FUNCTIONAL BLOCKS FOR DEICING

M. Inuzuka
Hokkaido Institute of Technology
Sapporo, Japan

S. Nagata
Hokkon International Precast Concrete, Inc.
Sapporo, Japan

Summary
Rubberized concrete blocks that include a deicing function can be used where icy roads are a problem. These blocks, which will form the road surface, will be attached via an adhesive layer to a water tight foundation. This will allow them to shift as vehicles pass over the blocks. As the blocks move or shift slightly, two things happen: 1) the solid ice on the surface of the block is crushed into smaller pieces; and 2) the surface of the block is supplied with a freeze-prevention liquid. The thawed ice may flow into the spaces between the blocks, locking them together to defeat the purpose of the design. To circumvent this, a system is proposed that will prevent ice from forming between the blocks and effectively locking the blocks together. Experiments that have been conducted under varying conditions to remove this ice are discussed.

Introduction
Skidding on icy roads is a serious problem at any time but it is especially so in cold regions. Various anti-skid devices and methods currently in use to inhibit skidding cause road surfaces to deteriorate prematurely, including the formation of irregular grooves or ruts from metal chains on wheels and rusting of the steel reinforcing rods from the deicing agents spread over the road surface. If the ice can be removed with the aid of passing vehicles (or rendered harmless by changing its state) the aforementioned difficulties may be alleviated and traffic safety will be enhanced. The environmental pollution that results from the use of common deicing agents may also be mitigated.
In the past, roads were considered satisfactory if they performed their basic function of providing sufficient load bearing capacity for the designed load. With the new technology available today, it is possible to design special road surfaces to meet the specific demands of man and nature. Block paving fits these requirements because the individual components can be produced accurately and in sufficient quantities in manufacturing facilities that exist today and which are quite capable of integrating this new technology into their normal into their regimen.
The special problem for this design is road icing: a many times unpredictable phenomenon and one that must be dealt with promptly; and with at least a modicum of success. Today, some of the best tools we have are the snow removal equipment, which stands on alert throughout the cold winter periods, ready to push the snow aside and spread deicers across the

surface of the road. The economic and environmental costs of this system are high and it is not uncommon for the present equipment to be involved in accidents.

Another way of looking at the basic problem is to pose a question: can the passing traffic help in alleviating icing; and if so, to what extent? With regard to the former and if this were possible, then much of the energy required would come from the passing vehicles that are normally using the road anyway, which in turn would reduce the need for externally-applied energy that derives from the utilization of special maintenance equipment. We know from experience that today's equipment provides only a partial solution because of their limited mobility, especially in heavily traveled areas.

One of the weak points of the current system is the use of chemicals (such as salt) to counteract the effects of road ice. Excessive amounts may be used, which are bound to affect the environment adversely, because we do not have a controlled system that will retain the deicing agent at a particular place for a designated period.

This paper and the experiments already conducted center on the development of a new system to crack and remove road ice by utilizing a special deicing device that works concomitantly with the passing traffic. The system combines concrete blocks with a deicing liquid agent to accomplish this. It is all explained in detail in the following paragraphs.

