EVALUATION OF INTERFACE BOND CONDITION BETWEEN TWO BITUMINOUS LAYERS

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Abstract

1. Introduction

A bituminous pavement is a multi layered structure, generally made up of surfacing, base, sub-base and subgrade. The boundary between any two consecutive layers is the layer interface. Tack coat or prime coat is generally applied at the interface. This prime/ tack coat also comprises of thin layer of bitumen, and its objective is to provide adequate adherence between the layers. If the quantity of bitumen used is excess or less than the requisite one, the interface bonding will not be satisfactory.

The present thesis attempts to develop methodologies to evaluate the interface bond condition between two bituminous layers by non-destructive techniques. Laboratory testing has been performed with various quantities of bitumen as tack coat between two bituminous layers to obtain the optimum bitumen quantity. Bituminous slabs are cast and seismic testing is performed on pair slabs placed one over the other with or without tack coat. The response acquired by the accelerometer is analysed for their fractal dimensions.

2. Motivation

For pavement design purpose full bond/ partial bond/ no bond – all are possible. If bond is not present, increase in strain results, leading to shorter pavement life. So interface is playing vital role in load carrying capacity of pavement. Basic motivation is to evaluate the bond condition of pavement in a non-destructive way. Shear force is main cause for the interface failure. Generally interface bonding strength can express in terms of shear strength.

3. Objective

The objectives of the work are identified as follows:

- Finding out the optimal quantity of bitumen as interface between shear samples for dense asphalt concrete (DAC) and semi dense bituminous concrete (SDBC).

- Collect the slabs responses in terms of amplitude-time signals for interface bond condition through impact hammer test.

- Evaluating the interface bond condition of pavement through Fractal analysis.

4. Background study

Initially research is started with interface as thin material of thickness ‘t’ mm. There after some numerical models has came up on interface by assuming various interface conditions. After words a impact hammer method is proposed for quantifying bond condition. In this work also, a non-destructive hammer method is used to estimate the interface bond condition through fractal analysis. Here fractal dimension is evaluated the through box counting method.

The word tack relates to a sort of stickiness. Coat is a small thickness of layer. It is a thin layer of bitumen or emulsion laid on a road to enhance adhesion of the course above it. Absence (too little) of tack coat develops poor bond (inadequate bond) between pavement layers. Poor bonding between layers can result in slippage followed by longitudinal wheel path cracking, top-down cracking, alligator cracking, potholes, and other distresses such as rutting that greatly reduce pavement life. Over applied tack coats will cause a shear plane resulting is slippage or shear cracks in the hot mix. A prime coat is a sprayed application of a cutback or emulsion asphalt applied to the surface of untreated subgrade or base layers. Prime coats seal and bond surfaces and make a good base for the next layer of surface course.

5. Need of experimental investigation

Interface bond failure is due to mainly shear force only. In this research work, there is a need to perform the shear test and impact hammer test to quantify the bond condition. In this study, this equipment is designed and fabricated for measurement of interface shear strength. It comprises of mould, proving ring and sliding arrangement. A shearing apparatus is designed and fabricated to hold the specimens during testing. Then switched on the motor, proving ring will measure the shear force at failure at a constant shearing rate of 10 mm/min. Before performing the test, all the screws are tightened in such a way that rate of application of load is constant.

Mix preparation comprises of aggregate mixing and bitumen mixing. This mix is used to prepare the square samples of DAC and SDBC for shear test. Bitumen content of grade 80/100 for the DAC is 5.6 percent with respect to the total weight of the aggregates and bitumen content of grade of 60/70 for SDBC is 5.0 percent with respect to the total weight of the mix. Mix is poured into the mould size of 100×100× 50 mm mould. Then material was compacted by giving 100 blows using standard modified Marshall hammer.

A shear test sample consists of two cured samples, top and bottom, with known bitumen quantity at the interface of these samples and left it curing for one day and then tested. Take a precaution in such a way that upper sample is in sliding part and lower sample is remain in the mould which is fixed to base plate during testing. No normal load was applied to the specimens during testing. This test was performed twice for each material for various quantities of bitumen. Initially by adding the more and more quantity of bitumen, the adhesion between the samples would increase. So more shear force is required to shear the interface bond. By adding more bitumen, the bituminous layers (slabs here) would tend to slip against each other due to lubrication effect. So, the shear strength of the interface bond would fall. The particular bitumen quantity, at which the shear strength of the interface is observed to be highest, can be called as optimal bitumen quantity for highest interface strength. This quantity of tack coat should therefore be used for construction purposes.

