Mustansiriyah University / College of Engineering
Highway &Transportation Engineering Department

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Lecture Six

There are several types of rigid pavement that you can choose from when you decide to put down concrete pavement in your local area. Each type has its own positives and negatives, and each one is designed to fit the right job. If you're thinking about having a new road built, now might be the time to do some research into the different types of rigid pavement and learn more about how they all work!

Fig.1: Concrete Pavement Constructio

Types of Concrete Pavements -Construction Details and Applications

Following are the different types of concrete pavements and their applications and advantages:

- Jointed unreinforced concrete pavement
- Jointed reinforced concrete pavement
- Continuously reinforced concrete pavement

1- Jointed Unreinforced Concrete Pavement

As it can be observed from Figure-2, jointed unreinforced concrete pavement is composed of batch work of concrete slab layers, which are small square units, connected by employing tie bars and dowels or joints that is provided to prevent cracks. So, the joint layout detailing of jointed unreinforced concrete pavement is important as it affects the design, construction, and services of the concrete pavement.

Fig.2: Jointed Unreinforced Concrete Pavement

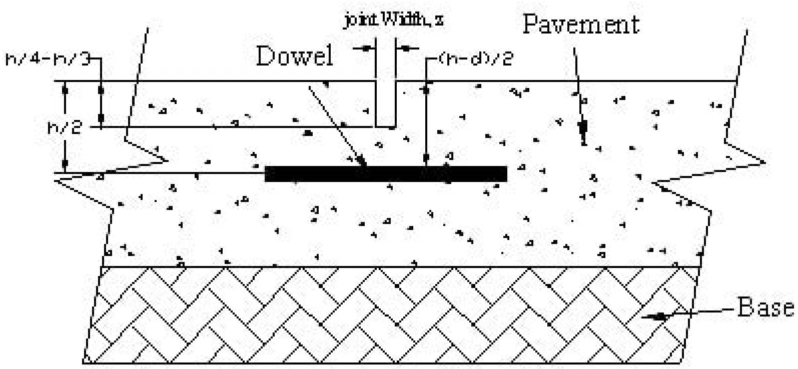

Fig.3: Details of Joints in Jointed Unreinforced Concrete Pavement

The success of jointed unreinforced concrete pavements depends on the tensile strength and flexural capacity of the concrete used which should withstand cracking and support imposed loads. The size of concrete pieces or panels is dependent on the concrete shrinkage strain created due to concrete hardening. Shrinkage strain creates tensile force in concrete and may cause cracks unless the tensile strength of concrete is greater than the tensile stresses generated by shrinkage strains. Designing, detailing and spacing of joints in the jointed unreinforced concrete pavements are considerably significant and joints need to be organized in such a way that produces square slab panels.

This could be obtained when the 90 degree between longitudinal joints and transverse joints are achieved as it can be seen in Figure-2. Additionally, the joint intervals in the jointed unreinforced concrete pavement is dictated by concrete slab thickness. The joint spacing increases as the thickness of the slab is increased and vice-versa. It is recommended to use steel dowels in the joints otherwise the ability of the joints to contain movements will be declined and eventually the slab thickness need to be increased. Table-1, which is taken with slight changes from American Concrete Pavement Association, provides guidance on determining spacing in concrete pavements.

Table-1: Joint Spacing for Concrete Pavement

Pavement thickness, cm	**Maximum recommended joint spacing, Limestone aggregate (m)**	**Maximum recommended joint spacing, Gravels and crushed stone (m)**
15	5.4	4.5
20	5.9	4.9
25	6.4	5.3
30	7.2	6

Applications of Jointed Unreinforced Concrete Pavements

Jointed unreinforced concrete slabs can be used in different applications which include airfield taxiway as it can be seen in Figure-4, airfield aprons see Figure-5, and industrial yard as shown in Figure-6.

Fig.4: Use of Jointed Unreinforced Concrete Pavement in Construction of Airfield Taxiway

Fig.5: Airfield Apron

Fig.6: Industrial Yard Constructed using Jointed Unreinforced Concrete Pavement

2- Jointed Reinforced Concrete Pavement

The jointed reinforced concrete pavement is a modified or developed version of jointed unreinforced concrete pavement. It is used instead of plain concrete pavement when there is doubt regarding materials and workmanship and differential settlement are anticipated. Not only does thickness of jointed reinforced concrete pavement is thinner but also its joint spacing is greater compared to that of jointed plain concrete pavement. Generally, reinforced concrete slab with length of 10m are used but there are cases in which the slab length can reach up to 20m. Jointed reinforced concrete pavement can be designed as crack free slabs or cracked slabs. The embedded steel reinforcement controls cracking and improves concrete slab stiffness. By and large, steel bars are installed in the middle of the slab but some designers locate reinforcements at both slab faces. The most outstanding benefit of steel bar installation in the middle of the jointed reinforced concrete pavement is balancing positive and negative moments equally and as a result the slab is permitted to flex prior to cracking. Added to that, the application of doweled joints in the jointed reinforced concrete pavement is a must because the spacing is large, which means the movement in the joint cannot be controlled if dowel ties are not used. Commonly, pavement slab thickness of 150mm is employed and it is influenced by number of practical parameters such as required concrete cover.

