



Crack Repair Methodology on the Basis of Various Crack Widths of Runway for Srinagar International Airport Jammu and Kashmir India

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ABSTRACT

Extensive cracking on the runway slabs at the Srinagar (Jammu & Kashmir) International Airport has taken place due to overloading of aircraft operations and poor sub grade stability. A visual crack survey was carried out. The survey detected cracks of width of less than 6.4 mm to more than 50 mm which were classified into four types according to their width of opening. Repair methodologies were developed for each category of crack. The repair works and the construction of the overlay were carried out at night as the runway has to be kept operational. The runway has been in service and no sign of distress has been observed since the completion of repair works and overlay construction in September 2010.

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Introduction

The construction of the runway at the Srinagar International Airport (Jammu and Kashmir), India, was taken up in the mid-sixties. After several interruptions in construction, the completion of the Project was delayed and the runway was opened for routine service in 1980. The Civil Aviation Authority of India (CAAI) allowed the operation of wide-bodied aircraft such as DC-10 and B-747 since the mid-nineties, though the runway had not been designed for the operation of these aircraft. Soon after opening of the runway to traffic, extensive cracking on the runway slabs, particularly at the touchdown and take-off areas of the runway, was reported. Exceeding load carrying capacity of the pavement due to operations of wide bodied aircraft together with poor sub grade stability aggravated the extent of crack development. Due to extensive deterioration of the runway slabs, a careful and thorough repair of the cracks followed by construction of an overlay became essential for structural strengthening of the runway pavement. This paper presents the results of the crack survey carried out and detailed methodology developed for the repair of cracks of various widths. A brief review of various types of cracks originated in pavements has also been presented.

Cracks In Asphalt Pavements-Flexible portion

Cracking takes many forms. Simple crack filling may be the right treatment in some cases. In others, complete removal of the affected area and the installation of drainage may be necessary before effective repairs can be carried out. ACI (1983) reports the various types of cracks and the repair techniques in asphalt pavements. These are briefly reviewed in this section.

Fatigue or Alligator Cracks

These are series of interconnected cracks forming a series of small blocks resembling an alligator's skin. In most cases, fatigue cracking is caused by excessive deflection of the surface over unstable sub grade or lower courses of the pavement. The unstable support usually is the result of saturated granular bases or sub grade. Since small localized fatigue cracking usually is the result of saturated bases or sub grades, correction should include removing the wet material and installing needed drainage.

Asphalt plant-mixed material can then be used for the full depth for a strong patch. In case of large fatigue cracking due to repeated loads which is an indicative of general structural failure, repairs should be made by placing a hot mix asphalt (HMA) overlay layer over the entire pavement surface. This overlay must be strong enough structurally to carry the anticipated loading because the underlying fatigue cracked pavement most likely contributes little or no strength.

Block Cracking

These are interconnected cracks that divide the pavement up into rectangular pieces. Blocks range in size from about 0.1 m² to 9 m². Block cracking normally occurs over a large portion of pavement area but sometimes will occur only in non-traffic areas. Block cracking is typically caused by an inability of asphalt binder to expand and contract with temperature cycles because of asphalt binder aging and poor choice of asphalt binder in the mix design. Applying crack seal to prevent entry of moisture into sub grade through the cracks and further raveling of the crack edges repairs low severity cracks 12.7mm wide. HMA can provide years of satisfactory service after developing small cracks if they are kept sealed. High severity cracks (> 12.7 mm wide and cracks with raveled edges) are repaired by removing and replacing the cracked pavement layer with an overlay.

Reflection Cracks

These are cracks in asphalt overlays, which reflect the crack pattern in the pavement structure underneath. The pattern may be longitudinal, transverse, diagonal, or block. They occur most frequently in asphalt overlays on Portland cement concrete and on cement or pozzolanic treated bases. They may also occur in asphalt overlays on asphalt pavements whenever cracks in the old pavement have not been properly repaired. Reflection cracks are caused by vertical or horizontal movements in the pavement beneath the overlay, brought on by expansion and contraction with temperature or moisture changes. Small cracks (less than 3 mm in width) are too small to seal effectively. Large cracks (3 mm and over in width) are to be filled with asphalt emulsion slurry or light grade of emulsified asphalt mixed with fine sand.

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Also, special asphalt compounds or heavier bodied asphalt material may be used to fill large cracks.

