ADHESIVE LAYER FOR OVERLAY WITH THIN CONCRETE BLOCKS

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UMMARY

'he eitheror of concrete or asphalt has been questioned for years. In the cold regions the use of studded tires and the number of cars is causing problematical rutting on the conventional roads of both materials. Thin concrete blocks covering the surface can protect vulnerable asphalt surfaces, since concrete resists rutting better than asphalt. Such a combination of concrete and asphalt can solve problems particularly due to rutting in cold regions. Concrete blocks can be considered as artificially cracked concrete panels.The significance of the artificial cracks will be discussed using a simple model. The proposal is to spread thin blocks on existing asphalt making them stick firmly using the adhesive of the asphaltic material. Thus the drawbacks of conventional pavements of concrete or asphalt can be overcome.This practice may work well as a prevention against both rutting and cracking, let alone wear resistance. This would be the appropriate share between the two --- load bearing by asphalt and surface protection by thin concrete blocks. This combination is normally the case in nature, where periodic surface replacement is a matter of course.Also in nature the adhesion between the two is critical to the success of the system. The significance of the adhesive layer between concrete blocks and the existing asphalt will be discussed by using a stress model. This study centers on the problem of adhesion, particularly the assessment of thermal effects in relation to the pot life in constructing the adhesive layer and when to open to traffic.

1. INTRODUCTION

Concrete blocks, however thin, covering the road surface can protect the vulnerable asphalt of conventional roads, since concrete is more resistive than asphaltic material. Such a combination between concrete and asphalt can solve some traffic problems particularly in cold regions. Concrete used as blocks can serve as artificially cracked concrete slabs. The significance of the artificial cracking was discussed in our previous work (Ref.1) from the view point of fractures ---proper fracturing can enhance the stability of the block pavement. If the block size is larger than the critical size, secondary stress will induce unexpected cracks,which can be avoided by prefracturing each block into smaller pieces. Fish have hard scales on their surface,but under these they have soft and flexible muscle to bear the load. Evolution has completed this wonderful combination. Concrete blocks and asphalt underneath ought to behave likewise under traffic.Our proposal is to spread thin blocks on the existing asphalt and to make them stick firmly by using the adhesive of the asphaltic material. With this system, drawbacks of conventional pavements either of concrete or asphalt can be overcome. This practice may work particularly well as to prevent both thermal flow rutting and cracking due to thermal shrinkage in winter, let alone wear resistance. The size and other characteristics of blocks can be of wide variety, depending on the problems to be solved. The choice of material would depend on the conditions in the specific site. An interesting application was made in the toll gate of Japan Highway Public Corporation in Sapporo. All cars have to stop once and start again. Therefore the surface is subjected to the severest abrasion. Photo-1 shows a place where both thin blocks and the asphalt overlay can be seen in good contrast. These blocks are resistive against the abrasion. Although these examples were completed at the same time, the difference is salient between the two after one winter's use. If the local conditions requires a much higher coefficient of friction or durability against freeze and thaw, materials such as polymar concrete of hard slag aggregates may be used. The key point, besides the material choice, is to produce the effective adhesive layers which can keep the blocks in place until the next replacement required because of abrasion or other construction work under the road. It is desirable to shorten the time for construction work at the site.Therefore the adhesive layer must change its physical property in a limited time from the plastic to the elastic. There are means to control the property change. Chemical control is one of them,but it may not be practicable, since its procedure is normally irreversible once hardening begins. A removal of blocks,if necessary, should not be difficult. Therefore control by heating may be advantageous for the thermoplastic material such as asphalt. The voluntary control of the physical properties of a material can simplify the construction in various aspects. In addition to the simple practice of block replacement for the later maintenance and other work, it would allow for the whole procedure to be flexible for sudden schedule changes or accidents. Another role for the adhesive layer to play is to prevent water seep through the base. A repetition of freeze and thaw can cause the deterioration or the volume change of soaked material underneath, as well as frost heave. Conventional blocks on a compact sand layer have occasional displacement problem in a cold region where the freeze-and-thaw problems are inevitable.