Applications of Jointed Reinforced Concrete Pavement

The jointed reinforced concrete pavement is used in the case where huge concentrated loads are expected and the designer has doubt about labor force who will build the concrete pavement.

Fig.7: Jointed Reinforced Concrete Pavement

3- Continuously Reinforced Concrete Pavement

This type of concrete pavement is built like long slab and reinforcement bars are placed at the middle of the slab. The longitudinal reinforcements, which are maintained at their position by transvers reinforcement bars, are employed to limit shrinkage cracks. Figure-8 shows embedded longitudinal reinforcements held by transverse reinforcement

Fig.8: Arrangement of Longitudinal and Transverse Reinforcement in Continuous Reinforced Concrete Pavement

Cracks in continuous reinforced concrete pavement are initiated in arbitrary manner as can be observed in Figure 9. It is required to provide anchors at the end of the continuous reinforced concrete slabs otherwise huge ripple or bump will be formed at the beginning of bituminous materials due to movements which are generated by temperature fluctuations.

Fig.9: Cracking of Continuous Reinforced Concrete Pavement

Continuous reinforced concrete pavement operation is substantially influenced by cracks spacing which is controlled by longitudinal reinforcement. Commonly, longitudinal reinforcement ratio used in continuous reinforced concrete pavement is specified to be 6 percent of sectional area. If spacing between cracks are considerably small then it is likely that concrete blocks fail in shear. There are various types of finished that may be applied for instance whisper concrete and thin bituminous wearing course on the surface finish of continuous reinforced concrete pavement.

Fig.10: Continuous Reinforced Concrete Pavement with Successive Whisper Concrete Resurfacing

Applications of Continuously Reinforced Concrete Pavement

Continuously reinforce concrete pavements may be employed for the construction of airfield runways and highway projects and it is specifically cost effective when massive quantity of aggregate is present at site.

Fig.11: Airfield Runway, Liverpool Airport, UK

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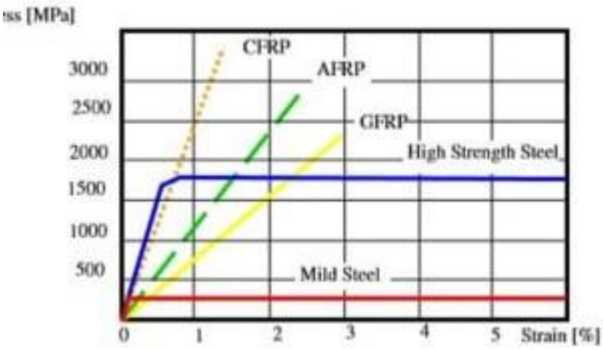


Distresses in Rigid Pavements and Causes

Distresses in **rigid pavements** can be classified into five groups, such as:

1. Deformations;
2. Cracking;
3. Joint seal and Spalling;
4. Surface defects; and
5. Edge

1- Deformations

Deformation in rigid pavements results from cracking of slabs or from relative movement between slabs due to load assisted and non-load assisted factors. Deformation affects pavement ride quality and helps water entering in the pavement structures.

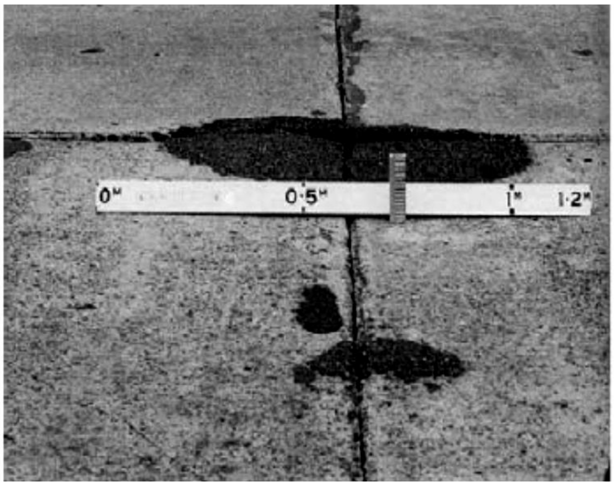
- The common types of deformations found in the rigid pavement are depression, faulting, pumping, rocking, and blowup/buckling.

