

CRACK SURVEY, CRACK REPAIR METHODOLOGY AND OVERLAY DESIGN FOR REHABILITATION OF A RUNWAY PAVEMENT

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Abstract: Extensive cracking on the runway slabs at the Zia International Airport, Dhaka took place due to overloading of aircraft operations and poor subgrade stability. A visual crack survey was carried out in 1993. 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 thickness of the asphalt overlay at the centreline of the runway was 200 mm and a slope of 1.5 per cent of the surface was provided. The repair works and the construction of the overlay were carried out at night. The runway has been in service and no sign of distress has been observed since the completion of repair works and overlay construction in 1996.

Key Words: Runway, Cracks, Crack survey, Crack repair, Overlay design

1. INTRODUCTION

The construction of the runway at the Zia International Airport, Kurmitola, Bangladesh 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 Bangladesh (CAAB) allowed the operation of wide-bodied aircraft such as DC-10 and B747 since the mid-eighties, 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. Moreover, vast areas of the airport including major portion of the runway was inundated due to devastating floods in 1987 and 1988 which reduced the overall stability of the subgrade. Exceeding load carrying capacity of the pavement due to operations of wide-bodied aircraft together with poor subgrade 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. Finally, design considerations and overlay design are presented in the paper.

2. CRACKS IN ASPHALT PAVEMENTS

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.

2.1 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 subgrade or lower courses of the pavement. The unstable support usually is the result of saturated granular bases or subgrade. Since small localized fatigue cracking usually is the result of saturated bases or subgrades, 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.

2.2 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 subgrade through the cracks and further raveling of the crack edges repairs low severity cracks 0.5 inch wide. HMA can provide years of satisfactory service after developing small cracks if they are kept sealed. High severity cracks (> 0.5 inch wide and cracks with raveled edges) are repaired by removing and replacing the cracked pavement layer with an overlay.

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

2.4 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.

2.5 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. Other causes are shoulder settlement, mix shrinkage, and trucks straddling 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.

2.6 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.

2.7 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.

2.8 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.

2.9 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.

3. CRACKS IN PORTLAND CEMENT CONCRETE (PCC) PAVEMENTS

PCC pavements are defined as “approximately vertical random cleavage due to natural causes or traffic action”. ACI (1983) reports the various types of cracks and the repair techniques in PCC pavements. These are summarized in this section.

3.1 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.

3.2 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 subbase or subgrade, 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.

3.3 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 subgrade 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.

3.4 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 subgrade under the slabs. These cracks are repaired by removing the broken corner and patching with dense-graded asphalt concrete (ASTM D3515 Mix) in layers not exceeding 100 mm each in thickness. The surface should be finished flush with the surrounding pavement.

3.5 Restraint Cracks

These are cracks which develop near, (within one metre or less) the outside edges of a 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.

4. THE EXISTING RUNWAY PAVEMENT AT ZIA INTERNATIONAL AIRPORT

The pavement subgrade at Zia International Airport, Dhaka was constructed by placing local soils from adjoining areas. The thickness of the compacted fill varied between 3 and 14 ft. (0.9 and 4.3 m). A 6 inch (150 mm) lean mix concrete with 1: 3 : 6 (cement : sand : aggregate) ratio was used as sub-base material to support the Portland cement concrete (PCC) slabs. The paved runway is an unreinforced PCC pavement, which is 10500 ft (3200 m) long with 900 ft (275 m) long stopway (overrun) strips at both ends. The runway width is 150 ft (45.7 m) with 25 ft (7.6 m) shoulders on both sides. The vertical alignment of the centerline has only small variation in level. The cross-section has a 1 per cent slope from the centerline to the shoulders and about 2 per cent slope along the shoulders. The shoulders are constructed of 2 inch (50 mm) asphalt concrete overlaying 6 inch to 8 inch (150 mm to 200 mm) of red brick soling placed on the compacted subgrade. Typical existing runway pavement cross-sections are shown in Fig. 1. The size of runway slabs at the two ends (500 ft each) is 25 ft by 25 ft (7.6 m by 7.6 m) and 25 ft by 20 ft (7.6 m by 6.1 m) in the interior. Generally, taxiways are formed by 25 ft by 25 ft (7.6 m by 7.6 m) slabs. Many of the edge slabs along both sides of the runway have a longitudinal contraction joint (dummy type) which divides them to a 12.5 ft (3.8 m) width. Chainage is zero at the south end of the runway.

