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Engineered cementitious composite (ECC) link slab for bridge deck

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ABSTRACT - *Engineered cementitious composite (ECC) which exhibits ultra-high tensile ductility and fine multiple cracking meets the essential requirements of safety and serviceability in developing modern infrastructures. This paper studies in detail, the defects of expansion joints in bridges and the effect of polyvinyl alcohol (PVA) fibers on the properties of ECC. The flow characteristics, abrasion resistance, and density variation of various ECC mixes were studied. ECC specimens were casted to analyze the behavior of ECC with varied proportion of fiber in it. Results showed that the %flow and density decreases as the fiber content increases where as there is significant increase in the abrasion resistance. Based on the performance of PVA-ECC, the material specifications for the implementation of ECC Link Slab Technology is proposed.*

Key Words: ECC (Engineered cementitious composite), PVA (Polyvinyl Alcohol) fibers, Fiber content, Link slab,

1. INTRODUCTION

Concrete being brittle in nature is good to take up compression whereas very weak in carrying tension. Also the development of cracks is a major concern. Since 19th century researchers were attempting to improve concrete strength against cracks, fatigue and shrinkage by the addition of steel fibers etc. but the results were not satisfying. This led to the development of Engineered Cementitious Composite (ECC).

1.1 Engineered Cementitious Composite (ECC)

ECC or bendable concrete is a class of improved high performance fiber reinforced cementitious composite (HPFRCC) [1] developed by Li et al. [2-4] based on the principle of micromechanics and fracture mechanics in Japan. The fiber used here for the study is polyvinyl alcohol (PVA) fibers, since it has a high Young's modulus and greater adhesion to concrete. It is characterized by micro cracking behavior and high tensile strain capacity in the range 3 - 7 % compared to a value of .01% for conventional concrete. These properties allow ECC to withstand tensile, flexural and shear loads as well as to increase ductility.

2. JOINTS IN BRIDGES

Expansion joints provided in multi-span bridges have a lot of defects such as damaged seals, accumulation of debris in the joint components, cracking of concrete, corrosion of steel reinforcement, water leakage, improper joint alignment, joint vibration during vehicle passage etc. So, the durability of expansion joints is a major concern to bridge owners. The maintenance cost of bridges is relatively higher than the initial cost.

3. ECC LINK SLAB CONCEPT

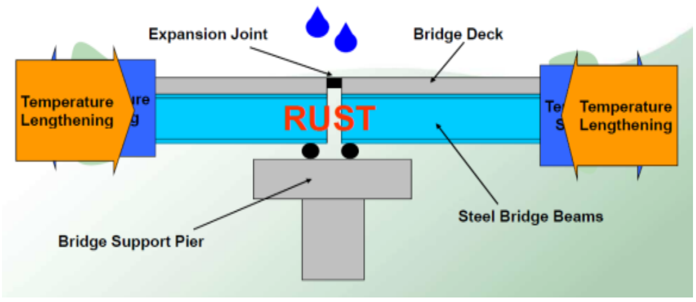

Fig -1: Conventional expansion joint design

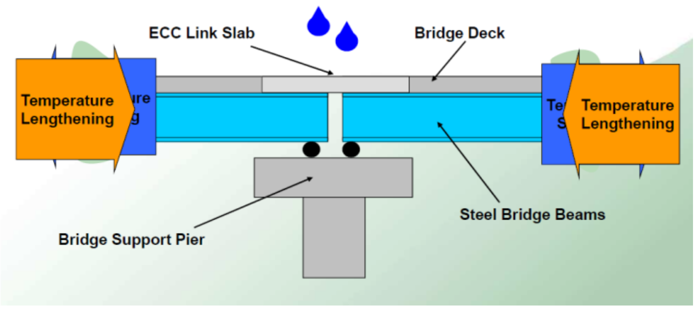

Fig -2: Link slab concept

The unique features of ECC are exploited in this project to improve bridge deck performance, sustainability and durability. An ECC link slabs allow for a joint free bridge deck, eliminating leaking problems which lead to low durability while creating a smoother riding surface. These link slabs maintain the simple span performance of bridges while accommodating the mechanical and environmental loads typically accounted for by expansion joints.

4. CONSTITUTENTS OF ECC

The physical and chemical properties of each ingredients has considerable role in the desirable properties of ECC like strength and workability. Material Specifications for Preparing ECC are given in table – 1.

Unlike in conventional concrete, the usage of coarse aggregate is being eliminated in the preparation of ECC. This is to achieve a lesser value for elastic modulus resulting in more strain when it attains its compressive strength. Fine M sand with maximum particle size 300 μm is used in this project. The required quantity of sand is sieved through a 300 micron sieve. Moreover, higher amount of sand leads to reduced ductility and toughness. Thus, the best ratio of sand to be used in ECC to obtain better flexural toughness and ductility is 0.2.

The fiber was collected from Kuraray Co. Ltd. Japan. Detailed fiber specifications are given in table – 3. The ECC mix ratios and weight of ingredients per 1 m3 are illustrated in Table - 3. Density variations and flow values are displayed in table 4.

Table -1: Material Specification

Materials Used	Specification
Cement	OPC - Grade 53
Sand	Particle size < 300 μm
Water	Potable Water
Super Plasticizer	Water Reducing agents
Fiber	Polyvinyl Alcohol

Table -2: Fiber Specifications

Details of the fiber used - PVA REC 15/12mm	
Diameter	40 μm
Length	12 mm
Tensile Strength	1560 MPa
Elongation at break	6.5 %
Young's Modulus	41 GPa

Table -3: Mix-proportion used in ECC specimens

Item	Quantity Kg/m3)	Remarks
Cement (C)	820	C/C = 1
Sand (S)	656	S/C = 0.8
Water (W)	303.4	W/C = 0.37
Super Plasticizer(SP)	3.28	(SP/C)% = 0.4

Table -4: Flow characteristics and density variations of ECC specimens with varied fiber content

Fiber content (V_f %)	Density (kN/m3)	Flow (%)
0	22.27	324
1.5	20	302
2	18.5	286
2.5	17.6	264

5. CONCLUSIONS

Based on the present study, the following conclusion can be drawn. The addition of PVA fibers was found to greatly influence the mechanical properties of ECC. As the fiber content increases the fresh matrix suffers a difficulty in dispersing the PVA fibers which in turn results in low workability and less homogeneity of mix. ECC is lighter when compared to plain concrete. Based on the study carried out, the optimum fiber content was found to be 2 % by volume. The cracks formed in ECC specimens with no fibers under loading were large and jagged in tension, due to which the specimens were divided in two parts. On the other hand, micro-cracks were generated in beams and strips having PVA fibers. ECC link slab technology proves to be the best in attaining crackless and continuous pavement eliminating expansion joints.

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