Edge Cracks

These are longitudinal cracks a third of a metre or so from the edge of the pavement with or without transverse cracks branching towards the shoulder. Usually, edge cracks are due to lack of lateral (shoulder) support. They may also be caused by settlement or yielding of the material underlying the cracked area, which in turn may be the result of poor drainage, frost heave, or shrinkage from drying out of the surrounding earth. In the last case trees, bushes or other heavy vegetation close to the pavement edge may be a cause. For temporary repair, fill is used as for reflection cracks. For more permanent repair, cracks are filled with asphalt emulsion slurry or emulsified or cutback asphalt mixed with sand.

Edge Joint Cracks

An edge joint crack is really a seam. It is the separation of the joint between the pavement and the shoulder. It is treated as a crack, however. A common cause of "cracking" in a pavement shoulder joint is alternate wetting and drying beneath the shoulder surface. This may result from poor drainage due to a shoulder higher than the main pavement, from a ridge of grass or joint-filling material, or from depressions in the pavement edge, all of which trap water and allow it to stand along and seep through the joint. If water is the cause, the first step is to improve the drainage by getting rid of the condition that traps water. Then the cracks are repaired following a procedure similar to reflection cracks.

Lane Joint Cracks

Lane joint cracks are longitudinal separations along the seam between two paving lanes. This type of crack usually is caused by a weak seam between adjoining spreads in the courses of the pavement. These cracks are repaired similar to reflection cracks.

Shrinkage Cracks

Shrinkage cracks are interconnected cracks forming a series of large blocks, usually with sharp comers or angles. Frequently, they are caused by volume change of fine aggregate asphalt mixes that have a high content of low penetration asphalt. Lack of traffic hastens shrinkage cracking in these pavements. Filling cracks with asphalt emulsion slurry followed by a surface treatment or a slurry seal over the entire surface repairs these cracks.

Slippage Cracks

These are sometimes crescent-shaped cracks that point in the direction of the thrust of wheels on the pavement surface. Slippage cracks are caused by the lack of a good bond between the surface layer and the course beneath. The lack of bond may be due to dust, oil, rubber, dirt, water, or other non-adhesive material between the two courses. Usually, such a lack of bond exists when no tack coat has been used. Slippage cracks may also be due to a mixture having a high sand content, and they can occur whether the sand is sharp or rounded. Sometimes slippage may develop under traffic because improper compaction during construction caused the bond layers to be broken. The only proper way to repair a slippage crack is to remove the surface layer from around the crack to the point where good bond between the layers is found. Then the area is patched with plant-mixed asphalt material.

Widening Cracks

Widening cracks are longitudinal reflection cracks that show up in the asphalt overlay above the joint between old and new sections of a pavement widening. The causes of development of

these cracks and repair of these cracks are similar to reflection cracks.

Cracks in Concrete pavement- Rigid pavement

Cracks that occur in the rigid pavements of the runway at operational readiness platform ends 13 and 31 are as:-

ACI (1983) reports the various types of cracks and the repair techniques in PCC pavements. These are summarized in this section.

Transverse Cracks

These cracks are approximately at right angles to the centerline of the pavement. Some major causes of transverse cracks are overloads, repeated bending of pumping slabs, failure of soft foundations, "frozen" joints, lack of joints, too shallow joints, and shrinkage of the concrete. Cleaning the cracks of all loose matter and fill with a rubber asphalt sealer repairs these cracks. If the crack is caused by pumping, the void beneath the pavement must be filled with rubber-asphalt compound.

Longitudinal Cracks

These cracks are approximately parallel to the center line of the pavement. Some causes of longitudinal cracking are shrinkage of the concrete (if the pavement is too wide and has no longitudinal joint), expansive sub base or sub grade, warping stresses in combination with loads, too shallow centerline joints not sawed early enough, loss of support from edge pumping. These cracks are repaired following a procedure similar to transverse cracks.

Diagonal Cracks

These cracks are diagonal to the centerline of the pavement. Diagonal cracks generally are caused by traffic loads on unsupported slab ends. The foundation settles or the slab curls, then sub grade soil pumps out, mostly along the edge. This results in a diagonal crack. Repair for this type of crack consists of filling the void beneath the pavement and cleaning and sealing the crack with the rubber-asphalt compound.

Corner Cracks

These are diagonal cracks forming a triangle with a longitudinal edge or joint and a transverse joint or crack. Corner cracks can be caused by traffic loads on unsupported corners or curled or warped slabs.