2. ADHESIVE LAYER

When a vehicle passes by,blocks are subjected to a moving load. Under the simplified assumption that the distributed stress p due to the vehicle on a block is uniform and that the deformation of the blocks is small and linearly distributed,the stresses q1 and q2 under block's ends are to pulsate. It is also assumed that the stress in the adhesive layer is proportional to the vertical displacement. Taking a block element, as shown in Fig.1,the load on the element is pbx. Thus, when

$$0<x<L \qquad (1),$$

the equilibrium equation with respect to the vertical force is

$$bL(q1+q2)/2-pbx=0 \qquad (2)$$

here b is the block width and L is the lock length.

he equilibrium equation with respect o the moment at the centre of the lock is

$$(1/2)(q1-q2)bL(L/2-L/3)-pbx(L/2-x/2)=0 \qquad (3)$$

The vertical stress at the left end where the load comes in is

$$q1=(\ p/L\ )x(4L-3x) \qquad (4)$$

The vertical stress at the right end where the load goes out is

$$q2=(p/L\ )x(3x-2L) \qquad (5)$$

When $x>L$ (6),

$$q1=p \qquad (7)$$

until the full load pL begins to reduce with the rear end of the load coming in, then the q1 curve becomes the identical to the q2 curve but symmetrical with respect to

$$x=L \qquad (8)$$

This phenomenon occurs whenever a wheel passes through on the block. When the speed is v,one quasi-cycle takes time t

$$(L+a)/v=t \qquad (9)$$

where a is the length of the load. The results are shown diagrammatically in Fig.2 ,which suggests that the adhesive layer is subject to repetitive tensile stresses. Therefore the fatigue tests are required for the adhesion.

On the actual road a block may not be mechanically independent from adjacent ones to which the stresses can be transmitted through joints. Therefore it is vital either to fill the joint gaps with appropriate materials or to introduce a curve linear joint such as of the interlocking blocks. Complicated joint lines would make it easy for the horizontal stress to be transmitted to adjacent blocks which would reduce its intensity.

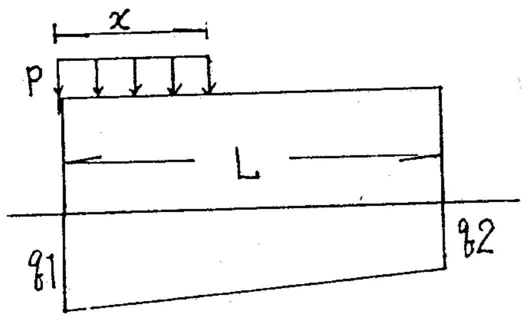

Fig.1 Block Element Diagram

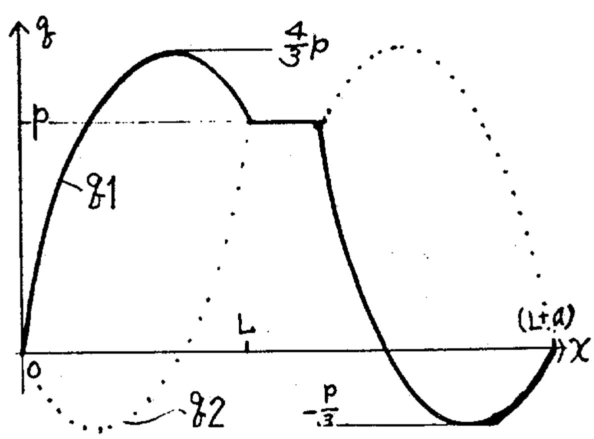

Fig.2 Stress in Adhesive

3. ADHESION

3.1 ADHESIVE STRENGTH

A mixture of asphalt(penetration grade 83) and fly ash from a power station was employed for the adhesives, since this was easy to produce and does not flow by selfweight up to 70 degree C, the highest temperatures within roads in the midsummer. The adhesion was tested with respect to the surface roughness and the working temperatures experimentally.

The scheme of the tests is shown in Fig.3.The test pieces are of the cross section of 4cmx4cm.

The strength is plotted as to these significant factors as shown in Fig.4 and Fig.5.