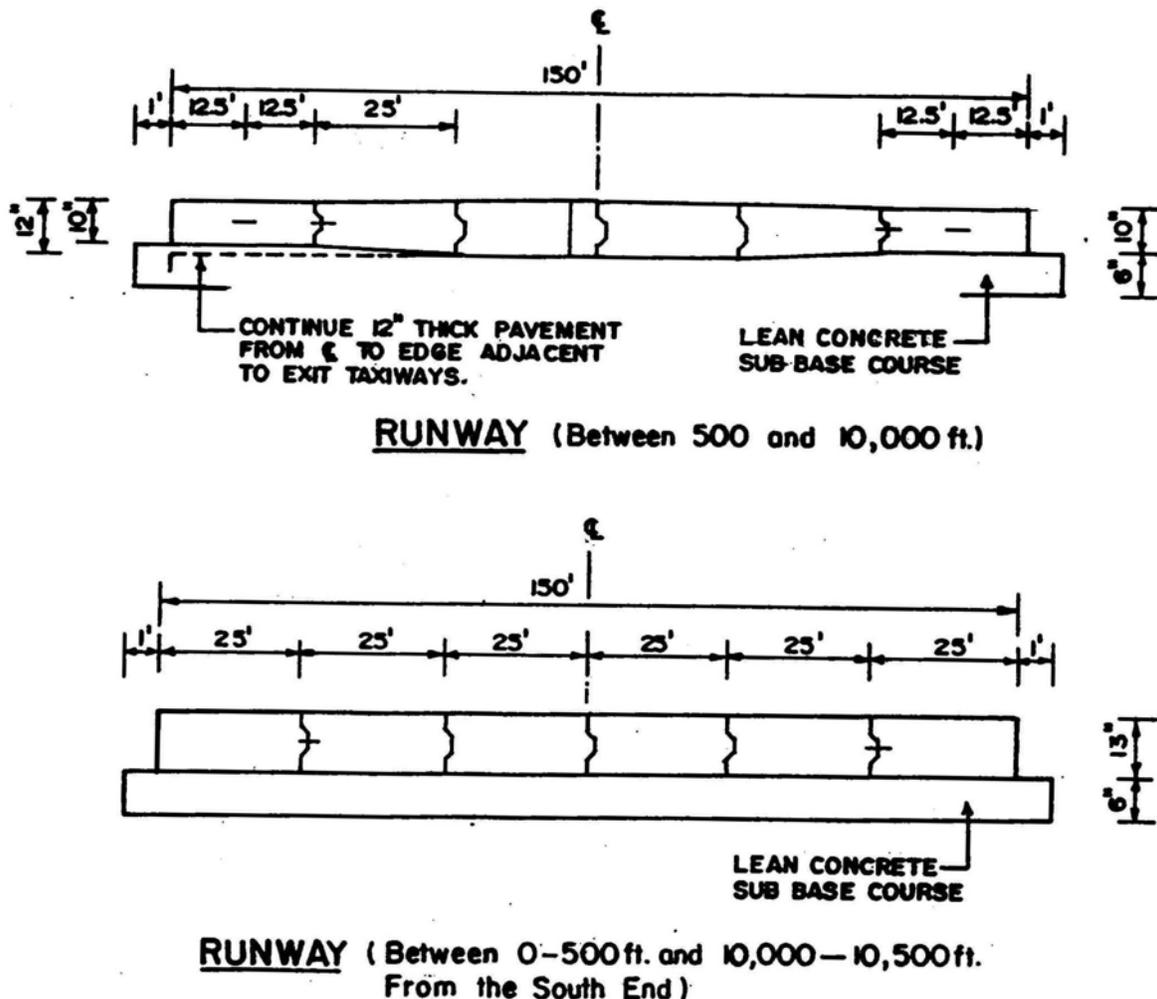


Figure 1. Cross-Sections of Existing Runway Pavement

5. PREPARATION OF PAVEMENT FOR OVERLAYS

Careful and thorough preparation of the existing pavement prior to the construction of overlays, is essential for good construction and maximal overlay performance. The following preparatory works were included:

- (i) Removal of rubber deposit and paint markings from the runway.
- (ii) Seating slabs using heavy roller and undersealing (if any movement is noticed).
- (iii) Repair of individual slab
- (iv) Repair of spalled areas.
- (v) Removing and replacing badly disintegrated and damaged slabs.
- (vi) Repair of patched areas
- (vii) Repair of corner breaks
- (viii) Resealing of joints
- (ix) Sealing of cracks and crack repair

5.1 Removal of Rubber and Paint Markings

The rubber deposits and paint markings on the runway were removed using high pressure water jets, chemicals, high velocity particle impact or mechanical grinding.

5.2 Seating Slabs Using Heavy Rollers

Heavy rollers (minimum weight - 50 tons) were used for seating of the slabs up to 50 ft. on either side of the centre line of the runway. The roller was allowed to move at slow speeds (4-8 km per hour) and movement, if any, of slab at joint was observed. Where visible movement of the slab was observed, the slabs were undersealed using asphalt meeting the requirements of ASTM Specification D 3141 as shown in Table 1. The specification for undersealing Portland Cement Concrete Pavements with Asphalt (CL- 13) of the Asphalt Institute (1983), USA was followed.