They may also be caused by loads over weak spots in the sub grade under the slabs. These cracks are repaired by removing the broken corner and patching with dense graded asphalt concrete (ASTM D3515 Mix) [1] in layers not exceeding 100 mm each in thickness. The surface should be finished flush with the surrounding pavement.

Restraint Cracks

These are cracks which develop near, (within one metre or less) the outside edges of a PCC (plain cement concrete) pavement and progress in an irregular path toward the longitudinal joint. Restraint cracks are caused by foreign matter, such as hard gravel, becoming lodged deep in a transverse joint and restraining the slabs from expanding. The blocked transverse joint should be plowed out and resealed with a rubber-asphalt compound. The restraint cracks should be cleaned and sealed if they are wide enough to require sealing

Classification of Cracks

A visual crack survey was carried out for this work. The cracks have been classified into four categories according to their width of opening. The four categories of cracks are as follows:

- (i) cracks less than ¼ inch (6.4 mm) in width
- (ii) cracks between ¼ inch and 1 inch (6.4 mm and 25 mm) in width

(iii) cracks between 1 inch and 2 inch (25 mm and 50 mm) in width

(iv) cracks more than 2 inch (50 mm) in width

Cracks of width less than 6.4 mm are well defined, easily visible but have very little width fall under this category. Concrete adjacent to these cracks was in good condition. Most of the cracks under this category had not been repaired previously.

Cracks of width between 6.4 mm and 25 mm are very well defined and many of these have been repaired without cutting the sides of the cracks. The cracks have widths ranging from 6.4 mm to 25 mm.

Cracks of width between 25 mm and 50 mm where the width refers either to the actual crack width in the pavement or to the present state of the crack after spalling of concrete took place from the adjacent areas. The previous repair work of this type of cracks had been not done and overlay of the P.C.C slab was placed without repair of the cracks. It is better to repair the crack by cutting about 25 mm wide grooves. The groove must be then filled with an epoxy based joint sealant.

Cracks of width more than 50 mm must be repaired after cutting 150 mm wide and 75 mm deep grooves and then filling with asphalt concrete to the level of the pavement. The cases where two minor cracks were formed at about 50 mm spacing, with the concrete in between weathered, were also classified under this category. Available reports indicated that the extent of cracks increased over the last few years. Present survey shows that most of the central slabs (middle 15.2 m) are badly cracked and broken into a number of pieces (six pieces or more). In the touch down and take-off areas on both sides (152.4 m to 518.2 m in the North end and 2438.4 m to 2895.6 m in the South end) the central slabs are severely cracked. Fig. 2 shows a typical results of crack survey for 12 panels, each 20 ft (6.1 m) in length, of the runway slabs from 3500 ft to 3740 ft (1066.7 m to 1139.9 m). It can be seen from Fig. 2 that the central slabs are severely cracked while the half-width edge slabs, which do not experience aircraft loads are, in general, in a much better condition, showing no sign of cracks.

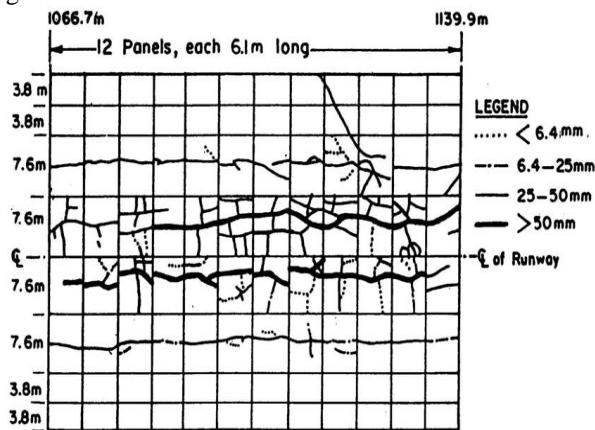


Figure 1. A Typical Portion of Runway Slabs Showing Extent of Cracks of Varying Widths

Crack Repair Methodology (Flexible)

Cracks in flexible pavement sections may be load induced fatigue, reflective (from cracks in the base), shrinkage or caused by a deficient mix design. Each type of crack shows up in a particular manner, for instance load induced cracks typically start as longitudinal cracks and progress to alligator cracking. Reflective cracks typically follow the shrinkage crack or joint pattern of the base material. Repair methodologies were developed for the repair of cracks of different categories. Repair methodologies have been described in the following sections.

The entire repair work should be carried out at night and the runway, being the only runway of the airport, must be kept operational for air traffic during the day.

