A STUDY ON POROUS ASPHALTIC CONCRETE MIX AND ITS VALUE IN PAVEMENT CONSTRUCTION

by

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ABSTRACT

The factors affecting the porosity of a porous asphaltic concrete mix was studied and the effect of these on its Marshall Stability was evaluated. Based on the results of porosity and stability tests of several mixes, the value of a porous mix design to porous pavement construction is presented.

INTRODUCTION

A porous pavement is a pavement whose surfacing is permeable to water. Normally, an ordinary pavement surfacing, whether portland cement concrete or an asphaltic concrete surfacing, should protect the underlying layers, the subbase and the subgrade, from the penetration of water from the surface. The penetration of water into the subbase and subgrade layers severely weakens their bearing capacity and causes the pavement structure to fail earlier in its designed life and capacity. Thus the strict requirement is that a pavement surfacing should be impervious.

A porous pavement has much voids in it that it has the capacity to store rainwater until such a time that it is returned back to the atmosphere by evaporation and to the ground by infiltration. In one study[1], a porous asphaltic concrete was found to be the optimal porous road material to use to alleviate combined sewer overflow pollution and reduce the design parameters of storm sewer systems. This was due to its capability to store a considerable volume of a rainfall, thus reducing the volume of the surface runoff. In that study, a very strong subbase material was used such that the effect of percolating water from the surfacing was not a detriment to the bearing capacity of the pavement. In addition, the design CBR (California Bearing Ratio) used for the subgrade was 2%, a very conservative value for a pavement subgrade at its weakest condition.

Sidewalks, parking spaces and playgrounds are examples of pavements that do not require a high bearing capacity. These types of pavement do not carry as much individual wheel loads as highway pavements do, and therefore, expensive high quality subbase materials is not a strict requirement. ordinary subbase materials in their submerged condition are often sufficient to withstand the light traffic normally applied to them. For these types of pavement, a porous surfacing may be used without much additional expenses for a better quality of the subbase layer.

The reasons for desiring a porous pavement surfacing are manifold:

1. It eliminates the problem of ponding over the pavement surface after a short rainfall.
2. It enhances better growth of vegetation in its vicinity (for sidewalks).
3. It prevents ground settlement by putting back water into the clay layer.
4. It alleviates future water shortage where the water source is groundwater.

The abovementioned reasons are only the water permeability-related good effects. Other desirable properties of an asphaltic porous pavement material is that it offers a very promising colored pavement, it reduces noise created by tire-pavement contact during rainfall, increases pavement visibility and a higher skid resistance.

The purpose of avoiding ponding especially in areas traversed by pedestrians could otherwise be achieved by a careful consideration of the gradient of the pavement surface. This could easily be achieved in sidewalks, but for wide areas, it may not be as easy, and normally, several drains may be needed. The other good effects are not likely to be achieved when using a non-porous pavement.

OBJECTIVE

The two most important properties of a porous pavement surfacing are porosity and stability. The specific objective in this research is to make a study of the factors that control the porosity of an asphaltic concrete mix, and the effect of these factors on the stability of the mix.

TEST PROGRAM

The most important properties desired in the surfacing of a porous pavement are stability and porosity. Both these properties can be tested from a Marshall test specimen. The most probable parameters affecting these properties are:

1. The gradation of the aggregate mixture

2. Asphalt content of the mix

3. Degree of compaction of the mix

To observe the variation of porosity as affected by the gradation of the aggregate mixture, different mixes varying the sand and coarse aggregate components were tested. The coarse aggregate component was varied from 5 to 20% (at 5% intervals) by weight of the asphalt mix in combination with a variation of the sand component also from 5 to 20% (at 5% intervals) by weight of the asphalt mix, making a total of 16 mix combinations. The pea gravel component was adjusted to complete the mixture. Each mix proportion was mixed with asphalt contents ranging from 4.0 to 6.0% by weight of the asphalt mix at intervals of 0.5%. Three test specimens were prepared for each asphalt content.

The gradation curves of the mixtures were compared with the specified limits for a gap graded mix of other agencies (Fig. 1a and 1b). It can be seen that the mix combinations tested are closely identified with the California specification for a gap graded mix. The mix combinations contain smaller coarse aggregates as compared with the JIS (Japan Industrial Standard) specifications for an open graded asphaltic concrete.

The asphalt concrete mixtures are labelled by their aggregate components, e.g., 10-70-20 means 10% Coarse aggregate, 70% Pea gravel and 20% Sand components.

