A Study on Reflective Cracking Mitigation Strategies for Rigid Pavement Overlaid with Flexible Pavement

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Abstract : *Currently on national interstate highway system several thousand kilometer of Asphalt concrete overlay of Portland cement concrete exit as huge percentage of PCC pavements are in need of repair work or approaching towards end of design life span. It was estimated back in 1991 that PCC pavements on Illinois interstate highway system had been overlaid with AC due to increase in heavy truck traffic loading on concrete pavements. Hence composite pavements are increasing at tremendous rate. As a result of this reflective cracking which is common type of distress is observed in composite pavement. When underlying joints and cracks in PCC Pavement reflects through the AC overlay then it is termed as reflective cracking. Propagation of reflection cracking shown by practical experience is at the rate of 1in per year. Based on the study of literature survey a summarized review is presented for each reflection cracking mitigation method studied.*

Key Words: **Reflective cracking, mitigation strategies**

1. INTRODUCTION

Nowadays, widespread construction measure is adding a paving asphalt layer on cracked cement concrete pavement. The bearing capacity of the structure decreases as a result of defects in the cement concrete layer. The effects of the interface bonding on the overlay response amplify due to increase in temperature [8]. When structural and functional pavement conditions have reached an unacceptable level of service, hot-mix asphalt (HMA) overlays are commonly applied on existing flexible and rigid pavements. The reflection cracking caused due to cracks and joints in underlying layers propagates through HMA overlay due to continuous movement at the discontinuity prompted by thermal expansion and traffic loading. The structural capacity, increase roughness, and reduce serviceability of the pavement are reduced as the reflective crack deteriorate under repeated traffic and environmental loading. Falling temperature leads to contraction of PCC pavement which induces horizontal stresses in the AC overlay due to opening of cracks and joints. Cracks are initiated at the bottom of Ac overlay propagating to the surface as reflective cracks with time due to repeated thermally and traffic induced stresses [1]and its serious challenge as it leads to premature failure of the Overlay and allows water infiltration through the cracks, resulting stripping in HMA layers, weakening and deterioration in the subgrade [9].After spending considerable resources and efforts inexpensive techniques were found to delay reflection cracking[12].For enhancing pavement resistance to reflection cracking various methods are suggested.The major problem in literature survey is contradictory opinions and experiences, some studies emphasized the surplus advantages, such as substantial savings in hot-mix asphalt (HMA) thickness, on the other side use of treatment method ineffective[10,13]

2. MECHANISM OF REFLECTION CRACKING

The existing pavement causes three critical pulses, one maximum bending, and two maximum shear stresses when wheel passes over a crack[14].The increase in movement of the crack, the propagation of the crack to the overlay occurs faster as shown in Fig.1. Contribution to reflective cracking is also given by thermal movements. horizontal stresses are induced in the HMA overlay due to opening of cracks resulted from contraction and curling of the old pavement temperature variation. loads can be applied on a pavement structure in a following combination of three fracture modes [15]

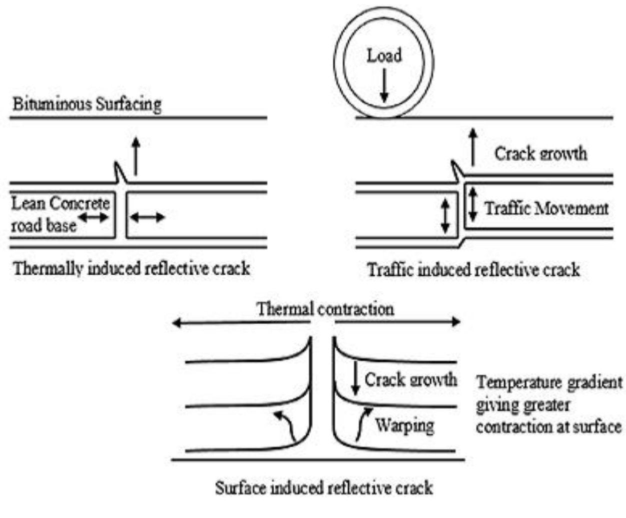

Fig. 1. Mechanisms of reflection cracking. Adapted from Sheng et al. [11]

1) Mode 1 - loads that are applied normally to the crack plane (thermal and traffic loading).

2) Mode 2 - loads that are applied in-plane shear loading, which leads to crack faces sliding against each other normally to the leading edge of the crack (traffic loading).

3) Mode 3 - loads that are applied out-of- plane shear loading parallel to the crack leading edge(tearing mode).But this mode of loading is negligible for pavements.

