for the last eight years.

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Plate 1. DETERIORATION OF EIGHT YEAR SPECIMENS



Plate 2. CRACK BEGINNING OF FIVE YEAR SPECIMENS (HEXAGON, INTERLOCKING AND SQUARE)



Plate 3. CRACK BEGINNING OF FIVE YEAR SPECIMENS (SQUARE, INTERLOCKING AND SQUARE)

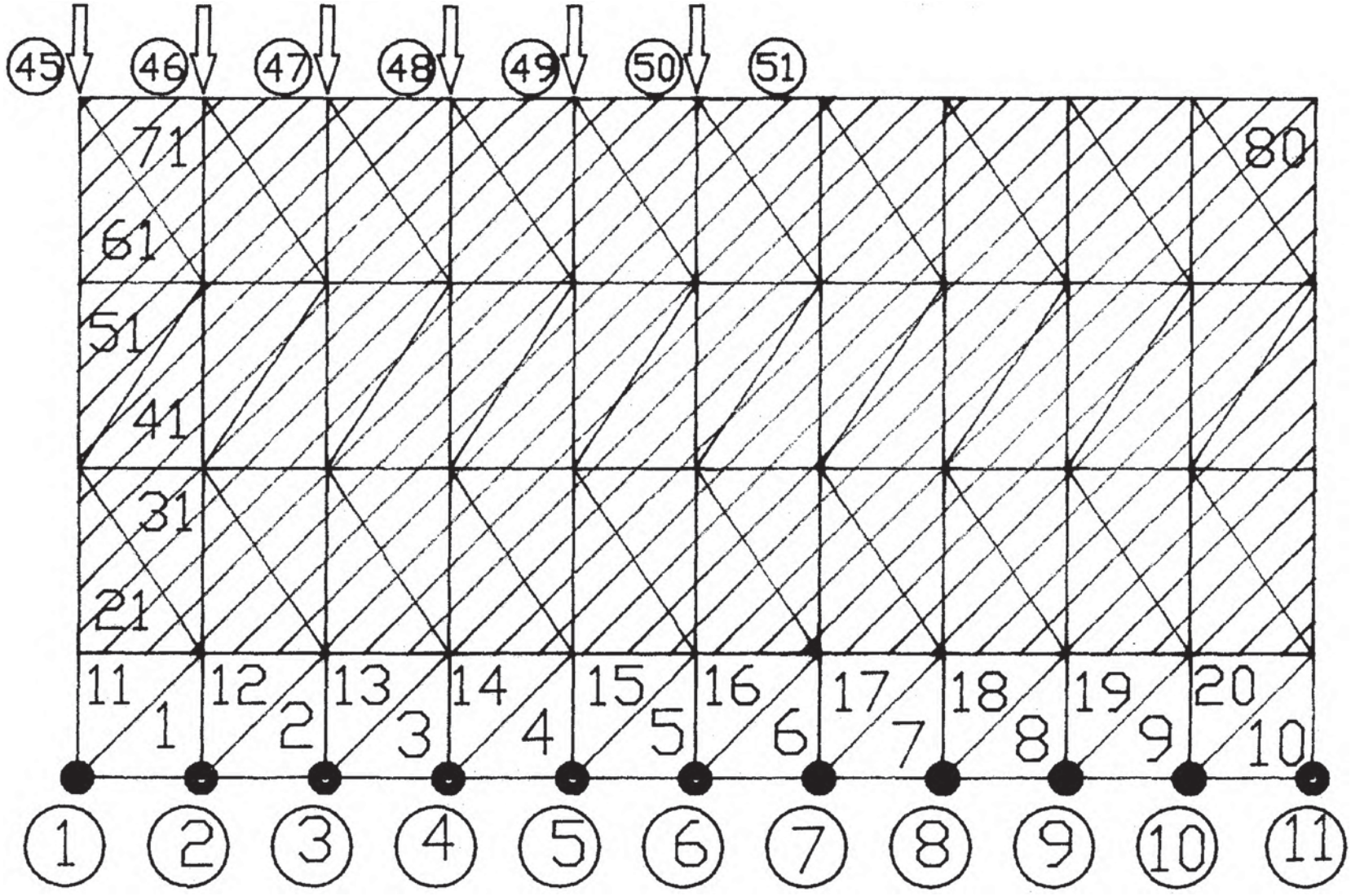