In preparing the test specimens, the ASTM D 1559, Resistance to *Plastic Flow of Bituminous Mixture Using Marshall Apparatus*[2], was followed, with the following control conditions:

Mixing Temperature:	146-151 °C
Compacting Temperature:	135-140 °C
Compaction Blows:	35 per face

The stability of a specimen was tested using this method, and the porosity was measured using the principle of a falling head permeameter. The scope of work for each mix combination is as follows:

1. Aggregate Blending

2. Preparation of Test Specimen (ASTM D 1559)

3. Density and Voids Analysis (ASTM D 1188)

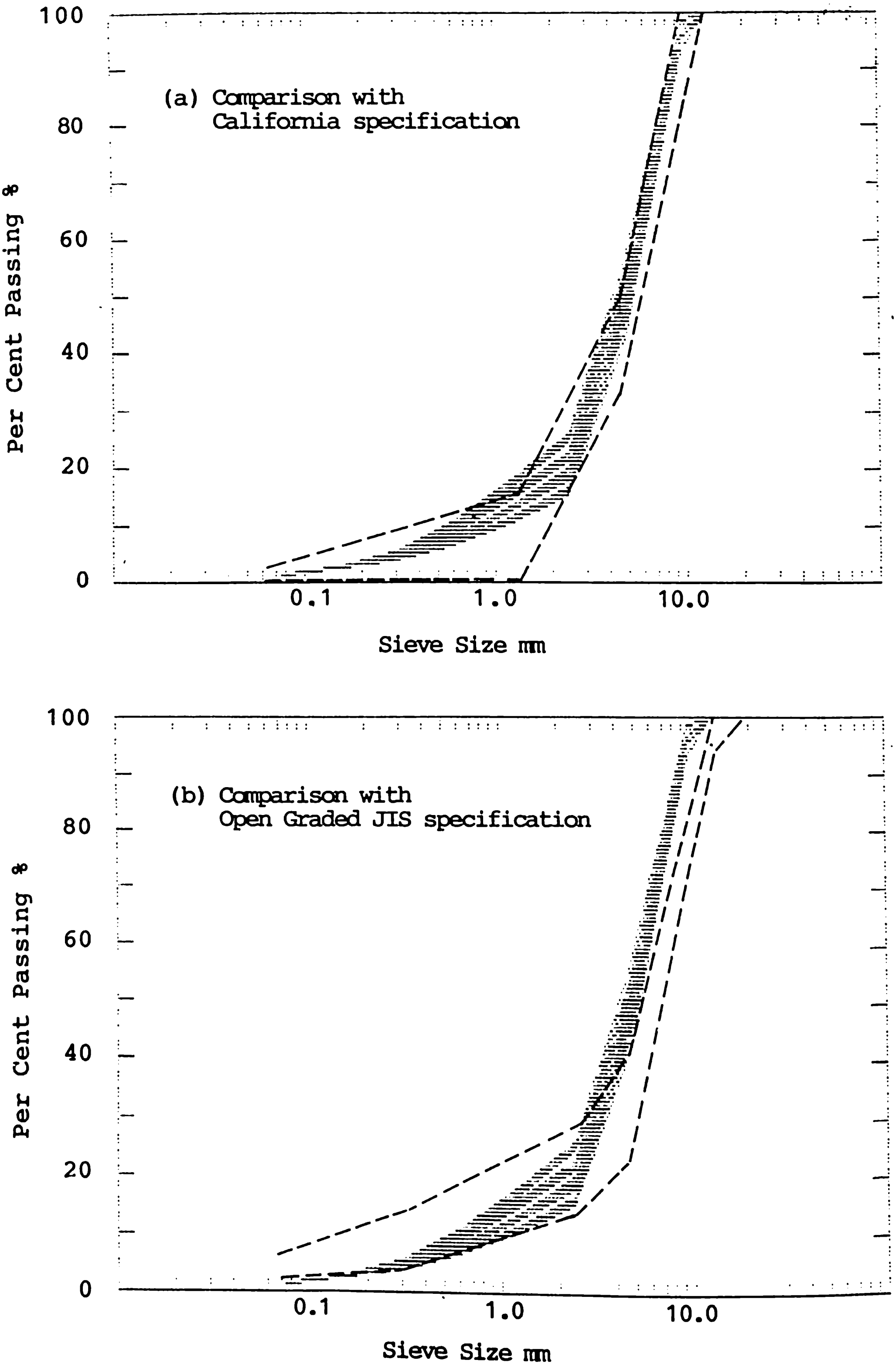

Figure 1. Test Program Aggregate Mixtures

4. Porosity Tests (Falling Head Type Permeameter)

5. Marshall Stability and Flow Tests (ASTM D 1559)

TEST MATERIALS:

The aggregate mixtures were proportioned from three sets of aggregates.

Coarse aggregates, 3/4 in. max

Pea gravel, 3/8 in.

Sand, washed and screened

These aggregates were purchased from Phil. Rock Products Inc. The portion of the coarse aggregates retained in 12.7 mm sieve, as well as the portion of the pea gravel retained in 9.52 mm sieve were discarded, and the sand was utilized as it was. Their individual gradation curves are shown in Fig. 2. The asphalt binder used was a penetration graded AP 85/100 purchased from Petron Corp.

