Proc. Instn Civ. Engrs, Part 2, 1980, **69**, Dec. 1067–1070

8315 DISCUSSION

An experimental investigation of the behaviour of a concrete block pavement with a sand sub-base

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In addition to the two forms of pavement mentioned, there are two other cement-based materials generally available, namely in situ concrete and precast concrete rafts. Rigid in situ concrete is particularly susceptible to subgrade settlement but the precast concrete raft can be applied successfully to lightly trafficked residential roads and to heavy duty industrial pavements.

44. Research is currently being undertaken at the University of Newcastle upon Tyne into the use of 2 m × 2 m precast concrete rafts for both lightly trafficked roads on low California bearing ratio (CBR) subgrades and also for heavy duty industrial pavements on subgrades with CBR values of 2%.

45. Instead of using ungraded sand with its significant deformation in the early loading stages, I feel that a type 1 aggregate, fully compacted, would be more suitable, thus eliminating the need to lift and relay the blocks. By using the 2m × 2m raft block the handling and laying costs would be greatly reduced and a larger area would be laid in the same time.

46. When settlement takes place, the rafts are easily lifted, the sub-base is relevelled and the raft is relaid. There is no problem of ensuring interlock between the rafts to distribute the load, as in the case of the blocks.

47. If ungraded sand is used as a sub-base, and there is significant running water, the sand may be washed away and the block pavement rapidly collapse. In the case of the rafts, the sand movement will have to be over a larger area, because of the size of the raft, and there will be an improved chance of its being remedied, before pavement collapse occurs.

48. Rafts do not need lateral edge restraints for interlock.

Dr A. A. Lilley, Cement and Concrete Association

In my view, the Paper fails to help the designer of very lightly trafficked roads. Road note 29[1] allows for the design of this type of road with concrete or asphalt surfacing. It recommends a design life of 40 years and assumes a 4% annual growth in the number of commercial vehicles using the road. At the end of the design life the road is considered to have reached a terminal condition and will require partial reconstruction or a major overlay. The 40 year design life was chosen for minor

Paper published: *Proc. Instn Civ. Engrs*, 1980, **69**, Mar., 139–155.

roads to minimize the frequency of problems arising from the need to match the surface of an overlay to fixed levels at access points and to drain gullies.

50. Unlike in situ concrete or asphalt, concrete paving blocks can be lifted and reused, so there is no need to consider the problems arising from an overlay. In a cul-de-sac of 10–20 houses it is difficult to imagine an annual growth of commercial vehicles approaching 4%. Would the Author agree that Road note 29 overestimates the volume of damaging commercial traffic on many estate roads and that the 40 year design life could be reduced when paving blocks are used as the surfacing?

51. I question the conclusion made by the Authors that 500 mm of compacted sand has been shown to provide an adequate sub-base in the situation described. The trial roads carried only just over 4000 standard axles while a cul-de-sac, according to Road note 29, would carry 100 000 standard axles in a 15 year period. Despite the low traffic volumes, the trial roads suffered what I consider to be an excessive amount of surface deformation. In reference 4, under the test conditions, a sub-base 550 mm deep is recommended, using one of the materials detailed in clauses 803, 805–807 or 810 of the Department of Transport specification.[7] These recommendations were intended to give a design life of 40 years.

52. I believe that nearly all the reported surface deformation has arisen from settlement of the poorly graded sand. This view is supported by the fact that the sand sub-bases of 500 mm, 600 mm and 700 mm all gave similar performances. It is probable that the sub-base had a CBR of about 10% which, in my belief, is inadequate. A sub-base material should have a CBR of at least 20% and preferably more than 30%. Suggesting an inferior material for use as a sub-base is false economy.

Mr Barber and Dr Knapton

Dr Bull is correct in stating that a fully compacted, well graded material, such as a type 1 or type 2 aggregate, would not show the significant deformation in the early stages of trafficking. However, such materials are relatively expensive to import and substantial economies could be made if a lower quality, locally available sub-base material could be used. This experiment was specifically designed to determine the behaviour of such a construction under vehicular loading conditions.