Table 1. Requirements for Asphalt for Undersealing Portland Cement Concrete Pavements

Properties	Minimum	Maximum
Softening point, °C (°F)	85 (185)	96 (205)
Flash point, °C (°F)	225 (437)	-
Penetration at 0°C (32°F), units	6	-
Penetration at 25°C (77°F), units	15	35
Penetration at 46°C (115°F), units	-	90
Ductility at 25°C (77°F), cm.	2.5	-
Solubility in trichloroethylene, %	99	-

5.3 Repair of Individual Slab

When an individual slab has cracked, or has settled at its joint with another slab because of an isolated cavity the following procedure was adopted for repair:

Drilling holes: Holes were drilled not closer than 1 m from and on each side of the transverse crack or the joint. If corner pumping was observed, holes were drilled not closer than 1 m on

each side of the joint and about 1 m from the edge of the pavement closest to the affected corner. In case it became necessary to underseal a complete slab or a series of slabs because of a pattern of continuous voids, holes were spaced at intervals of between 2 to 4 m near the centerline of the slab. The holes in the two slabs were staggered so that, generally, the longitudinal distance between holes in two adjacent lanes was between 1.2 to 1.8 m. Other patterns may be developed as long as precautions were taken to avoid breaking the concrete slabs. The holes were approximately 50 mm in diameter and extended up to the bottom of the slab.

Blowing Holes: Compressed air at approximately 70 psi (480 kPa) pressure was blown through the holes for not less than 15 seconds nor more than 60 seconds to blow out water and mud through the joints and adjacent holes. Temporary removable wooden plugs were used if necessary. If a cavity cannot be adequately dried and asphalt was pumped underneath pavements in the presence of free water and thin mud, provision was made for the escape of air and steam through nearby holes or cracks. In such cases higher asphalt temperatures and pressures were used and the entire operation was performed at a rapid rate.

Preparation of Asphalt: The asphalt was heated to a temperature of 400°F to 450°F (204°C to 232°C) before pumping operations begin. The asphalt was circulated prior to pumping in order to free and warm up the lines of the circulating hose. When single-line metal patching hose was used, the hose and nozzle were connected. The nozzle placed in the open manhole on top of the distributor tank, and the asphalt circulated to warm up the hose line.

Pumping Asphalt: After the holes are blown out and the asphalt nozzle is firmly wedged into the hole, asphalt was pumped at a pressure of from 175 to 415 kPa until the underside of the slab was sealed and all cavities filled, or the pavement is being raised excessively. To prevent any asphalt that may leak out from around the nozzle from sticking to the pavement, water, lime water, or sand was sprinkled around the hole prior to pumping.

Plugging Holes: After pumping was completed, the nozzle was removed and the hole quickly plugged with a temporary cylindrical plug. After the asphalt has hardened, the temporary plug was removed and the hole completely filled with an asphalt surface course mixture, thoroughly tamped in place.

5.4 Repair of Spalled Areas

The spalled areas along the joints and elsewhere on the runway to be overlaid were marked. The spall was removed by sawing the slab approximately 1 inch back of the spalled concrete and to sufficient depth (minimum 50 mm) until sound concrete is reached. The surface was cleaned and dried. Emulsified asphalt tack coat (CSS-1 or CSS-1 h) was applied on the surface and edges of the groove. The area was then back filled with hot asphalt mixture as specified for surface course of the overlay. The mixture was then be compacted with hand tamper or with hand operated vibrating roller to the satisfaction of the Engineer. In case the compacted thickness of the fill was more than 75 mm, the fill was placed and compacted in layers of maximum compacted thickness of 75 mm.

5.5 Replacement of Slabs

Appreciable cracking took place on the central slabs on either side of the center line of the pavement. Some of the slabs have shown multiple cracks. Special treatment method was

applied for repairing of slabs in the central 50 ft of the runway. Eventually some 50 slab panels showing multiple wide cracks and heavily damaged were removed and replaced by precast panels. The slabs had holes as required to release water and air from underneath the slab after placement. In case it was found that lean concrete subbase under the slab being removed was cracked or have been damaged during lifting of the slab, such cracks and damages was repaired using lean concrete or hot mix asphaltic concrete. In case no new lean concrete is placed a sand cement mortar (of proportion not leaner than 1:4 by volume) of thickness 6 mm was placed on the sub-base. The precast slab was then be set on the sub-base and rolled using a 10 ton roller to level the slab and bring up about 12 mm of mortar up into each hole and around the perimeter.

5.6 Repair of Patched Areas

During the last few years, the Civil aviation Authority of Bangladesh (CAAB), as a part of its routine maintenance, applied asphalt concrete patches for about 930 m² on some slab panels. The thickness of these patches varies between 25 mm to 75 mm. Much of these patches were in poor condition. The existing bituminous patch was removed in order to examine whether cracks developed on the surface of these concrete slabs. If cracks were found, they were repaired following the appropriate method as discussed in the following sections.