It is noticed that the reflection of cracks in rehabilitated pavements is a complex process involving a mixed mode of loading identified in the literature as a combination of Mode I and Mode II loading [16].It is recognized that, at about one-third of the overlay depth, Mode I loading becomes less significant and only Mode II loading will propagate the crack to the surface [16]

3. REFLECTIVE CRACKING MITIGATION STRATEGIES

Beginning from the early 1960s,various treatment methods have been suggested for controlling reflection cracking including different types of geosynthetics,metallic grids, fractured-slab approaches asphalt-based interlayers.The following sections present an overview of each class of treatment method

3.1. Steel reinforcement mesh

Fig 2 Steel reinforcement mesh

Steel reinforcement mesh is one of the oldest idea which appeared in early 1960s used for delayinf reflective cracking in flexible pavement.The general concept behinned this was that if HMA is weak in tension and strong in compression reinforcement could be used for resisting tensile stresses.[28]But in early 1970s,using steel reinforcement in HMA was abandoned due to tremendous installation difficulties .In early 1980s, again this idea resurfaced in Europe with development of new class of steel reinforcement. The current steel mesh product consists of a double-twist, hexagonal mesh with variable dimensions, as shown in Fig. 2. The elimination of installation difficulties and any variation in HMA densities caused earlier by welded reinforced steel was possible because of no welding requirement in new generation of steel reinforcement.

3.2 Fractured slab approaches

In order to prevent concrete layer movement and in turn reflection cracking fractured slab approaches are methods that aim at reducing or eliminating the effective length of the original slab [21]. Fractured slab approaches involves crack and seat, break and seat, and rubblization. First existing asphalt overlays are removed and then the concrete layer is cracked with the helpof pavement breaker and seated back subbase followed by applying 35–50 ton rubber tire roller passes for 2-3 times.Tinterlock for reducing pavement due to thermal expansion and contraction,concrete is broken down ito pieces into approximately 18-24 in for ensuringo provide alevel of aggregate . In this case, the concrete stability of broken concrte layer and to reduced void in fractured material seating step is important.Crack and seat used for jointed plain concrete pavement (with or without dowel bars) [17] and is suitable for concrete pavements that have not been completely damaged.Then the critical work is selection of a slab size for the success of this rehabilitation technique and to ensure that reflection cracking does not occur post construction.Overly thickness ranging from 4 to 6 in. (101.6–152.4 mm) is also required to prevent reflec- tion cracking. It is recommended the use of an asphalt–rubber membrane interlayer to reduce reflection cracking [18].In case of break and seat cost can be significant, and it may not completely control reflection cracking and only delay it for 3 to 5 years [19].

3.3 Geosynthetics

Past studies have proved that speed of propogation as well as delay in reflective cracking can be achieved by using geosynthetics[2]. A synthetic polymeric materials incorporated in soils, pavements, and bridge decks makes a geosynthetics [23]. geotextile, also known as paving fabric; geogrid; fiberglass; geocell; geomembrane; geonet; and geocomposite. Geotex- tile are seven divisions of geosynthetic. Reflection cracking control treatments geogrid, fiberglass, and geocomposite have been tested by acting as rein- forcement or as a strain energy absorber, also known as stress relieving layer. Product manufacturers recommend that a minimum overlay thickness of 1.5 in. (38.1 mm) should be used[25]. Additional details on the use of geosynthetics against reflection cracking have been presented elsewhere [22].five types of geosynthesis were used and a laboratory simulation was performed on cracked pavement with testing is carried by tensile force for each type.with stress strain graph secant modulus was obtained . All five types were tested under cyclic loading for geosynthetic reinforced asphalt beams and results reflected the effect of using geosynthetics and its modulus on increasing the loading cycles required for crack initiation and propagation. Also geosynthetic modulus was the affecting factor for vertical displacement of the overlay and number of load cycles before failure, crack growth rate, displacement at the bottom of the overlay, In this research, placing the geogrid at one-third depth of overlay thickness from bottom has showed optimal performance [2]

3.4 Stress absorption membrane interlayer (SAMI)

SAMI is placing of a seal coat made of rub- ber asphalt binder (80% asphalt cement and 20% ground tire rubber) on the surface of the old pavement and then followed by rolling in coarse aggregate chips. This layer may be used as a stress-relief interlayer.To retard crack propagation and improve the tensile strength at the bottom of the overlayis the main role of SAMI[8]Investigation of anti-crack performance of high viscous asphalt sand stress absorption layer(HVASAL)and rubber asphalt stress absoption lyer(RASAL)were carried out by force controlled fatigue crack propogation testing which three types of overlay structure with three types of pre –crack (middle,side,inclined 45 degree)were designed. The fatigue life of structure was seen to be increased after adding stress absoption layer.The effect on fatigue properties of asphalt overlay on cement concrete basement was noticed which was different for 3 types of structure and three different types of cracks.Reflection cracks were delayed because stress absorption layer could disperse the concentrated stress and reduce the peak stress caused by crack in cement concrete.side crack has minimum life ,middle crack has in between life and inclined has maximum fatigue life.The stress absoption layer can effectively increase service life and also can minimize crack propogation layer and also it has good anti crack fatigue performance and that the RASAL is better than HVASAL[3]