54. Rigid in situ concrete construction was widely used for residential roads before the Second World War. However, owing to problems of aesthetic appearance, difficult services access, overlay repair and the regular joints felt by the vehicles, its use declined in favour of asphalt. The differential in cost between concrete and asphaltic construction has remained minimal. It was through a desire to reverse this trend that concrete blocks were introduced to the UK and applied to these classes of road. There is no doubt that concrete blocks overcome many of these points, but they also offer substantial long-term savings through reduced and easier maintenance.

55. Precast rafts are manufactured with a series of three concrete mixes, including a very high density surfacing, double mesh reinforcement, steel angle surround and an overall thickness greater than the 80 mm concrete blocks used here. Concrete blocks are compression moulded from a moderate strength concrete mix and demoulded immediately. Rafts, therefore, are substantially more expensive to manufacture; current quotes show a 5 : 1 cost advantage towards the blocks. Although block laying is relatively labour intensive, no heavy plant is required and the overall cost ratio is unlikely to be below 3 : 1.

56. The raft system also requires a higher quality sub-base preparation than that used in this experiment. The problem of a fine sub-base being washed out is extremely unlikely if normal construction practice is followed. All block pavements have been laid on a 50 mm layer of sand and there have been no failures attributable to saturation and subsequent pumping. The joints between the blocks are small and substantial load transfer is achieved, thus totally confining the sand. In areas of subgrade or sub-base settlement, the block surfacing deforms to accommodate this with no loss of surface integrity or block fracture. Raft construction cannot accommodate such local settlement without partial loss of support to the unit; as there is no load distribution between adjacent units pumping can develop rapidly.

57. Edge restraint to prevent horizontal block movement is important, but not difficult to achieve. Standard precast kerbs benched in dry lean concrete are perfectly adequate.

58. We agree with Dr Lilley that the design philosophy adopted by Road note 29[1] is not applicable to concrete block construction on very lightly trafficked roads. The principal aim of this design guide is to prevent excessive stresses within the pavement structure causing fracture of the asphaltic surfacing and subsequent major reconstruction. This design constraint does not apply to a segmental block surfacing and we feel that the design method used for these structures should be revised.

59. The only design criterion applicable to this class of pavement is the serviceability limit of excessive deformation destroying drainage falls; this will always occur before the structural failure of a block pavement. The only method of establishing such an empirical design code is the full-scale trial of this form of construction with a variety of sub-base designs to find a minimum specification.

60. Road note 29 requires a sub-base CBR in excess of 30% for pavements carrying more than 0·5 million standard axles. However, this does not apply to the two classes of pavement considered here. The strength, or CBR, specification for granular materials is based on an empirical laboratory test, where the specimen is confined and subjected to relatively large vertical strains through a plunger. This does not reflect the true loading conditions within the pavement structure.

61. The strength of a granular material in a pavement, in terms of its elastic modulus, is a function of the subgrade strength and the layer thickness. It is independent of the material type. For sub-base thicknesses of 200–300 mm a modular ratio of 2–2·5 is generally applicable; for thicker constructions where the sub-base is built up in layers the overall modular ratio is unlikely to exceed 4. This is because it is impossible to achieve a higher compaction over an elastic subgrade. Thus, the in situ CBR of a sub-base over a subgrade of CBR 8% will not exceed 16–18%, which can be achieved with a type 2 material.

62. Thus, the specification of potentially higher strength granular materials is not rewarded by a stronger pavement. Applying these ratios to the test conditions here, given adequate compaction the required in situ CBR of the sub-base is approximately 8%, which is lower than the anticipated maximum for such a material.

63. This only considers the resilient, or elastic, behaviour of the material under dynamic wheel loads and not the plastic, or permanent, deformation. Obviously a well graded material is easier to compact and is more stable under vehicular loading than the uniformly graded sand used in this experiment. We believe that, given sufficient compaction, the lower quality sub-base material does not decrease the resilient strength of the structure and maintains adequate stability under a block

surfacing to prevent excessive deformation. We agree with Dr Lilley that the surface settlement was due to poor compaction, and if this had been overcome then the sub-base thicknesses of 500 mm, 600 mm and 700 mm would have behaved adequately for the type of loading under construction.

64. Since the introduction of blocks to the UK there has been a distinct lack of pavement failures in residential areas. This is surely indicative of conservative design.