A new patch was placed in advance of the overlay when the average thickness of the patch is determined to be more than 38 mm. It has estimated that new patch would be required to place on 465 m² area.

The following steps were followed for the placement of new patch:

- (i) The surface on which a new patch is to be placed was cleaned of all debris using shovels and brooms.
- (ii) At tack coat of emulsified asphalt of CSS-1 or CSS-1h was then applied uniformly in required amounts.
- (iii) Hot asphalt mix similar to that specified for the surface course of the overlay was then placed on the tack-coated surface.
- (iv) The mixture was then compacted to using rollers of approved type.

5.7 Repair of Corner Breaks

These diagonal cracks forming a triangle with a longitudinal edge or joint or a transverse joint or crack was repaired before the overlay operation. Such broken corners were marked and removed using pavement saw/cutter. The sub-base was cleaned of all debris. The area was patched with dense graded asphalt concrete similar to that used in the surface course of the overlay. The asphalt concrete was placed in layers and compacted.

5.8 Resealing of Joints

During the crack survey, the conditions of the joints (both longitudinal and transverse) were observed in order to identify the locations where the joint seal has been damaged and where sealing material protrudes above the pavement surface and there is excess sealing material on the surface. It was found that joint seals of about one-third of these joints (50000 rft, i.e., 15240 m) were in poor condition. These joints were resealed and repaired before the placing of an overlay. The following method was used for cleaning and resealing the joints:

- (i) The old seal was plowed out to a depth of 1.5 inch (38 mm)
- (ii) The vertical faces of the joint were cleaned to remove foreign materials and old seal from the pavement surface at least 1.5 inch (38 mm) on each side of joint.
- (iii) Vertical faces of joint and the pavement surface were sand blasted at least 1.5 inch (38 mm) on each side of the joint. Hand tools were used to remove any traces of old seal that might be left.
- (iv) The joints were blown out with compressed air.
- (v) The seal material was placed into the joint. A concrete joint sealer satisfying the requirements of ASTM D1191 (ASTM, 1986) was used. The outer ends of transverse joints were dammed to prevent sealing material from running out on to the shoulder.
- (vi) A tack coat of hot AC-20 which satisfies the requirements of ASTM D3381 (ASTM, 1986) was uniformly applied on the joint area and a layer of high density fabric (PavePrep) of width of 300 mm was placed on the tack coat.

PavePrep, a patented product, is a stress relief interlayer material consisting of high-density, heavy-duty mastic between two layers of rugged polyester fabric (McAdams, 1987). The mastic core provided PavePrep with durability, water impermeability and compatibility with the final hot-mix asphalt overlay. The polyester fabrics add to the durability, impart dimensional stability, and above all, confer exceptional flex resistance. This tough synthetic combination is capable of surviving installation stresses and loads encountered on airports.

6. 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 $\frac{1}{4}$ inch (6.4 mm) in width
- (ii) cracks between $\frac{1}{4}$ 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 preceded by a cutting about 25 mm wide grooves. The groove was then filled with an epoxy based joint sealant.

Cracks of width more than 50 mm were 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.

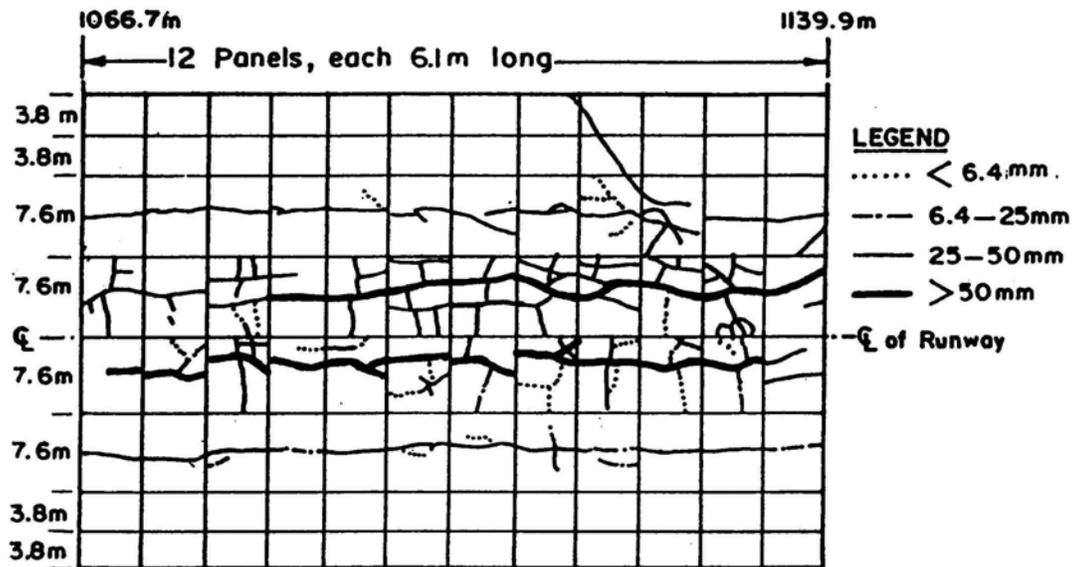


Figure 2. A Typical Portion of Runway Slabs Showing Extent of Cracks of Varying Widths