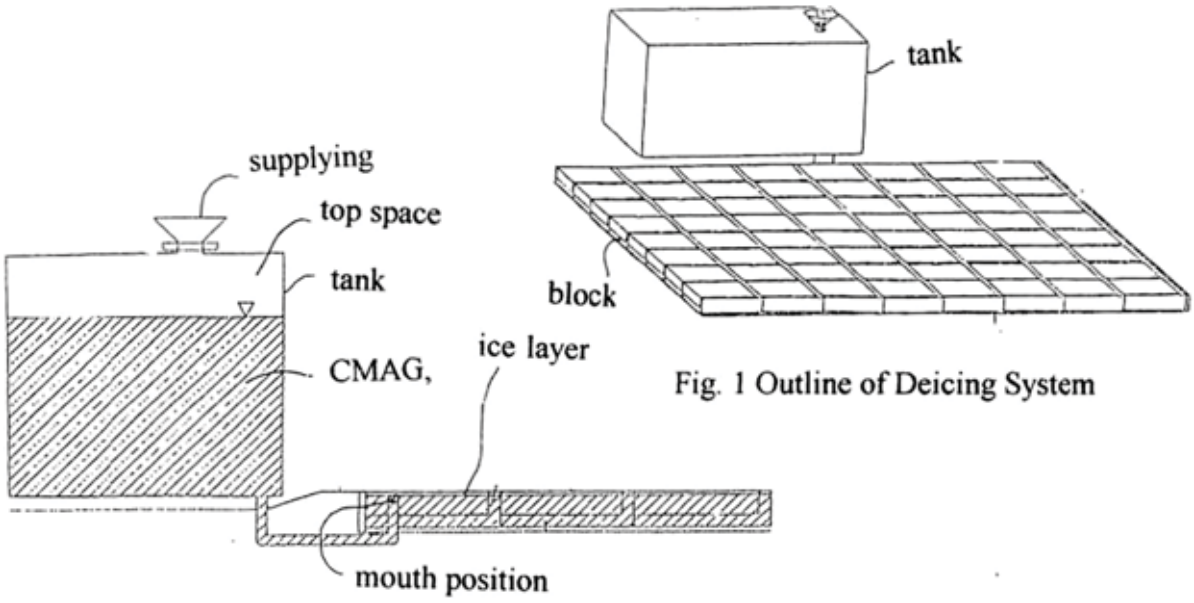


Fig. 1 Outline of Deicing System

Fig. 2 Cross Section of System

Functional Block System

An outline of the deicing system model is shown in Fig. 1 and its cross section in Fig. 2. The tank supplies the joints and the base with a deicing liquid. The head of the liquid is kept constant by closing the top of the tank and maintaining the mouth position of the supply pipe at the same level. As the liquid is consumed or evaporates, compensatory amounts are pumped from the tank. Each block is on an elastic rubber base that is made of granulated tires, which will deform under tread pressure. The joints between blocks are formed with rubber sheets, also made of granulated tires.

The blocks are arranged and fixed with a bituminous membrane in a shallow box. The tire treads of passing cars will press against the block, which in turn forces the liquid onto the surface of the blocks. When the snow on the surface of the road turns to ice (or is ice to begin with), passing vehicles will cause the ice over the lines formed by the joints to crack. The deicing liquid, together with the repeated stress on the surface from the passing treads will

then cause the sheets of ice, which have now been separated along the block joinsts, to be ripped away.

Theory

The layer of ice can be assumed to be an infinite plate on an elastic foundation. When the contact pressure q of a circular tread is uniformly distributed the differential equation for the plate with respect to the deformation w is:

$$\frac{\partial^4 \omega}{\partial \chi^4} + 2\frac{\partial^4 \omega}{\partial \chi^2 \partial \gamma^2} + \frac{\partial^4 \omega}{\partial \gamma^4} = \frac{q-p}{D}$$

where

p = reaction pressure on rhe lower ice surface

D = flexural rigidity of the ice plate - Eh/12(l-l/m)

E = Young's modulus

1/m - Poisson's ratio

h = ice thickness

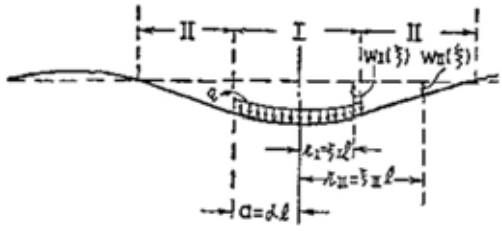


Fig. 3. Ice Layer Deformation

The general form of the solution, given by Kubo [1] and other researchers, is shown in Fig. 3. Because the tire tread moves, the ice is subject to alternate stresses until it cracks, reducing the strength due to fatigue.

Deicing Agent

Many kinds of chenucak agents, such as sodium chloride, have been used for deicing. Some of them are harmful to the environment. Most of them are produced in either a powder or granular form. It is said that CMA, composed of calcium, magnesium, and acetic acid, is less damaging to the environment. When CMA is combined with glycerin, it makes a liquefied deicer, CM AG, which has been proven to be safe on concrete blocks in preliminary freeze-thaw effect tests, this CM AG has been adopted for use in the deicing system in this experiments.

In conventional operations, deicing liquids will not remain on the road very long. However, inside a controlled system, it will remain much longer, thus avoiding excessive use. To provide the optimum amount per vehicle, the liquid level in the system must be adjusted properly.