Repair of Cracks of Width less than 6.4 mm

Field survey revealed the presence of about 3353 m of cracks of this type. Of these about 2743 m of cracks are not wide enough to receive any sealing material with ease. About 610 m of wider cracks in this category were sealed. The cracks must be repaired using the following procedure:

(i) Using wire brush, stiff bristled brooms and compressed air the pavement surface around the cracks and the cracks were cleaned of all dirt, dust, loose material and vegetation.

(ii) The cracks were then filled with hot asphalt AC-20 by a pressure injection method.

Repair of Cracks of Width 6.4 mm and 25 mm

There were about 3657 m of cracks in this category. In order to repair the cracks the following procedure should be adopted :

(i) The vertical faces of the cracks were sand blasted to a depth of at least 25 mm and the pavement surface at least 25 mm to each side of the crack.

(ii) The cracks were then cleaned of loose debris, dirt, previously placed filler material and vegetation using wire brushes, shovels and compressed air.

(iii) The cracks were filled with rubberized asphalt that met Federal Specification S-SS-1401 and satisfactory for local environmental conditions. Concrete joint sealer of the hot poured elastic type (ASTM 1190) which meets the requirements of ASTM D1191 (ASTM, 1986) [1] was also used. Care was taken to ensure that the material was not heated to too high a temperature or for too long a time. Direct heating was not used. Positive temperature control, mechanical agitation and re-circulating pumps were used.

(iv) A tack coat of hot AC-20 was then applied followed by placement of a 500 mm wide high-density stress relief fabric, namely, PavePrep. Typical crack repair and placement detail of fabric is shown in Fig. 3

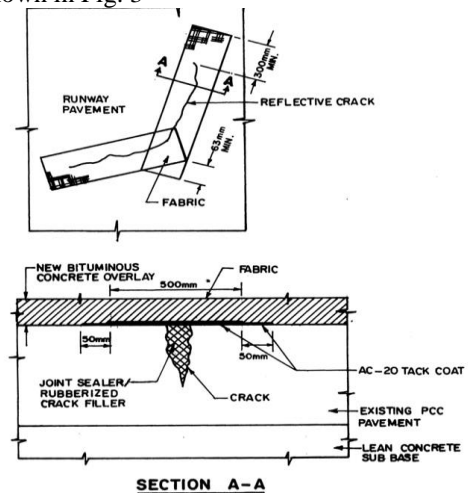


Figure 3. Typical Repair Method of Cracks of Width 6.4 mm to 25 mm and Placement details of Fabric.

Repair of Cracks of Width more than 25 mm

Three types of cracks of this category have been identified which are as follows:

Type 1: These are single non-interconnected cracks which are relatively straight and where cutting of grooves can be done without causing damage/disturbance in the areas adjoining the cracks are included in this type. These cracks are predominant in the slab panels between 25 ft (7.6 m) and 50 ft (15.2 m) on either side of the centreline of the runway. It was estimated that about

30% of the cracks of this width in the central slab panels (between 0 and 25 ft on either side of runway centerline) would also be in this category. Total cracks of this type were about 6096 m. Cracks of this type must be repaired using the following standard procedure:

- (i) The area should be marked taking at least 25 mm from the edge of the cracks.
- (ii) Trenches of 300 mm wide and 75 mm deep must be formed, as shown in Fig. 4, using concrete cutting wheel/machine.
- (iii) The debris and milled materials then removed using sweepers with vacuum hose attachment.
- (iv) Using air compressor with hose and nozzle attachment, the remaining dust should be blown from the trench.
- (v) Cracks / cavity at the bottom of the trench, if present, was filled up using either a liquid sealer (as in case of cracks of width 6.4 mm to 25 mm) or a hot-mix asphalt similar to that used for the surface course (for large cracks and cavities). A hand tamper can be used to compact the hot-mix asphalt in the bottom of the trench.
- (vi) A tack coat of hot AC-20 has to apply on the bottom surface and the edges of the trench.
- (vii) A high-density stress absorbing membrane (i.e., PavePrep) should be placed.
- (viii) Additional tack coat using the same material (as in step (vi)) must be applied on top of the Pave Prep.
- (ix) The trench then must be filled with hot-mix asphalt, similar to that specified for surface mix, and compacted to 98% of laboratory density using a roller. The surface of the compacted asphalt mix shall be at the same grade as the existing PCC slabs.
- (x) A tack coat of hot AC-20 needed to be applied on the trench area and another layer of Pave Prep similar to that used at the bottom of the trench but of width of 600 mm has to be placed.
- (xi) Hot-mix asphalt overlay should be placed following the placement at the second layer of Pave Prep. Prior to hot-mix overlay, the top of the PavePrep was tacked over along with the existing surface at a rate determined by trials.