Fig. 1. ELEMETS DIAGRAM FOR FINITE ELEMENT METHOD

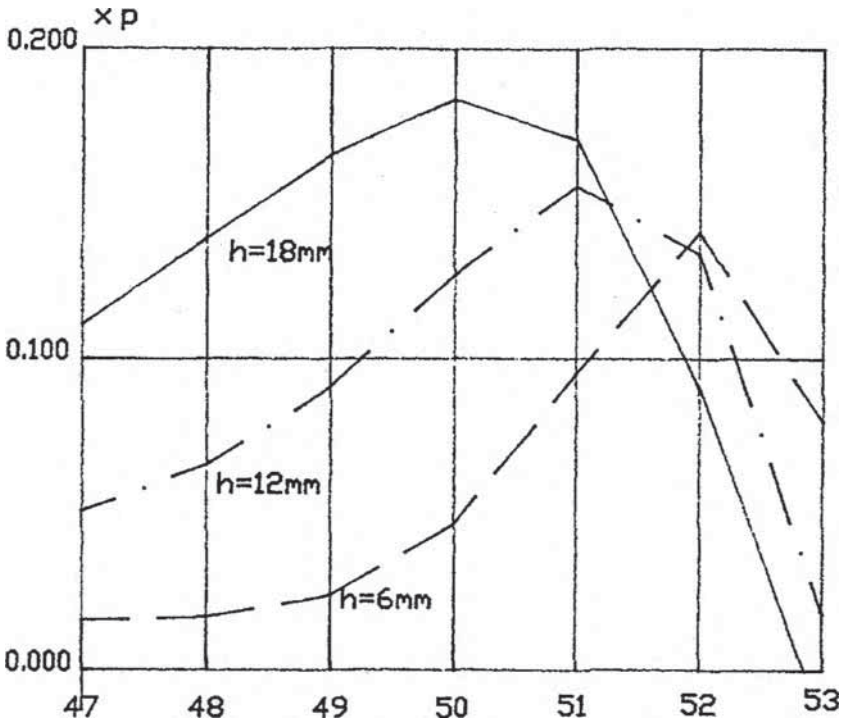

Fig. 2. VARIATION OF MAXIMUM TENSILE STRESSES OF NO.10 ELEMENT
(The adhesive layer thickness t is 3mm.)

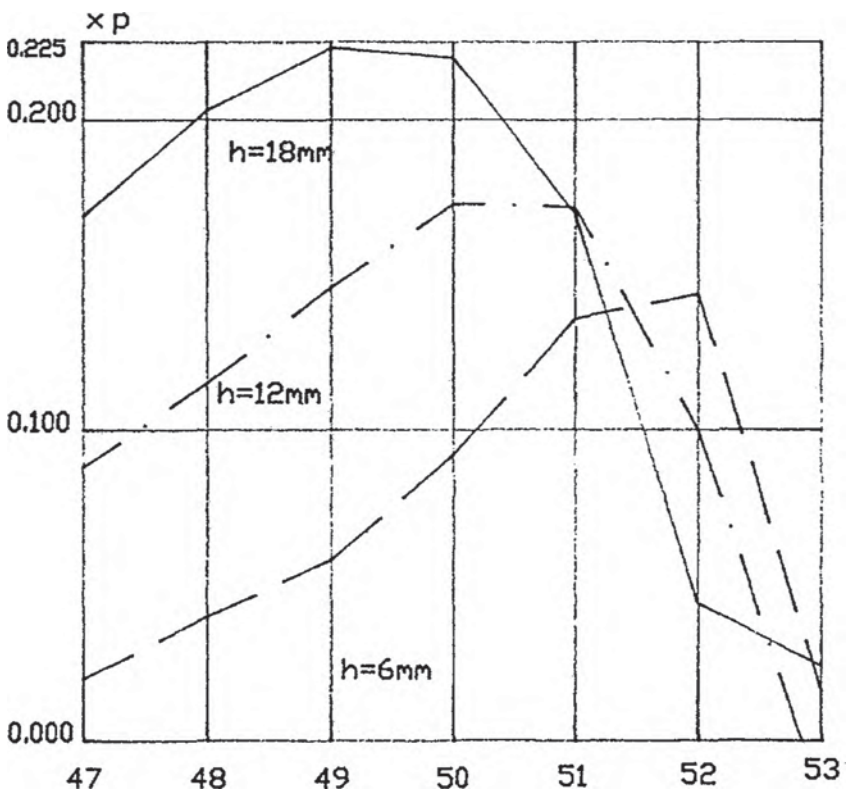

Fig. 3. VARIATION OF MAXIMUM TENSILE STRESSES OF NO.10 ELEMENT
(The adhesive layer thickness t is 6mm.)