Deicing Procedure

Once a crack has formed, the ice layers in the areas adjacent to a crack line are subject to a magnified punching shear from the moving tire treads. The result us a layer that has become divided into smaller layers contained wthin the fault lines, i.e., the joint lines between adjacent blocks. If the adhesive force between blocks and ice is weak, the piece of ice will separate from the block and fall away. Thus the key to success is to reduce this adhesive strength. Preliminaru tests have shown that smoothing the block surface is effective. Additional reductions in adhesion can be attained by covering the surface of the block with liquid or finishing it with resin.

Experiments

Laboratory Tests

Cracks in Ice The tests were carried out using the full orthogonal design of experiments L27 [2] , where the factors and levels are as given in Table 1. Each specimen covered with ice of a given thickness was tested under the designated conditions.

A sample deicing unit consists of 9 basic blocks, as shown in Figure 4. A tire tread at 170 kgf was pressed against the center of the specimen at -4 degrees C. The extent of deicing is indicated by the total crack length in one unit. The cracks were marked by a felt tip pen, as shown in Figure 5. The crack length was measured with a cyclometer or skiddometer. A distribution analysis found that 3 factors were statistically significant.

Liquid Oozing Recall that the deicing agent is expected to play two significant roles: first, to cause the ice to be tom from the road surface; and second, to prevent icing between blocks. If the agent functions effectively, the blocks will shift in accordance with the flow of traffic over them and icing will be inhibited.

Oozing for a given depth of deicing agent was determined under similar conditions by measuring the lost weight from a unit subjected to the passage of a tire. The test results are shown in Fig. 9. This curve gives information on the design with respect to the proper volume for the deicing supply.

Table 1. Factors and Levels for Crack Length in an Orthogonal Design

factor	**Level 1**	**Level 2**	**Level 3**	*test conditions (unit)*
A	10	20	30	*ice thickness (cm)*
B	4	2	0	*liquid depth (cm)*
C	1	3	6	*repetition times*