3.5 Reflective crack relief interlayer

Reflective Crack Relief System is polymer-rich dense fine aggregate mixture layer that is placed as interlayer between the deteriorated pavement and overlaid HMA(7)Impermeable interlayer using fine graded aggregate constitutes o e inch reflectivelayer.The interlayer alone cannot withstand everything i.e it must be covered with high quality overlay because relflective crack relief interlayer (RCRI) can absorb 80% of strain but the surface need to absorb remaining 20% strain.Also RCRI provides additional benefit of structural modulus .A success of 50% retardation of reflective cracking is achieved because of RCRI(6)

3.6 Engineered cementitious composites(ECC)

ECC is a ductiled engineered cementitius composite which is special kind of high performance fiber reinforced concrete interlayer that exhibit strain hardening behaviuor and high ductility under tension.Typical ECC consist of polymeric fibers, (Polyvinyl alcohol fibers(PVA) and polyethelene fibers(PE))silica,sand, cement, fly ash, water,and admixtures.ECC helps in delaying reflective cracking by providing firm base under HMA.Increased in thickness of of ECC interlayer showed increased fatigue life of pavement.A successful suppression of reflective crack and dramatically extended fatigue life was observed when ECC was used for repair of bridge deck and rigid pavement..Also a remarkable contribution was shown by ECC towards damage tolerance,repairability,structural ductility and deformation capability.Under various environmental impact like freezing and thawing cycles,chloride attack,hot and humid environment it has proved superior durability performance and high shear capacity[4].ECCEven if ECC interlayer gets cracked severly before construction it isstill possible to delay the initiation and propogation of reflective cracking by 5.6 to 5.7 times as compared to control samples.through ther study they also concluded that 30 to 37 times higher fatiue life was obseverd compared to control specimen without interlayer[5].

3.7 Saw and seal

For preventing random propogation of reflection cracking underlying PCC joint to top of HMA overlay saw and sealing method can be used.It is nothing but sawing the overlay to creat longitudinal and transverse joint at exact location of PCC joint and then sealing of construction joint.Applying the treatment at exact location of joint leads to success of saw and seal methods [20].For extending pavement service life as water infiltration and the possible stripping of HMA are the major causes of pavement deterioration sealing the overlay joints is of vital importance[26].Elseifi et al. (2011) investigated the performance of saw and seal in the pavements with HMA overlaid on existing Portland cement concrete pavement (PCCP) [27]. The eval- uation period was for 6 to 14 years. Based on the analysis, the authors con- cluded that 87% of the test sections showed positive improvement in performance for a service life of 1–12 years while 13% showed negative results. Theoretical investiga- tion conducted using 2-dimensional finite element (FE) analysis indicated significant reduction in strain levels at joints in rigid pavement.Key role of Saw and seal is that it dissipates the energy due to wheel loading and expansion and contraction of the concrete and allows the movement of the slabs underlying the overlay without formation of the cracks.

4. Concluding Remark

Combination of environmental (temperature) and traffic loading results into reflective cracking. Expansion and contraction of the PCC causing a horizontal movement due to daily temperature variations which creates temperature gradients in the PCC slab resulting into additional vertical movements at the PCC joint/crack..on the otherside,traffic loading creates both shear and bending stresses around the joint/crack area of the HMA overlay. Also if a void or poor support is present, severe distress can occur in the PCC . Hence the HMA mixtures need to be tested in equipment that can apply stresses relating to actual field movements to properly evaluate HMA overlay mixes. A number of studies have been conducted to delay the occurrence of reflective cracking. In this paper study is carried out on various reflective crack mitigation approaches. Like saw and seal, stress aborbing layer, geosynthetic, reflective cracking relief interlayer, Steel reinforcement mesh, ECC. In the case fractured slab, fracturing of the PCC is not cost effective due to the specialized equipment needed to fracture the slab, as well as the need for a thicker overlay to regain the necessary pavement structural capacity. Regarding geotextiles, Buttlar et al. (1999) investigated that geotextiles can delay reflective cracking for a few years at airports in warmer climates but the same geotextiles cannot delay reflective cracking to the same degree at locations with colder climates. About Reflective Crack Relief Interlayer (RCI) system has shown some promising results in mitigating reflective cracking. After Extensive work by Blankenship (2005) has noticed that as long as the RCI mixture can obtain the required laboratory performance criteria, a 50% reduction in the average crack rate can be achieved. And, very similar was witnessed by Makowski et al. (2005),that is even when the surface layer cracked, the crack did not propagate through the RCI layer. Also another treatment is the Interlayer Stress Absorbing Composite (ISAC).In this a three-ply composite interlayer usually placed as a 36-inch wide strip-type treatment over joints and cracks. Field testing and 3-D FEM analysis has shown that the use of the ISAC at airports reduced the shear and bending stress developed in the joint/crack area (Bozkurt and Buttlar, 2002).In short after going through various mitigation methods it can be also conclude that success of many techniques in mitigating reflective cracking highly site and environment dependent.

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