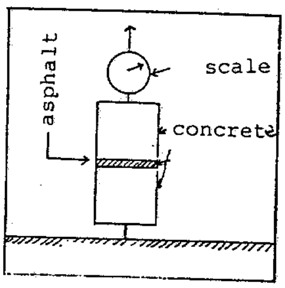

Fig.3 Test of Adhesion

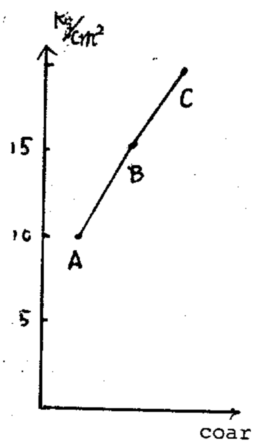

Fig.4 Adhesion and Surface

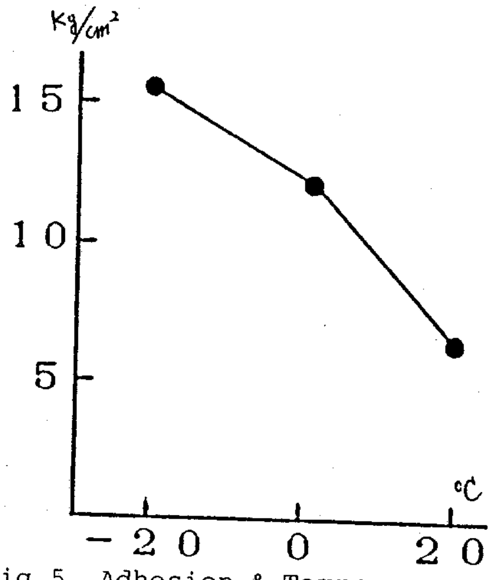

Fig.5 Adhesion & Temperatures

3.2 PRACTICE OF ADHESIVE LAYER

Insofar as heating is used fo viscosity control of the laye material, the asphaltic material may b appropriate because of its stability i physical properties and the supply The easiness of construction and th strength of blocks are dependent on th layer design. Since the adhesion an the gap filling can take place onl when asphalt is kept above certai temperatures, it is vital to secure th plasticity due to working temperature during the practice. Heating the laye materials can be carried out in tw forms---Preheating and Postheating. The preheating method, discussed in this report, is to heat asphalt before spreading, which is followed by the placement of blocks while asphalt is hot enough to be adhesive.On the other hand, the postheating is to heat the layer after the placement of blocks either by electricity or other means. In these procedures the pot life should be calculated reasonably accurately for given conditions.

3.2.1 THICKNESS

Since the elastic modulus of the adhesive layer is much lower even at the normal ambient temperatures than that of the base, the thinner layer should be desirable from a mechanical point of view in order to avoid the thermal flow causing rutting due to the high temperatures. When the thickness of a block and its material strength are given, the bearing capacity of one block increases with the base coefficient increasing. The optimum layer thickness can be extremely thin only in the condition that the lower lanes of blocks and the top surface of xisting asphalt are perfectly flat.As t is, the layer necessitates the orkable thickness not only for lugging dents on the lower surface of ach block but also for extending the ot life. On the other hand, the hicker, the more flexible the adhesive layer gets easing itself to fill the voids under the block and the longer o quench the molten adhesive in order o admit the traffic.Besides a longer erm of construction and more asphalt for the layer would raise the cost of he project.

3.2.2 POT LIFE

The pot life, a workable period of adhesive material until cooling, is the function of many variables such as the ambient temperatures. The temperature drop is relatively slow by the air cooling. Besides it may not be difficult to repeat heating, when the adhesive gets too hard to spread.

After the blocks are placed, the pot life is dependent on the heat conductivety due to the contact with the base and the blocks at ambient temperatures. For the simplicity sake it is assumed that the heat conduction is of one-dimensional system in an indefinite region of both blocks and the base as shown in Fig.6.

The equation for the temperature of v(x,t) at time t is(Ref.3)

$$\partial^2 v/\partial x^2 - (1/k)\partial v/\partial t = 0, -\infty<x<\infty \quad ,(10)$$

where k is thermal diffusivity.

If the region $-a<x<a$ is initially at temperature V and the region $x>a$ is initially at zero,

$$v=(1/2)V\left\{(\ \mathrm{erf}(y1) + \mathrm{erf}(y2))\right\}, \quad -\infty<x<\infty \quad (11)$$

where $y1=(a-x)/\ 2\sqrt{kt}, y2=(a+x)/\ 2\sqrt{kt}$

Thus, the initial temperatures are;

$$v(x,0)=\begin{cases} 0 & x<-d/2 \text{ cm... of base} \\ V & -d/2<x<d/2 \text{ ... of adhesive} \\ 0 & x>d/2 \text{ ... of blocks} \end{cases}$$

Putting a=d/2 and x=d/2 (cm),

$$v(d/2,t)-T=(1/2)(V-T)\ \mathrm{erf}(y) \quad (12)$$

where $y=d/(2\sqrt{kt})$

$$\text{Thus,}\quad y=\mathrm{erf}^{-1}(2(v-T)/(V-T)) \quad (13)$$

$$\text{Consequently}\quad t=(1/4ky^2)d^2 \quad (14)$$

Suppose the layer material loses its adhesion at v=50 C(or flexibility limit), thepot life time y, for the adhesive surface to get to the time limit can be calculated according to the error function table(see Ref.2),as shown in Fig.7.This graph shows the pot life time t in minutes to the adhesive thickness for the given temperatures of the blocks and the base. The pot life governs proper time to use the roller to strengthen the adhesion between the blocks and existing asphalt. Otherwise the roller can damage the blocks,even though the drum might be covered with rubber. The roller compaction should be carried out definitely while the adhesive layer can stick to.