7. CRACK REPAIR METHODOLOGY

Repair methodologies were developed for the repair of cracks of different categories. Repair methodologies have been described in the following sections. The entire repair works were carried out at night and the runway, being the only runway of the airport, was kept operational for air traffic during the day. The major part of the repair of cracks was completed by 1995.

7.1 Repair of Cracks of Width less than 6.4 mm

Field survey revealed the presence of about 11000 rft (3353 m) of cracks of this type. Of these about 9000 rft (2743 m) of cracks are not wide enough to receive any sealing material with ease. About 2000 rft (610 m) of wider cracks in this category were sealed. The cracks were 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.

7.2 Repair of Cracks of Width 6.4 mm and 25 mm

There were about 12000 rft (3657 m) of cracks in this category. In order to repair the cracks the following procedure was 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) 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 recirculating 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.

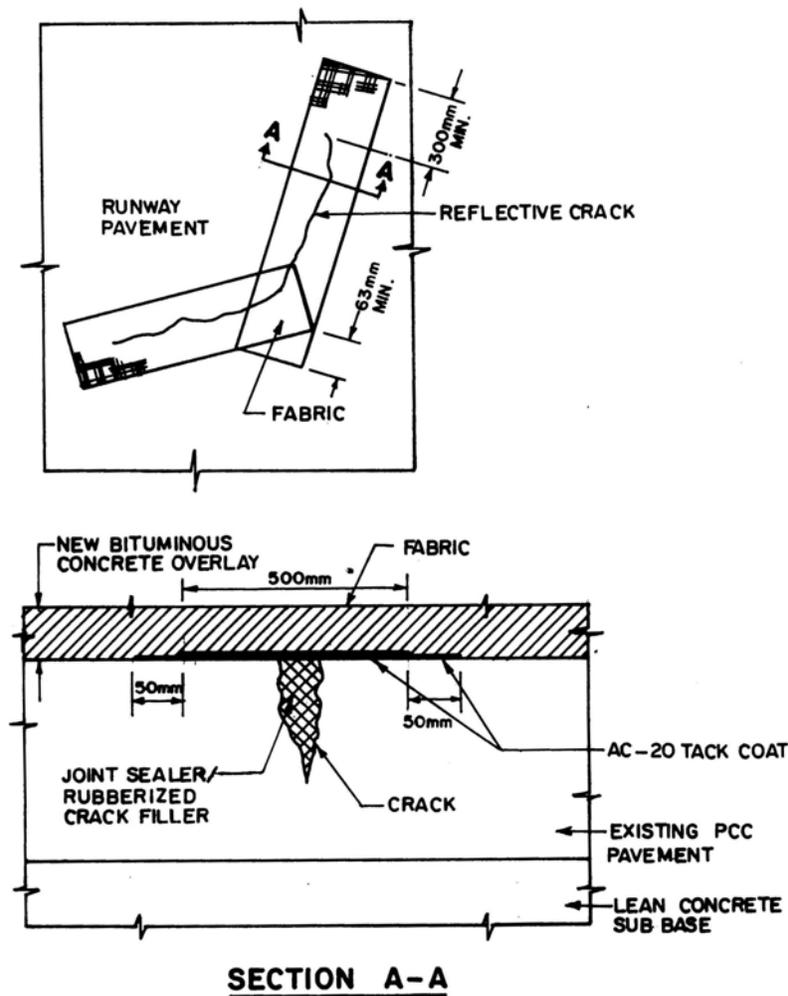


Figure 3. Typical Repair Method of Cracks of Width 6.4 mm to 25 mm and Placement Details of Fabric

7.3 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 centreline) would also be in this category. Total cracks of this type were about 20000 rft (6096 m). Cracks of this type was repaired using the following procedure:

- (i) The area was marked taking at least 25 mm from the edge of the cracks.
- (ii) Trenches of 300 mm wide and 75 mm deep was formed, as shown in Fig. 4, using concrete cutting wheel/machine.
- (iii) The debris and milled materials were removed using sweepers with vacuum hose attachment.
- (iv) Using air compressor with hose and nozzle attachment, the remaining dust was 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 was used to compact the hot-mix asphalt in the bottom of the trench.
- (vi) A tack coat of hot AC-20 was applied on the bottom surface and the edges of the trench.
- (vii) A high-density stress absorbing membrane (i.e., *PavePrep*) was placed.
- (viii) Additional tack coat using the same material (as in step (vi)) was applied on top of the *PavePrep*.
- (ix) The trench was then 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 was applied on the trench area and another layer of *PavePrep* similar to that used at the bottom of the trench but of width of 600 mm was placed.
- (xi) Hot-mix asphalt overlay was placed following the placement at the second layer of *PavePrep*. Prior to hot-mix overlay, the top of the *PavePrep* was tacked over along with the existing surface at a rate determined by trials.

