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Analytical flexible pavement design: a critical state of the art review 1984

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Mr J. D. Clarke, *Sunderland Polytechnic*

The use of repeated load triaxial tests to obtain material properties for analytical pavement design is a suggestion that ought to be encouraged. Most triaxial machines can be adapted to perform repeated load tests for an equipment cost of approximately £300, especially if air actuators are used. This applies to both 37 mm and 100 mm triaxial cells. Such systems, although lacking something in sophistication, are at least as good as the conventional CBR test for obtaining soil properties.

64. However, a number of procedural problems need to be resolved before repeated load tests can be universally accepted. These are as follows.

(*a*) The establishment of an agreed procedure to obtain an acceptable value of threshold stress for subgrades; agreement could be reached on the methods advocated by Heath *et al.* in 1972[80]

(*b*) An agreed number of load applications with a range of deviator stresses required to obtain a value of resilient modulus

(*c*) The use of an acceptable triaxial stress regime for use with granular soils.

65. The relationship $M_R = 10\ CBR$ MN m^{-2} depends on the value of the applied stress level. Recent investigations using local clays show that providing the applied stress is about one-half (the threshold stress), then a satisfactory relationship is obtained.

66. For a local glacial lacustrine clay, subject to such an applied stress, the following results were obtained: $10\ CBR = 11{\cdot}8$ MN m^{-2}; $M_R = 12{\cdot}2$ MN m^{-2} at 1000 load cycles; and $M_R = 13{\cdot}9$ MN m^{-2} at 10,000 load cycles.

67. With granular soils, the relationship $M_R = k_1 \theta^{k_2}$ has not given such good agreement when using crushed dolomite, principally because the modulus and threshold stress are very dependent upon the imposed stress regime.

Mr H. R. Elsdale, *Member*

Dr Kennedy's Paper reviews pavement design from a structural aspect, which is useful for explaining failures in bituminous overlays or providing a basis for preventing premature structural failure in such overlays. However, the Paper does not mention that structural failure could be avoided altogether if roads were constructed with deep strength so that they would not be vulnerable to structural damage from traffic.

69. All roads need routine drainage maintenance and periodic surface renewal, but deep-strength roads will withstand traffic indefinitely with only such basic

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maintenance; and if they are well used, at a fraction of the costs of operating vehicles on them. Some deep-strength roads built by General Wade and William Caulfield have lasted for more than 200 years.

70. *Dr Kennedy* does not mention that the load equivalence factors reproduced in Table 1 should be applied only to pavements designed in accordance with MOT guidelines, whose strength is concentrated in their upper layers but which are expected to fail after a specified number of loadings.

71. *Dr Kennedy* reproduces much interesting data about material properties, but he omits to mention what strength must be achieved in the subgrade by its preparation, drainage, compaction or stabilization to provide sufficient support for a road pavement so that traffic loading on it would be structurally immaterial. The paper does not indicate either what depth of cover is needed to protect bound capping layers from damage where they are used over subgrades weaker than this.

72. These questions may not be considered important in the United Kingdom where official economic guidelines deem traffic to have no value, and where normal discounting techniques favour cheap thin pavements without any margin of spare structural capacity to enable them to withstand more than the design traffic loading. However, they should perhaps be important in countries where traffic is deemed to be worth at least the operating costs of the vehicles (VOC) and where construction costs are deemed to be covered relatively soon by VOC so that busy roads become profitable investments. In this situation, the economic use of resources requires that pavements should be constructed with deep strength in order that they need only simple maintenance and to ensure that they *never fail* unless such maintenance is grossly neglected.

Dr Kennedy

The results presented by *Mr Clarke* are a most useful additional source of information on the dynamic characteristics of local soils; there is an urgent need for the provision of a data bank containing dynamic characteristics of local soils and granular materials to reduce duplication of laboratory testing when using the analytical approach to the design of highway pavements.

74. I do agree with Mr Clarke that an agreed testing regime for repeat load triaxial testing is required, but I am not sure that a major requirement is the definition of the number of load repetitions at which the resilient modules are measured other than to define the minimum number of load applications that are necessary to give a result which is sufficiently precise for engineering needs. Such a value could probably be set as low as 100 repetitions. Of more importance is the location and form of the strain measurement devices that are used. Ideally, these should be attached to the specimen and located so as to exclude the non-uniform behaviour observed at the top and bottom of specimens produced as a result of platten restraint. A standardized procedure for this test has been developed in the USA.[81]

75. The points raised by *Mr Elsdale*, concerning the necessary strength required of soils and capping layers, are covered in the recent Laboratory Report[82] which was published by the Transport and Road Research Laboratory (TRRL) after my Paper had been written. The question raised by Mr Elsdale, regarding the economics of producing 'deep strength' pavements as opposed to pavements of thinner construction with finite design lives, is beyond the scope of the original Paper, but the same TRRL publication[82] does consider this aspect, although it does not, in the economic model developed, include vehicle operating

costs. However, I would be surprised if the general condition of our major road network at critical conditions before restrengthening would have been sufficient significantly to affect these costs. It should be noted that the design methodology presentation in LR 1132[82] has extended the design life of flexible pavements by a factor of about 1·6, as compared with previous UK design standards, by considering the end of the design life as the onset of critical rather than of failure conditions. A further element of 'spare structural capacity' is introduced by using an eighty-fifth percentile performance curve, rather than the mean or fiftieth percentile performance curve adopted in previous design standards. Both these effects should mitigate against the selection of the pavements susceptible to early structural failure.

References

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82. POWELL, W. D. *et al. The structural design of bituminous roads.* Transport and Road Research Laboratory, Crowthorne, 1985, TRRL Report LR 1132.