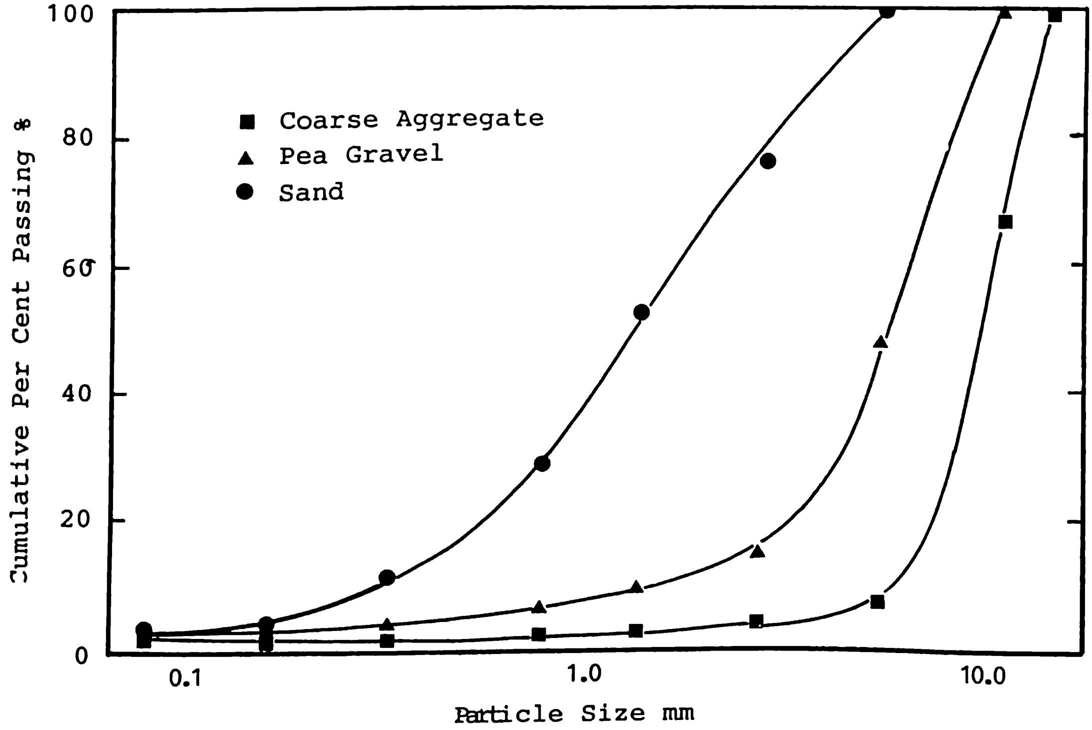

Figure 2. Aggregate Gradation Curves

TEST RESULTS

Porosity

The porosity tests on the different mixes show that the porosity of the asphalt mixtures are notably dependent on the gradation of the aggregate blend and on the amount of asphalt binder.

One single factor that affects the packing of an aggregate mixture is the distribution of the particles or aggregate gradation. As in a soil mass, the porosity of a compacted asphalt mixture depends largely on the packing of the coated aggregate components, hence the effect of aggregate blend gradation. The manner of packing of the aggregates determines the amount of voids. The voids can be decreased by filling it up with finer particles. Therefore, increasing the amount of finer particles reduces the amount of voids and increases the degree of packing, resulting to a decrease in the porosity of the compacted mix.

The asphalt in the mix acts both as a binder and a lubricant. The amount of binder in any asphalt mixture affects its workability, and for the compacted material, its stability and porosity. On a lean mix of 4.0%, a high percentage of voids is expected. Increasing the amount of asphalt facilitates the rearrangement of the particles for a denser compacted mix. Further increase of the binder fills up the voids. The general effect of increasing the binder content is to lessen the amount of voids in the compacted mix, and therefore, a tendency to decrease its porosity, until the mix becomes practically impermeable.

The results of porosity tests on the different test specimens are plotted in two arrangements shown on Figs. 3a and 3b. The first arrangement shows the variation of porosity as affected by increasing the sand component, while the second arrangement shows the account in increasing the coarse aggregate component.

The first arrangement, Fig. 3a, shows the pronounced effect of increasing the sand component on the porosity of the specimen. At almost all binder contents, the increase of sand component consistently decreases the porosity of the specimen. However, at 20% coarse aggregate, the increase in sand content does not seem to decrease the porosity, which for this case are already very low, except at 4.0% asphalt content.

The second arrangement, Fig. 3b, shows the inconsistent effect of gradually increasing the coarse aggregate component at fixed sand components. Expectedly, the increase of larger particles would create more voids in the packing of the aggregate mixture, and therefore an increase in porosity. But in this case, for an increase in the coarse aggregate, there is a corresponding decrease in the pea gravel (consisting of about 45% particles retained in 4.76 mm sieve). As can be seen, the effect seem to be the opposite of what is expected, and there is no

