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Fatigue characteristics of nano-clay modified bituminous concrete

M. Sivakumar[a] *, M. V. L. R. Anjaneyulu[b]

[a]*Research Scholar, Department of Civil Engineering, National Institute of Technology Calicut, Kerala,673601, India*
[b]*Professor, Department of Civil Engineering, National Institute of Technology Calicut, Kerala,673601, India*

Abstract

Fatigue cracking is the significant distress caused due to the repetitive axle loads combined with environmental conditions on flexible pavement surface. Commonly bituminous concrete used as surface course mixes produced with unmodified bitumen a viscoelastic material and temperature susceptible. It is also prone to permanent deformation under repeated axle loads. The modified binders are more stable under fatigue loads, braking and accelerating forces and thus show increased resistance to permanent deformation even in hot weather. This paper discusses the fatigue behaviour of nano-clay modified bituminous concrete by repeated load test results such as resilient modulus and tensile strain.

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Keywords: Fatigue life; Bituminous Concrete; Nano-clay;

1. Introduction

The fatigue cracking caused due to the repetitive axle loads of heavily loaded vehicles is main distress in flexible pavements. The unmodified bitumen is the most common binder used for the flexible pavements construction which is a viscoelastic material and temperature susceptible. It is also prone to permanent deformation under an applied

* Corresponding author. Tel.: +91 944 645 2997.
E-mail address: sivakumarm@nitc.ac.in

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load. The rate of deformation depends on the bitumen grade, its composition, ambient temperature, level of stress and load time. The modified binders are more stable under fatigue loads and accelerating forces. Modifiers like polymers, latex, and many chemical additives change the properties of the bitumen binder. But there are many other modifiers like fillers, fibers, and some polymers which do not blend with the binders. Development of nano materials for bituminous mixes shows improvement in mix performance as they have extensive and unique properties such as the quantum effects, structural features, high surface work, spatial confinement and large fraction of surface atoms.

An organosilane compound called nano-clay which reacts with aggregates, soils and stone powder surfaces converts silanol groups (Hydrophilic) to alkyl siloxane group (Hydrophobic). Nano-clay possesses an extraordinary potential for improving bituminous mix performance Pavement researchers have suggested that nano-clay have interesting performance enhancing characteristics that could improve the mechanical strength properties of both bitumen binders and mixtures. Common clays are naturally occurring minerals and subject to natural variation in their formation. Separation of clay discs from each other results in a nano-clay with a large active surface area (up to 700-800 m2/g). This results in an intensive interaction between the nano-clay and the bitumen. Adding nano-clay increases bitumen binder viscosity and improves the rutting and fatigue resistance of bituminous mixtures. A small amount of nano-clay enhances the physical properties of bitumen such as stiffness and tensile strength, shear modulus and thermal stability. Nano-clay modified bitumen has higher elasticity and lower mechanical energy dissipation and unmodified bitumen (Jahromi and Khodaii 2009). Nano-clay modified bitumen increases the shear complex modulus and reduces the horizontal strain failure rate of base bitumen (Yao, et al, 2012).

Resilient modulus is an index used for evaluating stripping, fatigue, and low temperature cracking of asphalt mixtures. Triaxial tests (constant and repeated cyclic loads), cyclic flexure test, indirect tensile tests (constant and repeated cyclic load), and creep test are the different methods employed for measuring resilient modulus. The indirect tensile test is the most common repeated load test to measure the resilient modulus of bituminous mixture (Sousa et al. 1991). The diametric test is more suitable for the repeated load testing associated with modulus measurements compared with diametric creep measurements which take longer time periods for testing (Moghadas et al. 2012). The main aim of this study is to understand the effects of nano-clay on fatigue behaviour of bituminous concrete by conducting indirect tensile test (repeated load).

2. Material characteristics

Bituminous concrete performance mainly depends on the various properties of the constituent materials. Mechanical properties, gradation, shape, and surface texture of aggregates have a great influence on mix properties. Fatigue cracks usually initiated in the form of micro cracks and change to macro cracks, these cracks grow due to shear and tensile stresses in pavements. The type and amount of binder used in the mixture, temperature and air voids affect the fatigue life of flexible pavements. Also aggregate gradation is the most effective material property for the fatigue resistance bituminous mixture (Hafiang, 2001).

2.1. Aggregate properties

Aggregate characteristics such as particle size, shape, and texture influence the performance and serviceability of bituminous pavements (Kandhal et al. 1992; Kim et al. 1992). Specific gravity and water absorption of coarse and fine aggregates are important properties required for the design of bituminous mixes. Aggregates having low specific gravity values are generally weaker than those having higher values. Aggregates having higher water absorption value are either porous or weak. The size and shape of the aggregates affect the aggregate's stability under fatigue loads. The mechanical properties of aggregates mainly depend on the type and source of aggregates used for mix preparation. Granite aggregates offer better compressive and shear strength and shows good interlocking properties. The aggregates used in this study are crushed granites collected from nearby quarry. The physical and mechanical properties of aggregates are evaluated using conventional tests as per the specifications of Indian Standards. The properties of aggregates used in this study are listed table 1.