The extended pot life is normally accompanied with the extended closing period. Particularly when the layer is thick, the layer deformation may take place when opened too early.

3.2.3 PROCEDURES

General procedures are shown inPhoto 2 to Photo 7.

3.2.4 CASE STUDIES

a.Case A : Thin blocks were applied to the bridge slab.When the ambient temperature was 35 degree C and both the base and concrete blocks were left at the temperature, the adhesive layer, a mixture of asphalt and sand, which was to be 23mm thick, was spread at 160 degree C over the existing asphalt in order to construct the thin block overlay. The actual pot life, which was approximately one hour in good agreement with the curve in Fig.7, enabled a full compaction, leaving little voids under each block, although the block size was comparatively large,60cmx100cm. This overlay seems good after the survival of two winters.

b.Case B : When the ambient temperature was 0 degree C, the practice, using the adhesive layer 3mm thick, was carried out in the way similar to the previous case. The pot life was 10 to 20 seconds. Therefore, under some blocks, the adequate compaction was not possible only to cause cracks of the blocks,although cracking per se may not cause any traffic trouble.

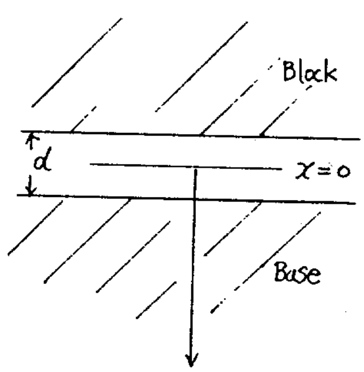

Fig.6 Conduction in Linear Flow

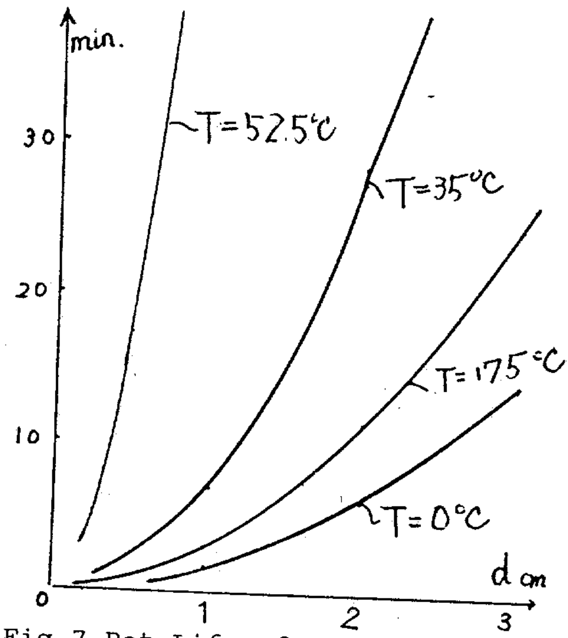

Fig.7 Pot Life of Heated Layer

5.CONCLUSIONS

1.The adhesive strength of the lay should be greater than one third of t compressive pressure caused by t traffic load. Its empirical lower lim seemed about 2 kg/cm.The coars texture of block surface may increa the adhesion.

2.The adhesive layer should be durab to the fatigue due to alternat stresses accompanied with other adver effects such as freezing and thawin Some of the laminated materials may no exert a long term adhesion.

3.The optimum thickness of the adhesiv layer should be given as the minimu from the unevenness of block surfac and the pot life. The thicker, th more vulnerable to various rutting i use.

4.The pot life of the adhesive layer i the function of time, the layer thickness, the initial temperatures anc the ambient temperatures. The eoretical pot life,which can be in od agreement with the actual one, may calculated using the diffusivity 0.0042.

Postheating, if available for the in adhesive layer, could shorten the osed period, simplify the whole eration and ensure the durability of e thin blocks overlay. In order to oid such faults, the postheating by ectrical means is desirable, only if on-off operation of switching can ntrol the material property.

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Photo 1. Comparison between Thin Blocks and Asphalt (by courtesy of J.H.P.C.)