1-1 Depression

Depressions in rigid pavement occur across a crack or joint, as shown in Figure (1-C), and are generally associated with significant cracking.

Causes: Poor compaction, weak subgrade support, and differential settlement of subgrade are possible causes for depressions.

Effects: It allows water ponding and increases the chance of water entering through joints and cracks.



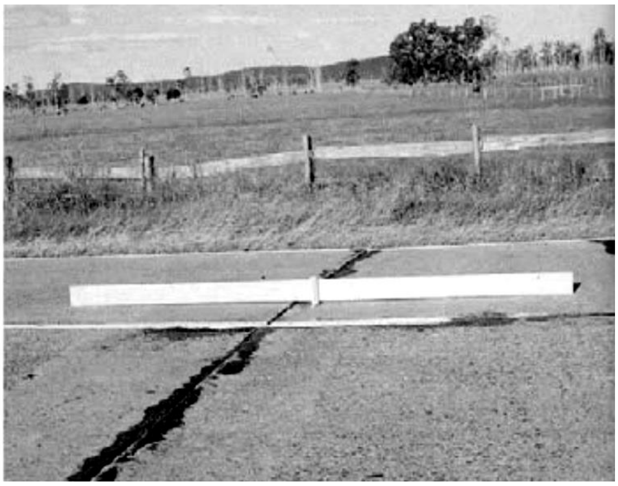


Figure (1-C) Depression in rigid pavement

1-2 Faulting

Faulting is a condition where concrete slab breaks into two pieces along joints or cracks and the vertical displacements between the broken slabs create a step, as shown in Figure (2-C).

Possible causes for faulting are

(i) volume change in the subgrade,

(ii) poor support in the subbase or subgrade,

(iii) rocking,

(iv) pumping as result of loss of fine material under one slab, and

(v) warping effects due to temperature and moisture gradients.

Effects: Faulting is a major distress in rigid pavements as it allows water entry in the pavement and affects ride quality.

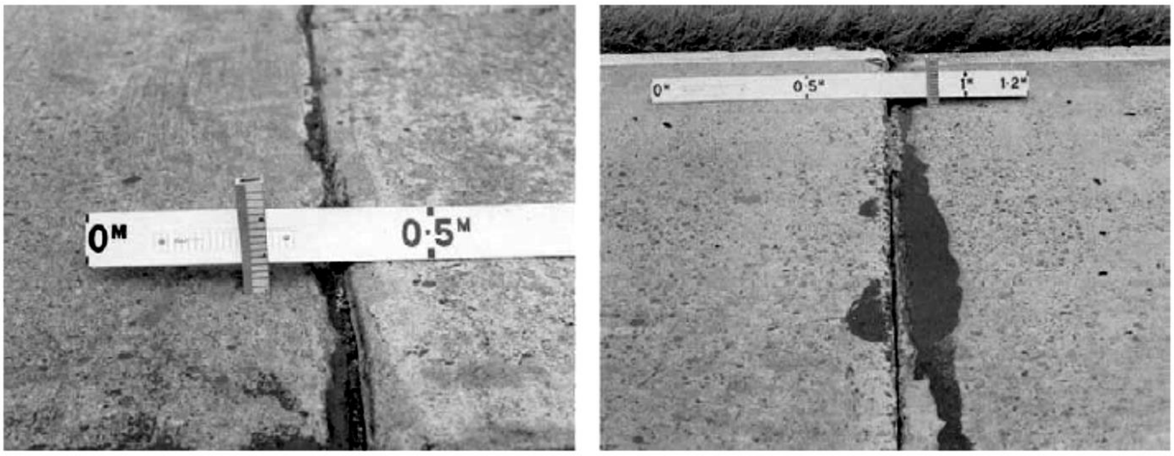


Figure (2-C) Faulting in rigid pavement

1-3 Pumping

Causes: Pumping in the concrete slab occurs when excessive moisture enters into the pavement through crack or poorly constructed joint and the excess water is ejected through cracks and joints, due to the upward wrap and curl of the slab near the joint or crack, and movements of traffic.

Effects: Pumping causes erosion of fine particles in the base course and thus causes structural deterioration such as, rocking, faulting, and cracking (see Figure 3-C).