The impact hammer technique works on the principles of wave propagation and consists of monitoring the generated surface waves in the test section. This provides information regarding relative stiffness and thicknesses of the individual layers. Surface waves may be generated through different devices like drop-weight type, vibratory or by strike hammers. Sensing element is a series of geophones or accelerometers. The obtained mixture is poured into 500×500×40 mm mould. Then it was compacted by giving 500 blows using standard modified Marshall hammer. The finished sample was left for curing for one day and then tested. Arrange the cast slabs one over the other and these are excited by hammer giving the impact to the surface. The slab response is captured by accelerometers. In this test, accelerometers are placed at 5 cm apart and source is also placed at 5 cm from first accelerometer throughout this study. The signals from the hammer and accelerometer were fed into the data card and monitored through laptop. Test is performed twice for each material i.e., without tack coat and with tack coat between slabs. The used optimal quantity of tack coat evaluated from shear test.

6. Fractal geometry

A geometric pattern that is repeated at ever smaller scales to produce irregular shapes and surfaces that cannot be represented by classical geometry. Fractals are used especially in computer modeling of irregular patterns and structures in nature. Fractal dimension, identified as D associated with a fractal geometry satisfies the equation $N = s^{D}$, where 's' is the factor, which is the ratio of L_{init} to L_i of the box dimension in the each step and N is the factor by which the number of basic units increases in each such step . In fractal geometry, the fractal dimension is a statistical quantity that gives an indication of how completely a fractal appears to fill space, as one reduces the box dimension to finer and finer scales. The estimated fractal dimension through box counting method is explained in the following.

An elementary technique for determining the fractal dimension is known as "Box counting". An initial square box dimension L_{init} is chosen and the number of boxes (N) are required to fully cover the complete signal is determined. In the next step, the box dimension is reduced to L_i and the number of new (smaller) boxes required to fully cover the signal is re-calculated. The procedure is repeated for smaller box dimensions in the subsequent steps. The number of boxes (N) is then plotted against (s), on double logarithmic scales. A straight line is then fitted to the data and the gradient of the line is the Fractal Dimension (F.D.). Based on Fractal dimension, one can conclude about the interface bonding condition. The fractal dimension values ranges from approximately 1.1

(bonded interface) to 1.3 (debonded interface). The tack coat added, provides a strong interface bond between the slabs. An accelerations in slabs developed by hammer with tack coat case are less than the without tack coat case. So number of boxes to cover the full signal will decrease.

7. Closing remarks

The salient findings of this study as follows:

- During the shear test, the optimal bitumen quantity required for interface between DAC-DAC shear sample, SDBC-SDBC shear samples and DAC-SDBC shear samples are 0.181 Kg/m^2 , 0.268 Kg/m^2 and 0.302 Kg/m^2 respectively. So the quantity of bitumen required for the interface between DAC sample is less than the SDBC sample due to their surface texture.

- In the case of impact hammer test, excitation (response) of slabs in terms of amplitude with tack coat as interface is lower than the without tack coat case.

- The F.D. can be used as a measure to estimate the interface bond conditions. The fractal dimension values for the DAC-DAC-tack and DAC-DAC-no tack samples are 0.98 and 1.05 respectively. The fractal dimension values for the SDBC-SDBC-tack and SDBC-SDBC-no tack samples are 0.96 and 1.02 respectively. The fractal dimension values for the DAC-SDBC-tack and DAC-SDBC-no tack samples are 0.99 and 1.06 respectively. The fractal dimension value for DAC-SDBC-tack sample is 0.97. Thus Fractal dimension of the signal with tack coat as interface is less than without. Due to the presence of tack coat between the slabs, the amplitude of signals is less than without tack coat case. Because, the presence of tack coat between the slabs would reduce the excitation.

8. Future scope

Following works that can be taken as further study:

- Impact hammer test can also be conducted on material like mastic asphalt with various interface conditions.

- The shear test may be performed on rectangular samples of DAC, SDBC and mastic asphalt materials and optimal bitumen content at which shear strength is high may be found.