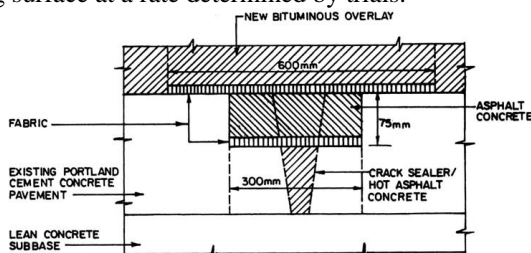


Figure 4. Repair of Wide Cracks (more than 25 mm in width) of Type 1

Type 2: Large cracks for which 150 mm wide and 75 mm deep trenches were cut and filled with asphalt concrete previously by the CAAI (about 2804 m) are included in this type. The following procedure was adopted for repairing for this type of cracks.

- (a) Where 300 mm wide trenches may be cut without damaging the adjacent areas, the procedure and materials specified for the repair of Type 1 cracks were used.
- (b) Where trench cutting similar to that for Type 1 was not possible without damaging the concrete in the adjoining area, the following steps were adopted for repair of these cracks:
 - (i) The existing asphalt mix in the trench was plowed out.
 - (ii) The vertical edges and bottom of the trench were cleaned and all foreign materials were removed using a joint cleaning machine and devices including hand tools.
 - (iii) All loose materials and debris were removed from the trench using sweepers with vacuum hose attachment.

- (iv) If no crack/cavity was found at the bottom of the trench, the trench was filled up with asphalt concrete [Fig. 5(a)]. Tack coat of hot AC-20 was uniformly applied on the edges and the bottom of the trench before placement of the hot-mix asphalt. The mix was compacted using vibratory rollers. The level of compacted asphalt was the same as the adjacent PCC slab. If on completion of step (iii) of this method, a large cavity was found at the bottom of the trench, it was filled up with a surface course of hot-mix asphalt and compacted to the level of the bottom of the trench. The mixture was tamped appropriately in place [Fig. 5(b)]. Tack coat of hot AC-20 was uniformly applied on the vertical edge and bottom of the trench and the trench was filled with hot-mix asphalt and compacted to the level of the PCC slab. If, however, on completion of step 3 of this method, cracks were found at the bottom of the trench, 50 mm diameter holes was drilled along the crack 600 mm centers up to the bottom of the slab. Using an air compressor with hose and nozzle attachment, the dust from the holes was blown out. An asphalt (AC-40) meeting the requirements of ASTM D3381 (ASTM, 1986) [1] was heated to a safe temperature to make it sufficiently fluid suitable for pumping through the holes using a pressure distributor at a pressure of 175 kPa to 415 kPa until the cracks up to the bottom of the trench were filled up. Requirements of AC-40 are shown in Table 2. Temporary round wooden plugs were used. After the asphalt had hardened, the temporary plugs were removed and the holes were filled with an asphalt surface course mixture, thoroughly tamped in place. Tack coat of hot AC-20 was uniformly applied on the vertical edge and bottom of the trench and the trench was filled with hot-mix asphalt and compacted to the level of the PCC slab.

- (v) A tack coat of hot AC-20 was uniformly applied on the trench area followed by placement of Pave Prep of width 500 mm according to the procedure shown in Fig. 5(c). (vi) Hot mix asphalt overlay was then placed after an uniform application of tack coat of hot AC-20 on the Pave Prep and the existing surface as mentioned in step (xi) for Type 1 cracks.

Type 3: Crack survey revealed the presence of many random and interconnected wide cracks where trench cutting similar to that for Type 1 cracks would not be feasible and any attempt to groove cutting is likely to cause serious damage to the runway slab. About 6096 m of cracks of this type were identified. These cracks must be repaired using the following method:

- (i) 50 mm diameter holes must be drilled through the entire slab on 600 mm centres along the crack.
- (ii) Debris from the holes has to remove by using compressed air. The holes were cleaned from dust, any loose and foreign materials.
- (iii) The cracks and holes were filled up using materials as mentioned in step (iv) for Type 2 cracks.
- (iv) Tack coat of hot AC-20 has to be uniformly applied and high-density fabric Pave Prep of width 500 mm need to be placed following standard procedures as shown in Fig. 6.
- (v) Tack coat of hot AC-20 needed to be uniformly applied on the top of the fabric and the existing surface before placement of the hot-mix asphalt overlay.
- (vi) The top of the fabric and the existing surface was tack coated before placement of the overlay.