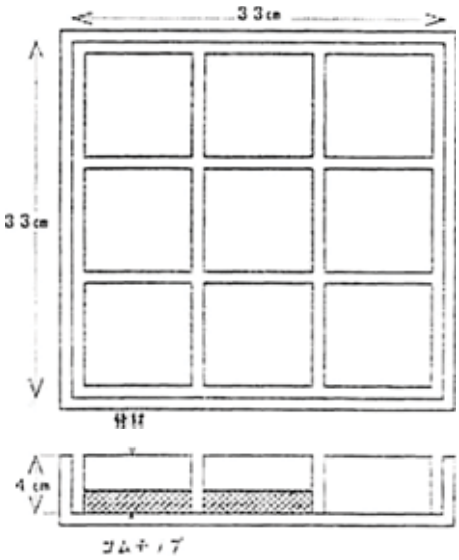


Fig. 4 Design of the Deicing Unit

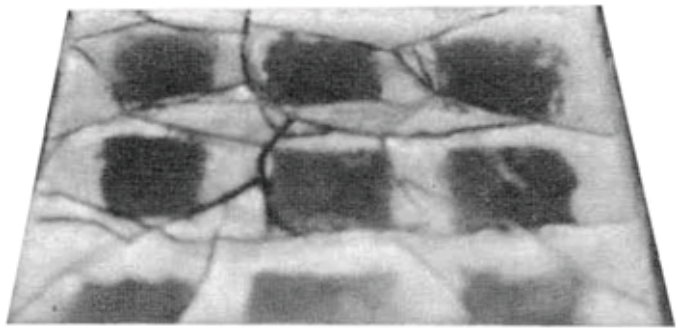


Fig. 5 Cracks in Surface Ice

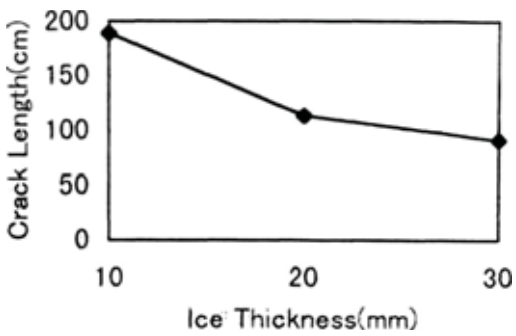


Fig. 6 Crack Length and Ice Thickness

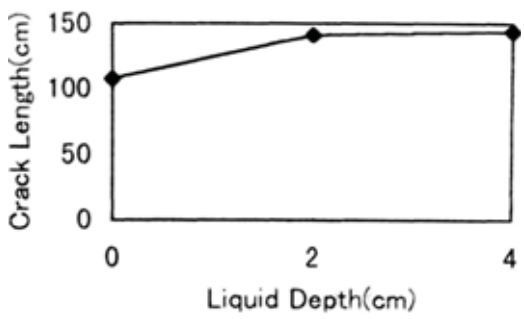


Fig. 7 Crack Length and Liquid Depth

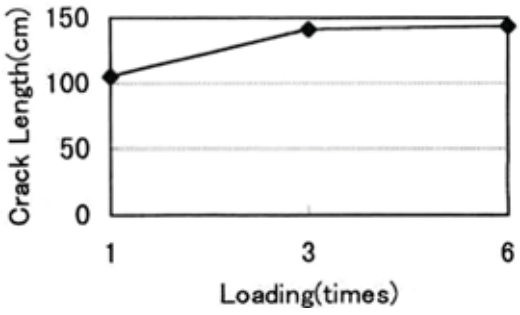


Fig. 8 Crack Length and Load Repetition

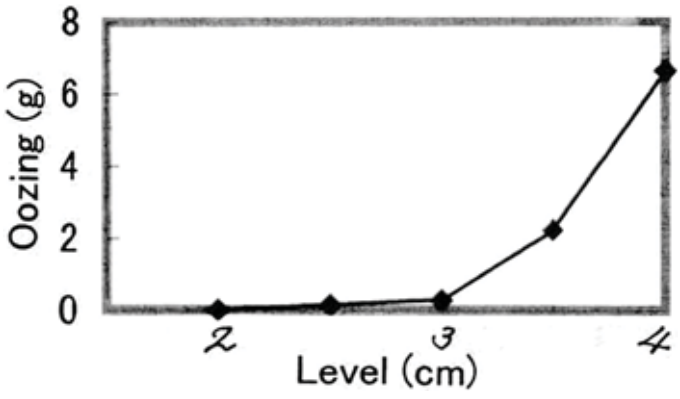
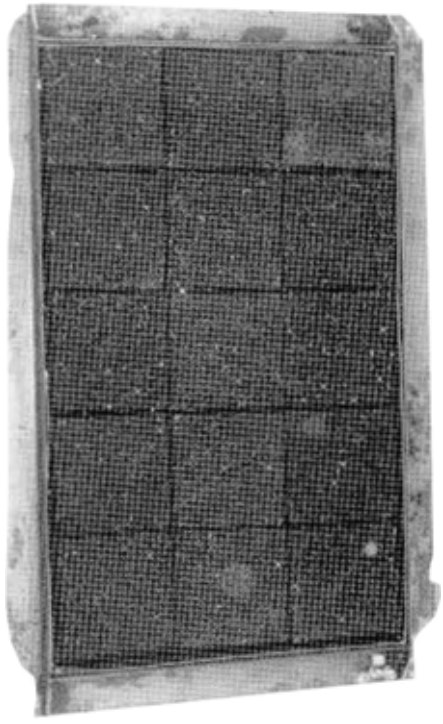


Fig. 9 Oozing and Deicing Agent Level

Outdoor Experiments

The system constructed on existing asphalt is shown in Fig. 10. A light lorry with 170 kgf at each tread was repeatedly moved over the specimen under conditions similar to those used in the laboratory. The total crack length increased, as shown in Fig. 11.