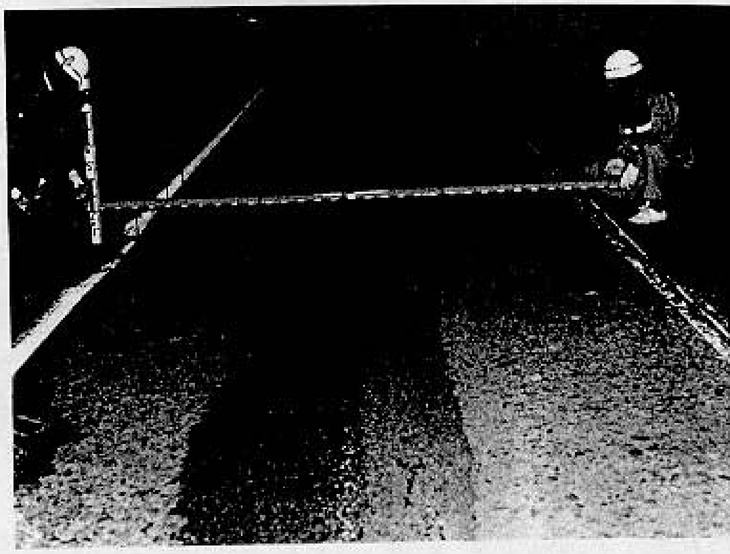

Photo 2. Preparation

Photo 3. Layer Construction

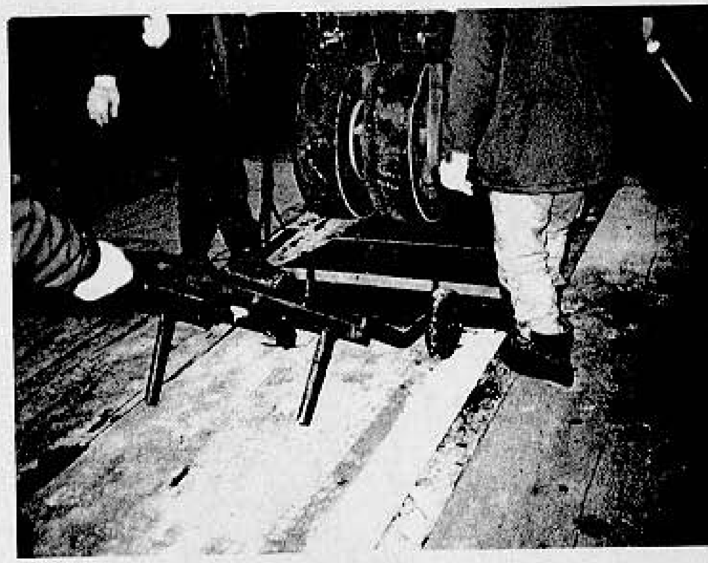

Photo 4. Block Placement

Photo 5. Roller Compaction

Photo 6 . Finished Blocks

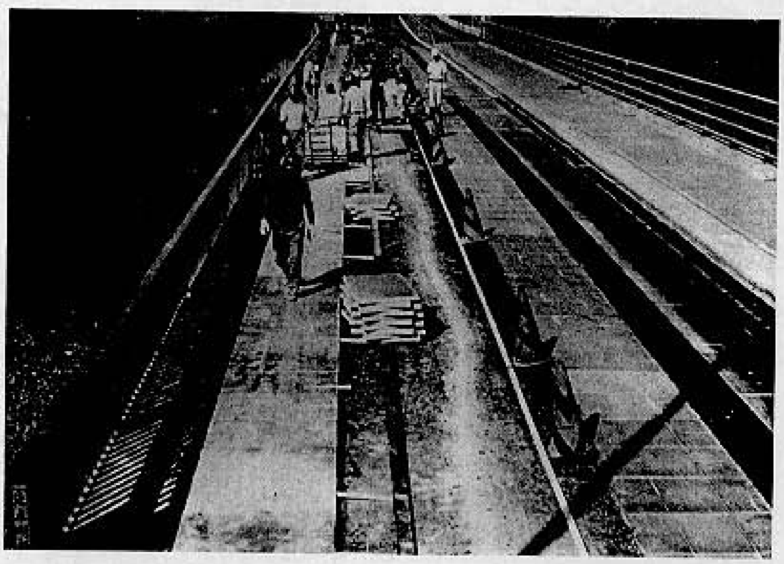

Photo 7.Blocks on Bridge