Crack Repair Methodology (Rigid)

Cracks in rigid pavements may be either traffic load induced, thermally induced, caused by chemical instability, caused by mix characteristics or by construction technique. These cracks vary in manifestation from slight crazing of the surface to full depth structural cracking causing loss of structural

integrity. In assessing crack distress of concrete pavements it is important to recognize the relationships between the location and orientation of the cracking to its failure category. For example, crazing or map cracking is typically categorized as a materials or technique problem that, while affecting durability, has a little or no bearing on the structural integrity of the section, whereas large corner cracks in slab sections are significant structural problems. Repair methodologies for rigid pavements at dumb ends(13 and 31) were developed for the repair of cracks of different categories. Repair methodologies have been described in the following sections. The entire repair work should be carried out at night and the runway, being the only runway of the airport, must be kept operational for air traffic during the day.

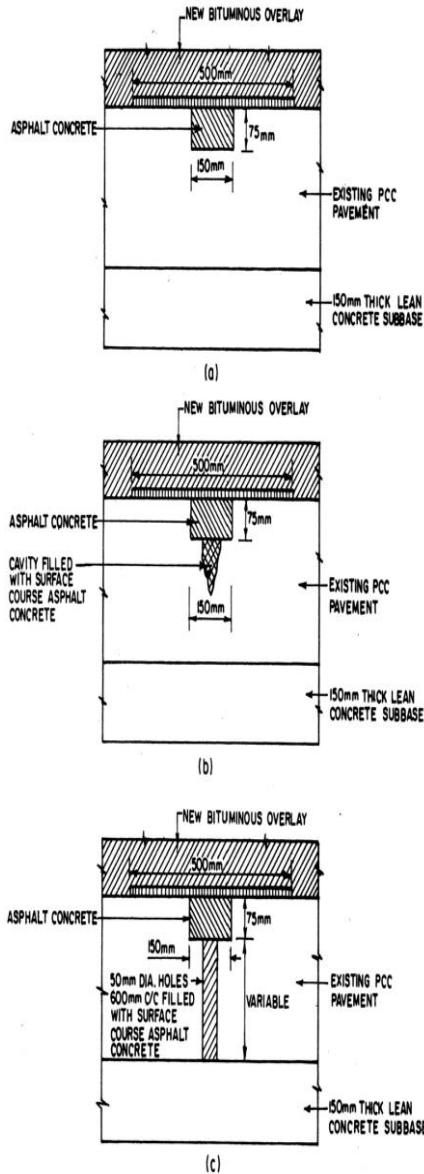


Figure 5. Repair of Wide Cracks (more than 25 mm in Width) of Type 2

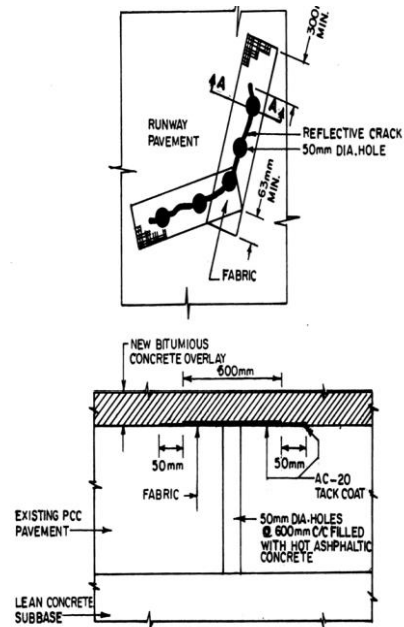


Figure 6. Repair of Wide Cracks (more than 25 mm in Width) of Type 3

Conclusions

A visual crack survey was carried out to assess the extent of crack development on the runway at the Srinagar International Airport, Srinagar. Cracks having width of less than 6.4 mm to more than 50 mm were identified which were classified into four categories. Wide cracks (more than 25 mm in width) of about 15500 m and narrow cracks (less than 25 mm in width) of about 7000 m were detected. Repair methodologies were developed for each category of crack. No sign of distress was found till date after the treatment, therefore depicts that crack of varying nature needs specified treatment rather a generalized treatment.

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