a. Unit



b. Ice Layer

Fig. 10 Outdoor Crack Tests

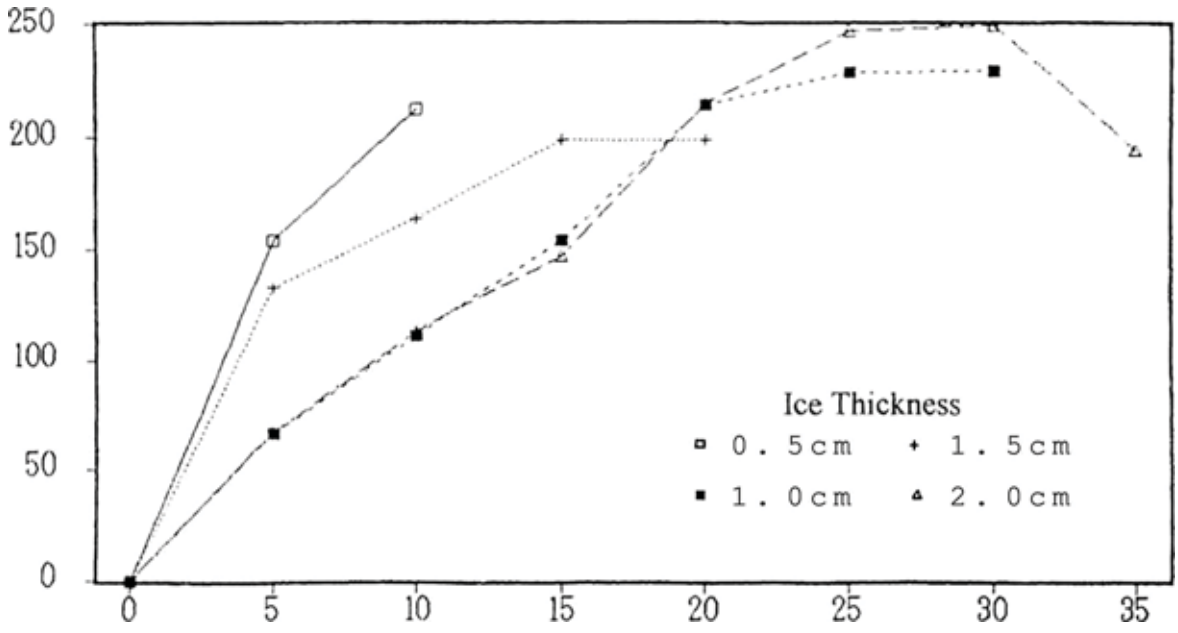


Fig. 11 Crack Length and Load Repetition

Discussion

A sudden temperature drop after ice thaws will give rise to black ice, a winter driving hazard. This may be the most adverse condition that drivers will face. Black ice removal is one of the objects of these experiments, in which it was removed after a certain number of loadings. The total length of the cracks could be increased to the critical limit, which caused ripping due to the repetitive stress created within the ice. This is shown in Fig. 12 where the left hand side is subjected to ripping.

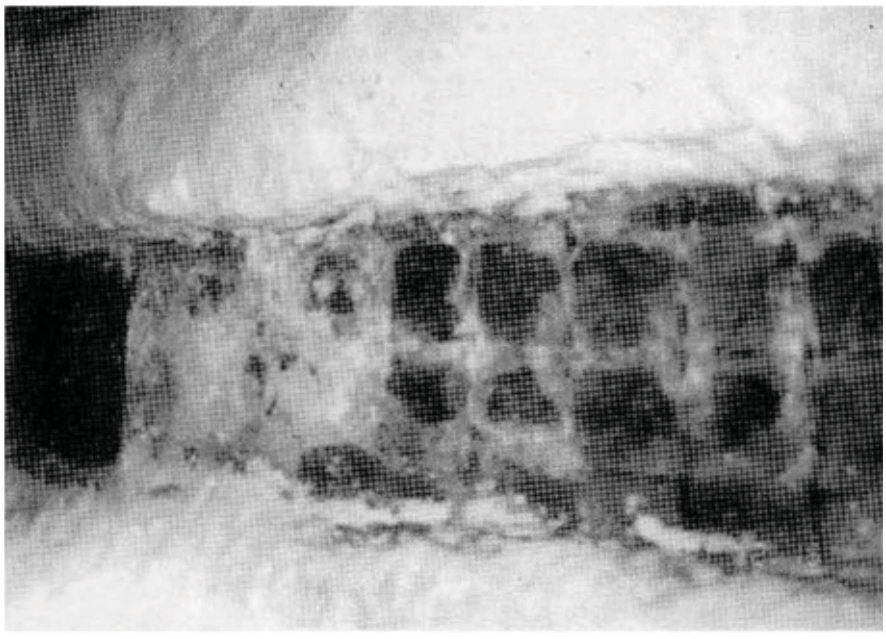


Fig. 12 Ripping and Cracking

The pumping action due to the rubber deformation accelerates the process, suffusing the surface of the block with the deicing agent to reduce ice adhesion. Because the subgrade coefficient of rubberized blocks is 120 kgf/cub.cm and the distributed stress of the tread is about 2 kgf/cub.cm, the maximum stress is relatively small; and particularly after the cracks are joined together (i s., become interconnected) and surround some blocks, load stresses will diminish. This mechanism is similar to the stresses that develop in concrete blocks where an enlarged block size is accompanied by a maximum stress that is reduced under the same tread pressure (3)

The experiments also demonstrated that increases in crack length will stop when the ice begins to come off. Regardless of the volume of the deicing agent supplied, the total length of cracks for the initial removal of ice appeared to be constant. Loading repetition Seems to press it out when the size of the section of ice becomes smaller than a certain size.