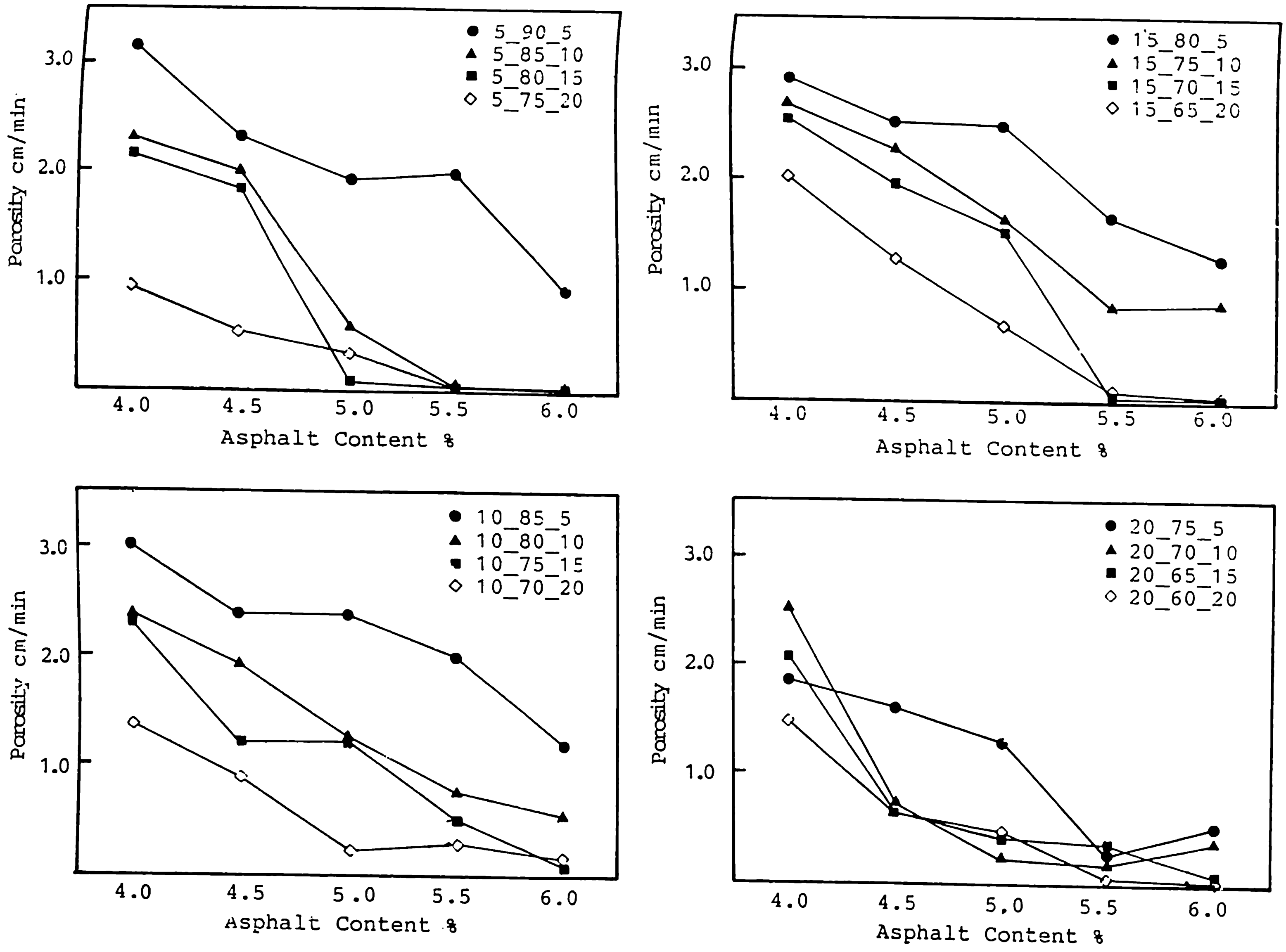

Figure 3A. Porosity at Variable Sand Component

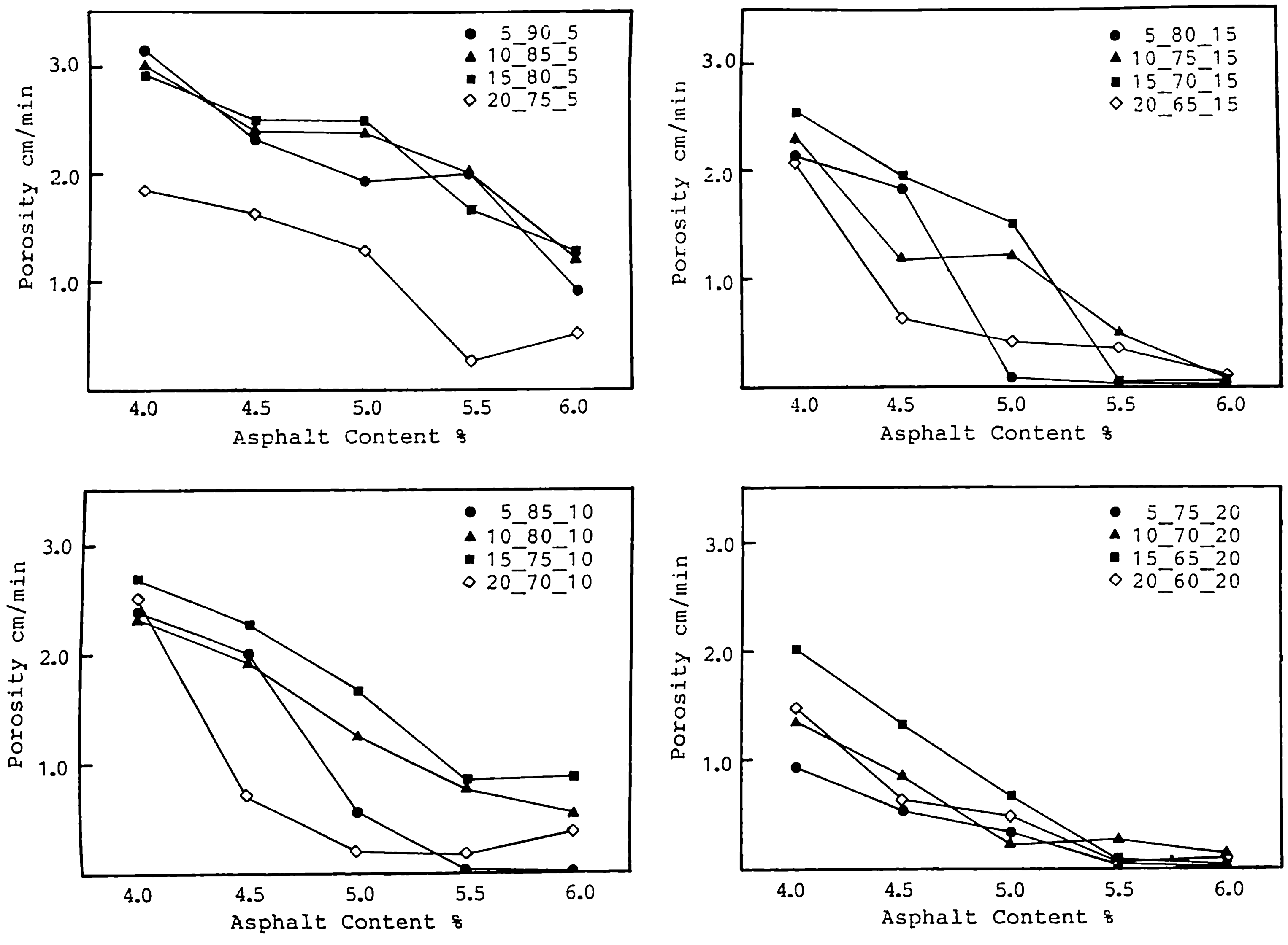

Figure 3B. Porosity at Variable Coarse Aggregate Component trend in the decrease or increase of porosity of the mixes. In this research, the relation of the increase and decrease of the finer particles as a result of varying the coarse aggregate and the pea gravel was not considered, and an explanation of the effect in the porosity is herein not attempted. What can generally be noticed from these figures is that the porosities at the same asphalt contents decrease gradually as the sand component is increased from 5.0 to 20.0%.

Stability

As in the first property, the stability of an asphalt mix is affected by the amount of binder used and the aggregate gradation. The results of stability tests are likewise presented in two arrangements shown in Figs. 4a and 4b. The first arrangement, Fig. 4a, shows the variation of the Marshall stability of the test specimens at a constant sand component and varying coarse aggregate component. Except at some portions of the figures (5.5% asphalt of 10% Sand and 4.5% asphalt of 20% Sand), the Marshall stabilities does not vary by more than 200 kg at the same asphalt content, while in the second arrangement (Fig. 4b) the scatter of the points are very wide. This implies that the sand component has more control in the variability of the stability of the mix. At 5% sand component, the stability almost remained at a constant value inspite of the increase in the binder content, and the increasing coarse aggregate component. The rate of increase in the stability with respect to binder content, however, seem to increase with increasing sand content. In Fig. 4b, it can be noticed that the mixes containing 20% sand displayed the highest stabilities. Looking back at Figs. 3a and 3b, these mixes has the lowest porosities. In contrast, those that displayed the lowest stabilities (5% sand) has the highest porosities. To maintain a balance in the porosity and stability of a porous surfacing mix design, the sand component is to be carefully considered.

In an ordinary asphalt mix, the increase in the amount of binder increases the bond between the aggregates until such an amount that the optimum is reached (usually about 6.0%), and further increase of the binder decreases the stability of the mix. In the design mixes considered, there is an indication from Fig. 4a that the optimum is likely to fall between 5.5 and 6.0%. At this amount, the porosities (implicitly air void contents), except at 5% sand content, are insufficient for a porous pavement surfacing. Mixes with lower amounts of asphalt are more likely to store a greater portion of a rainfall.