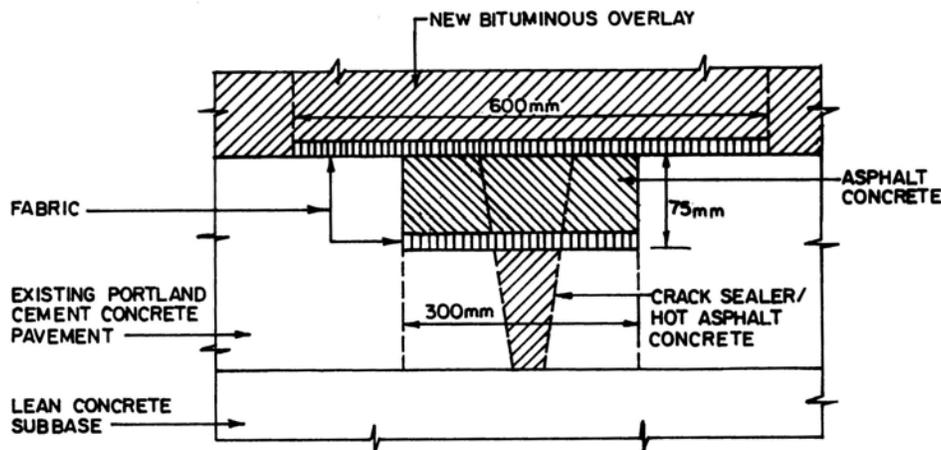


Figure 4. Repair of Wide Cracks (more than 25 mm in width) of Type 1

Type 2: Large cracks for which 150 mm wide and 75 mm deep trenches were cut and filled with asphalt concrete previously by the CAAB (about 9200 rft, i.e., 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 were drilled along the crack 600 mm centres 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) 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 is 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 PavePrep 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 PavePrep 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 20,000 rft (6096 m) of cracks of this type were identified. These cracks were repaired using the following method:

- (i) 50 mm diameter holes were drilled through the entire slab on 600 mm centres along the crack.
- (ii) Debris from the holes was removed and 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 was then uniformly applied and high-density fabric PavePrep of width 500 mm was placed following standard procedures as shown in Fig. 6.
- (v) Tack coat of hot AC-20 was 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.