This sequence of events can be inhibited from occurring by the adhesion between ice and paving block; therefore adhesion reduction by utilizing an oozing (deicing) agent is required.

The experimental results also suggest that the mobile load is accompanied by horizontal pressure — due to the geometrical discrepancy caused by the ice deformation — because removal did not occur when ice thickness reached a certain limit. Greater deformation or sinking of the rubberized block was necessary to raise the limit in the present loading intensity.

It was not easy to cover the outdoor system with experimental black ice, particularly when the deicing was prepared before the ice had formed The ice deformed and disappeared while the cover ice was in the making. Thus the core ice had to be made of snow and the surface was finished with a water spray to make the ice layer. This may prove that the system could prevent black ice under the condition that the deicing agent is supplied without dilution.

In some cases, heavy snow may fall on a busy road over a short period. Packed snow will soon turn into solid ice at subzero temperatures. The ice cracking mechanism should be equal to what has already been discussed above. In our experiments, the storm sewers or road drainage facilities were found to be vital. If the water from thawed ice remains on the paved surface, the agent will lose its capacity because of dilution. Therefore the excess water must be continuously removed; otherwise diluted water will turn to ice and connect all blocks into one large interconnected piece of so-called ice concrete, which will be a coarse aggregation of blocks that is very difficult to remove.

As the tire passed over blocks, it picked up some of the deicer and carried it forward to form a trail for quite a distance. This may be called a “padding effect" because it is similar to that incurred when an inked stamp pad is employed. Thus vehicle tires can play the role of a stamp to spread the deicing fluid. This suggests that the system may not have to cover the entire area under consideration because of this carry-over effect. The “trailing distance” depends on the agent level in the system and surface conditions of the area adjacent to the system. However, an ice-covered surface tends to extend the distance. Obviously the deicing liquid agent can be wasted, unless the supply is controlled in accordance with the ambient temperatures. A spongy material which is of a high temperature coefficient and permeable to the agent only under the icing point may be fit rather than some electrical sensor -controllers in the supplying pipe.

The freeze-thaw test proved that the rubber specimen remains intact in water, although durability tests with the deicing liquid agent still remain to be accomplished.

The agent supply function may also be used in other seasons to spray water continuously for a given period to inhibit dust accumulation or to clean lorry tires at a construction site. Blocks produced in masse in a manufacturing plant should be suitable for the implementation of a variety of tasks because their normal controls turn out products that meet high quality standards

Other functions, such as lowering the noise level, seem promising because rubberized blocks (with the rubber side facing upward) are commonly utilized for noise reduction. The inversion may reduce the deterioration of rubber part Except for the surface condition, inverted ones should have similar physical properties.

Conclusion

A combination of concrete blocks, an elastic base, and a liquid deicing agent in the present system can work together to prevent ice from building up on road surfaces. The serviceability of the road under these adverse conditions depends on the supply of the deicing agent, the key to the maintenance of the deicing function. Even if black ice forms, its removal seems to be possible with the passage of 20 to 50 cars, under the following conditions: the deicing liquid is deeper than 2 cm; the ice is not thicker than the depth of the liquid; and the excessive water that forms atop the blocks (i e., the road surface) due to the thawing of the ice can be flushed away. It should also be noted that the exact number of vehicles required to cause the removal of black ice depends on other factors such as the ambient temperature.

Reference

1. Kubo,Y. ''Introductory Remarks on Iecology Engineering." (Hyoukougaku Gakkai Kankoukai,Tokyo, 1980)
2. Taguchi,G."Design of Experiments."(Maruzen,Tokyo, 1962)
3. Inuzuka,M.and Sato,I.''Concrete Block Pavements on Asphalt Highways." Proc, of 2nd CBP Int. Conf. (1984) 322-329.