APPLICATION TO POROUS PAVEMENT CONSTRUCTION

In the design of a pavement surfacing, the selected mix design is the most economical one which will satisfactorily meet all the established criteria. The properties considered are stability, flow, and air voids, The stability requirement is to ensure resistance against applied wheel loads. The limits in flow values is to avoid rigid or brittle pavements that may crack under heavy volumes of traffic, especially where base and subgrade deflections are permitted to be

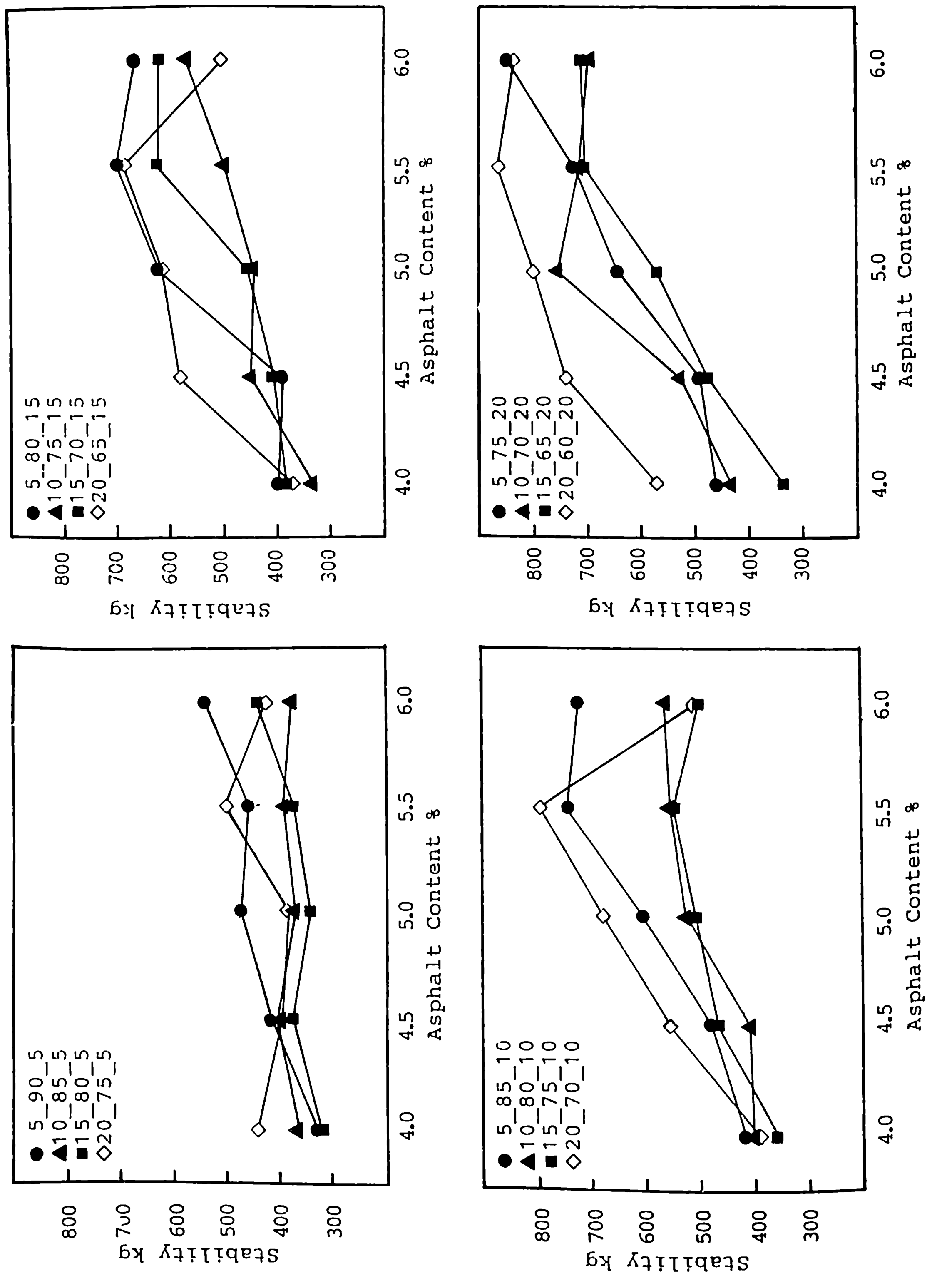

Figure 4A. Stability at Variable Coarse Aggregate Component

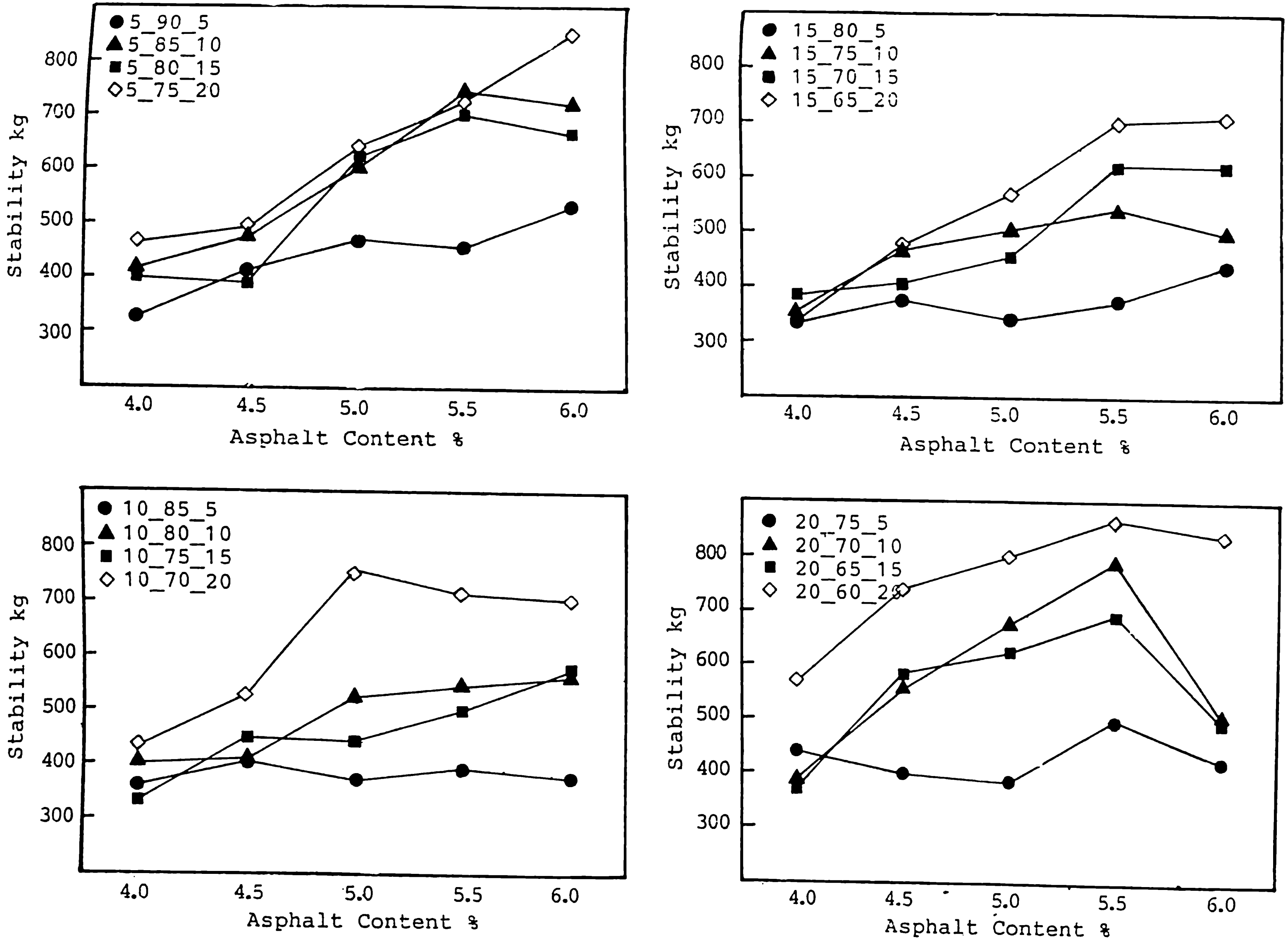

Figure 4B. Stability at Variable Sand Component moderately high. The reason for an upper limit in the air voids is to allow for a slight amount of additional compaction under traffic loading without flushing, bleeding and loss of stability while for the lower limit, to keep out harmful air and moisture[3]. Obviously, the last requirement would not apply to a porous pavement surfacing because the aim in this type of pavement is to produce enough air voids in the mix for greater storage capacity. other requirements, depending on the purpose and use of the pavement, may arise for porous surfacings.

For footpaths/sidewalks, the functional conditions which must especially be satisfied are skid resistance and penetration resistance[4]. In Japan, the standard pavement for footpaths is as shown in Figs. 5a and 5b. The asphalt pavement has an equivalent asphalt thickness TA of 60 mm (excluding the sand