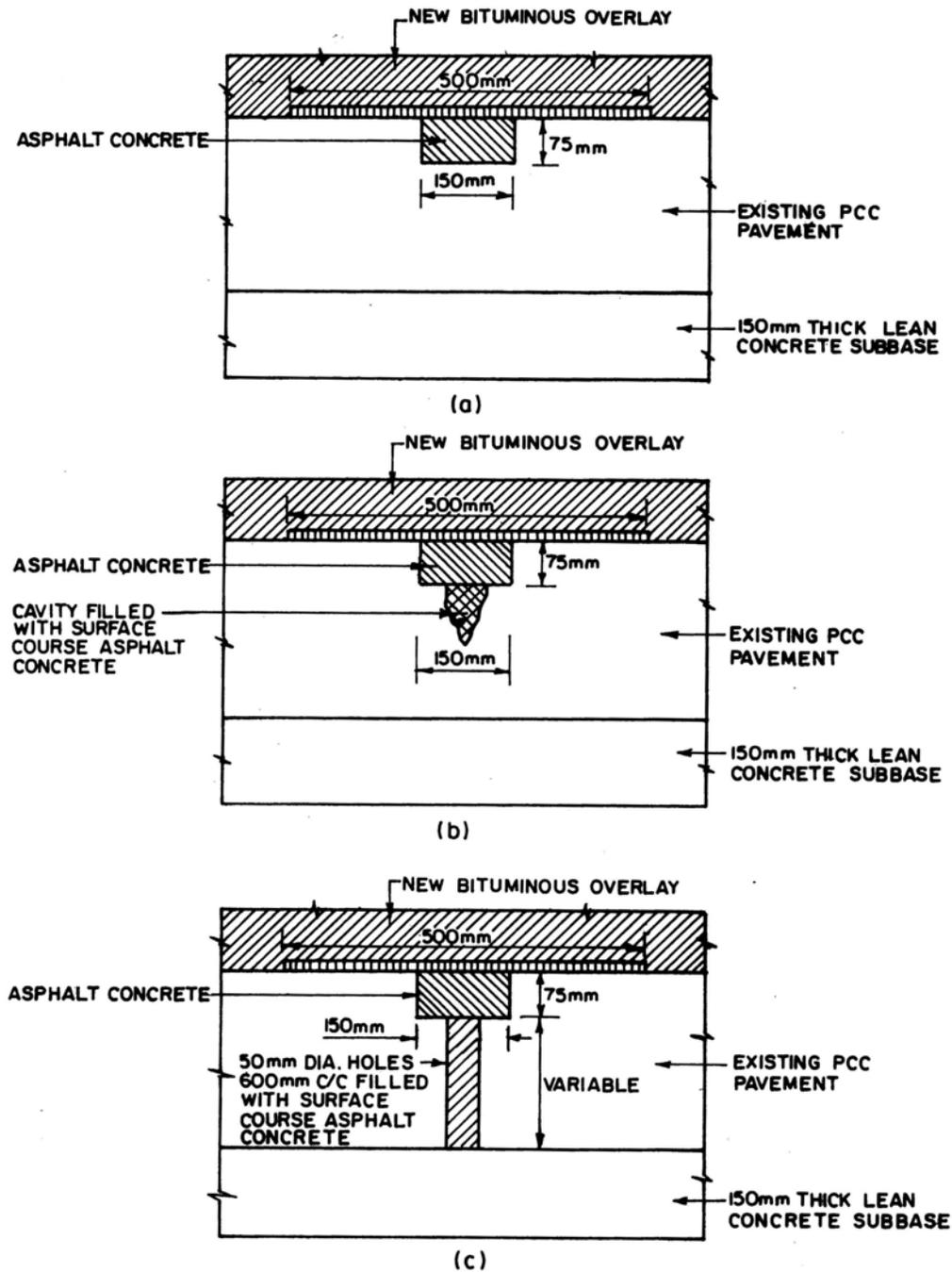


Figure 5. Repair of Wide Cracks (more than 25 mm in Width) of Type 2

Table 2. Requirements for Asphalt Cement AC-40

Test	Requirements
Viscosity, 140°F (60°C), Poise	4,000 ± 800
Viscosity, 275°F (135°C), minimum, cSt	400
Penetration, 77°F (25°C), 100g, 5s, minimum	40
Flash point, Cleveland open cup, minimum °F (°C)	450 (232)
Solubility in trichloroethylene, minimum, %	99.0
Viscosity on residue from thin-film oven test, 140°F (60°C), max. Poise	20,000
Ductility on residue from thin-film oven test, 77°F (25°C), 5 cm/min., cm	25

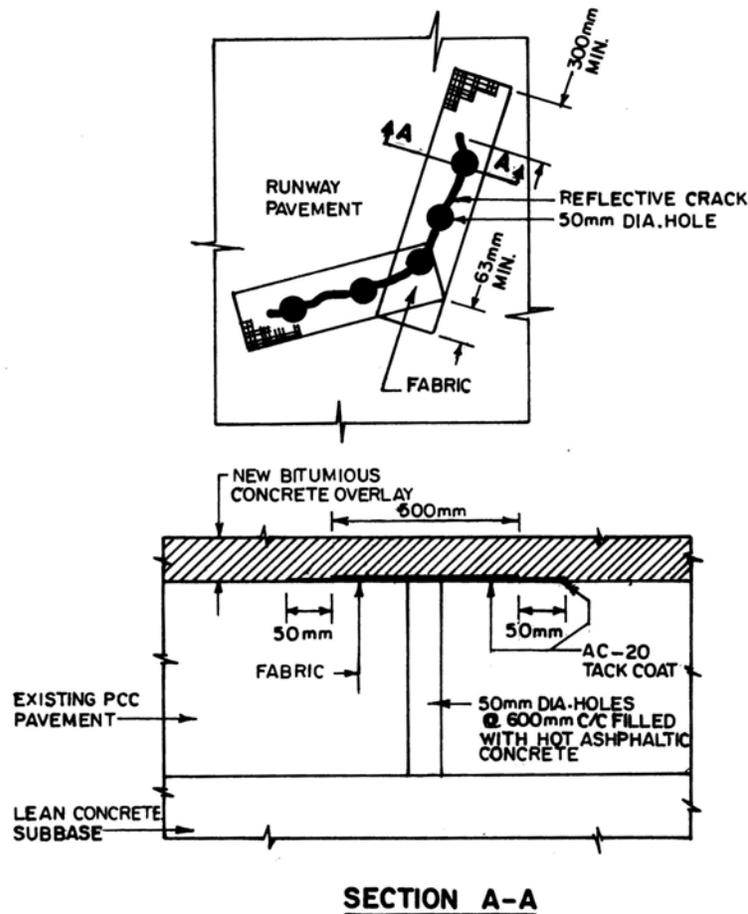


Figure 6. Repair of Wide Cracks (more than 25 mm in Width) of Type 3

8. DESIGN CONSIDERATIONS AND OVERLAY DESIGN

Field and laboratory tests were performed on subgrade, runway slab and lean concrete sub-base indicated the following values of different parameters as appropriate for design:

CBR (4-day soaked) of the subgrade at in situ density condition	= 7
Compressive strength of concrete in uncracked portion of runway slab	= 3700 psi (25.5 MPa)
Modulus of rupture of concrete in runway slab	= 490 psi (3.4 MPa)
Compressive strength of lean concrete sub-base	= 1890 psi (13.0 MPa)

Information on aircraft operation indicated that the wide-bodied aircraft DC 10-30/40 is the critical aircraft for overlay design. The overlay has been designed for an estimated annual departure of 12000 of the design aircraft having a gross load of 550000 lbs. However, the design was verified for annual departures of 6000 and 15000 for the design aircraft as well as other heavy aircraft such as 747-200 (gross load = 800000 pounds) and L1011-200. The airport pavement overlay design method contained in Aerodrome Design Manual published by International Civil Aviation Organization, ICAO (1983) was followed. A flexible overlay of thickness of 8 inch (200 mm) at the centreline was provided. This overlay ensures a PCN of the resultant runway pavement in excess of 59 as specified by the CAAB. A 600 mm wide and 150 mm thick strip of cement concrete was provided on either edges of the shoulder to provide protection from the encroachment of vegetation and ensure lateral support to the shoulder. In order to improve drainage, slopes of 1.5 per cent for the overlay surface of the runway and 2 per cent for the shoulder were provided. Taking into consideration of slope of the existing slab (1 per cent), 3.5 inch (89 mm) thick overlay at the edge was provided. The

thickness of the overlay on the shoulder was uniform and was equal to 3.5 inch (89 mm). Typical section of the overlay showing sequences of lane placing based on the use of 25 ft (7.6 m) wide paver is shown in Fig.7. A surface course of uniform thickness of 2 inch (50 mm) across the entire width was provided. The thickness of intermediate layer(s) varied with the depth, which reduced towards the edge. The shoulder was constructed in two layers. The thickness of the surface course was reduced to 1.5 inch (38 mm) for the shoulder. The entire construction of the hot-mix asphalt overlay was carried out at night and construction of the overlay was completed in mid 1996.

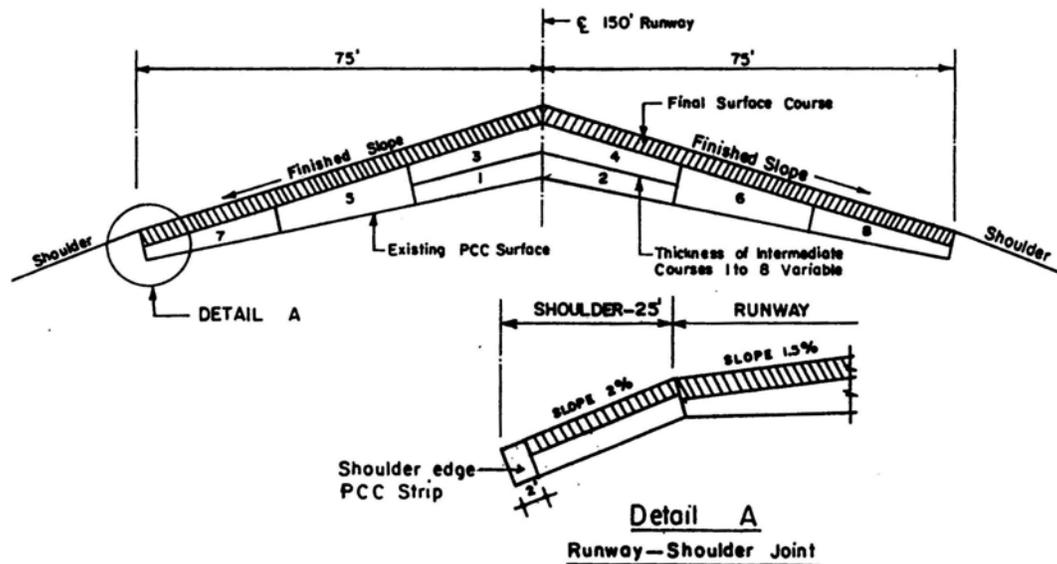


Figure 7. Typical Overlay Section Showing Sequences of Lane Placing Using 25 ft (7.6 m) Wide Paver

9. CONCLUSIONS

A visual crack survey was carried out to assess the extent of crack development on the runway at the Zia International Airport, Dhaka. 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. A flexible overlay of thickness 8 inch (200 mm) at the centreline of the runway was designed. The entire repair works and the construction of the hot-mix asphalt overlay were carried out at night. The major part of the repair of cracks was completed by 1995 and the construction of the overlay was completed in mid 1996. The runway has been in service including operation of wide bodied aircraft and no sign of distress or formation of cracks have been observed since the completion of the repair works and the construction of overlay.

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