layer) which is lesser than the requirement for a shoulder construction of TA = 100 mm. A porous asphalt mix of 100 mm thickness, as shown in Fig. 5c, therefore would not be insufficient to replace either the standard asphalt or concrete pavement footpaths. The mean annual rainfall of the Philippines varies from 965 to 4,064 mm, and a minimumm evapotranspiration of 2 mm/day[5]. The air voids (without allowance for absorption of asphalt by aggregate) of the test specimens for 4.0 and 4.5% asphalt contents is not lower than 5% (the void ratio and porosity roughly displayed a direct proportionality). A surfacing thickness of 100 mm can therefore store a 5 mm rainfall, and about 40% of this can be released into the atmosphere by evaporation in one day. A considerable portion can be brought back into the subgrade depending on the subgrade permeability.

The pavements of parking areas are to be chosen in the range of TA = 150 - 200 mm, with a minimum pavement thickness of 300 mm [4]. The higher value is for parking areas where a fairly high proportion of usage by trucks is expected. For ordinary parking spaces, a pavement design consisting of 150 mm thick porous surfacing with 150 mm thick unscreened gravel (Total TA = 187 mm) is sufficient. At 5% void ratio, this pavement can store a rainfall of 7.5 mm, not considering the added storage capacity of the subbase layer. The porosity of the mixes at 4.0 or 4.5% asphalt content (except for the 20% Coarse aggregate) are high enough to allow water to percolate into the subbase layer for more storage.

For ordinary highway construction, the Marshall stability requirement for light traffic (design EAL $< 10^4$) is 500 lbs (226 kgs). All the specimens tested produced a Marshall stability higher than 300 kgs at any asphalt content. The porous mix can then be sufficiently used as a surfacing for an ordinary light traffic pavement. Considering the findings of one research that the use of great thickness of granular material is an inefficient (uneconomical) way to increase the load carrying capacity of a pavement[6], a full depth porous asphalt pavement could well be employed, with the added benefit of reducing the design parameters of storm sewer systems.

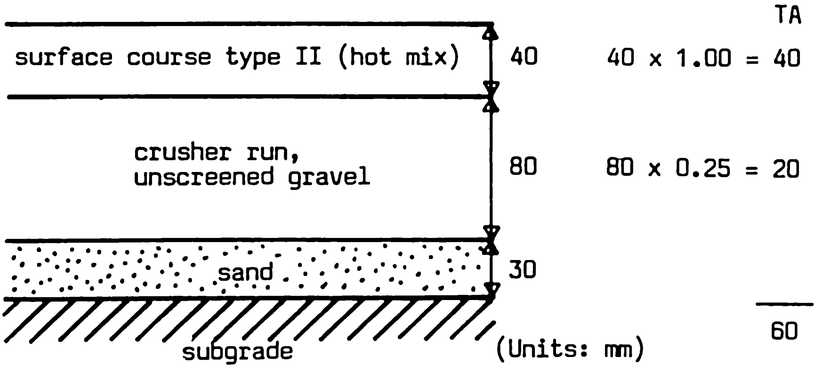

Fig. 5.a Standard footpath asphalt pavement

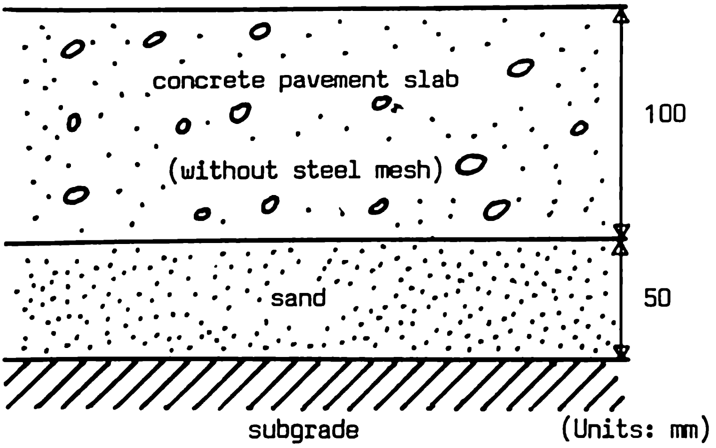

Fig. 5.b Standard footpath concrete pavement

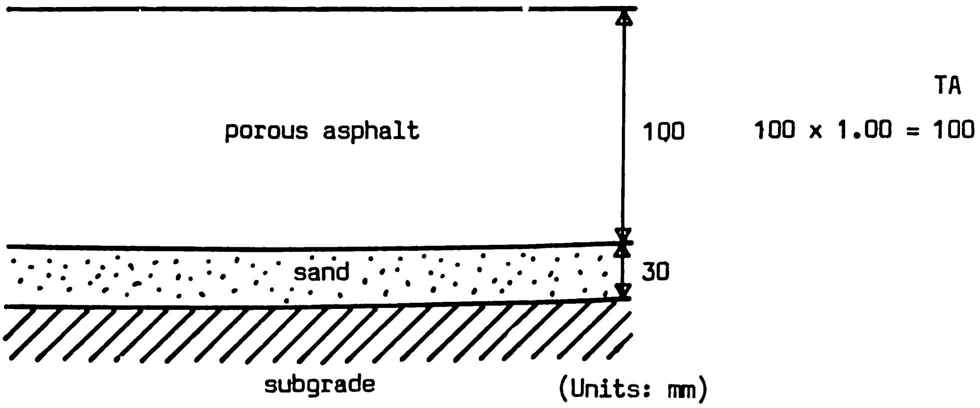

Fig. 5.c Proposed footpath porous pavement

CONCLUSION

The results of the tests show that the porosity of a porous asphalt mix is notably affected by its sand component. An increase in the sand component, while increasing the stability, consistently decreases the porosity of the mix, especially at lower asphalt contents. It was also observed that an increase in the binder content decreases the porosity of the mix. To achieve the highest porosity of the mix, it is best to keep the binder content at a minimum, but to the expense of losing a little strength. The first consideration in the mix design for a porous pavement surfacing, as fundamental in the design of any structure, is still stability. In the event that the stability at low asphalt contents satisfy the requirement of the pavement designed, the sand component is to be carefully considered for optimum porosity and economy.

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