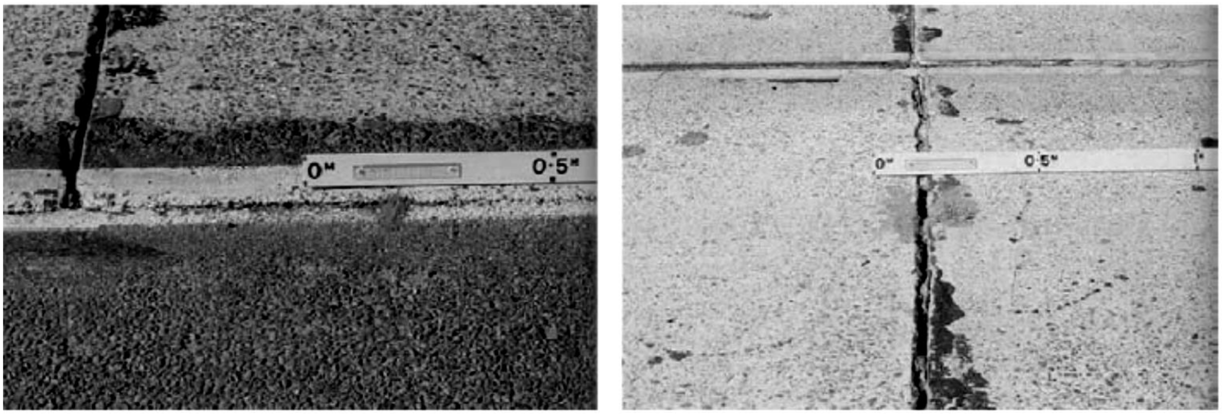


Figure (3-C) Pumping in rigid pavement

1-4 Rocking

Rocking is felt at a joint or crack with the passage of a vehicle where pumping has caused loss of support (see Figure 4-C).

Causes: the main cause is the pumping of fine particles of base materials, in addition to inadequate subbase or subgrade support or differential settlement in the subgrade.

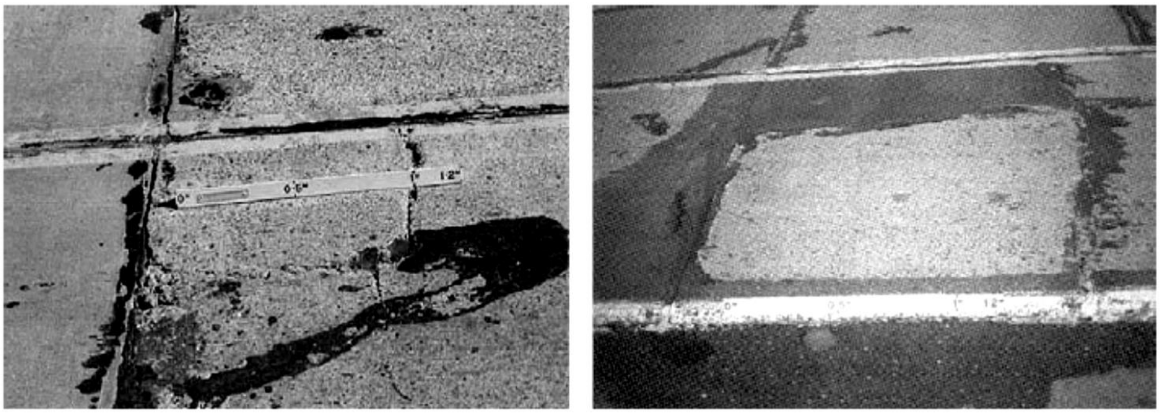


Figure (4-C) Rocking in rigid pavement

1-5 Blowup/Buckling

Blowups or buckles occur in hot weather, usually at a transverse crack or joint that is not wide enough to permit slab expansion. Blowups can also occur at utility cuts and drainage inlets (Figure 5-C).

Cause: The insufficient width is usually caused by infiltration of incompressible materials into the joint space.

Effect: When expansion cannot relieve enough pressure, a localized upward movement of the slab edges (buckling) or shattering will occur in the vicinity of the joint.

Figure (5-C) Blowup/Buckling

2- Cracking

Shrinkage cracks are common in rigid pavements but it does not affect pavement performance if the pavement is properly designed and constructed. Many patterns of cracks ranging from single isolated cracks to interconnected multiple cracks are found in rigid pavements.

Causes: The possible causes of cracking in rigid pavements include:

1- insufficient slab thickness,
2- shrinkage,
3- weak subbase or subgrade, and
4- differential subgrade movement.

Effects: Cracking causes a number of problems such as:

1- loss of load spreading capability,
2- loss of appearance,
3- deteriorate ride quality, and
4- entry of water into the pavement structures.

The common types of cracks in the rigid pavements are, as shown in Figure (6-C):

1- block cracks,

2- longitudinal cracks,
3- transverse cracks,
4- diagonal cracks,
5- corner cracks,
6- meandering cracks, and
7- durability ("D") cracking.

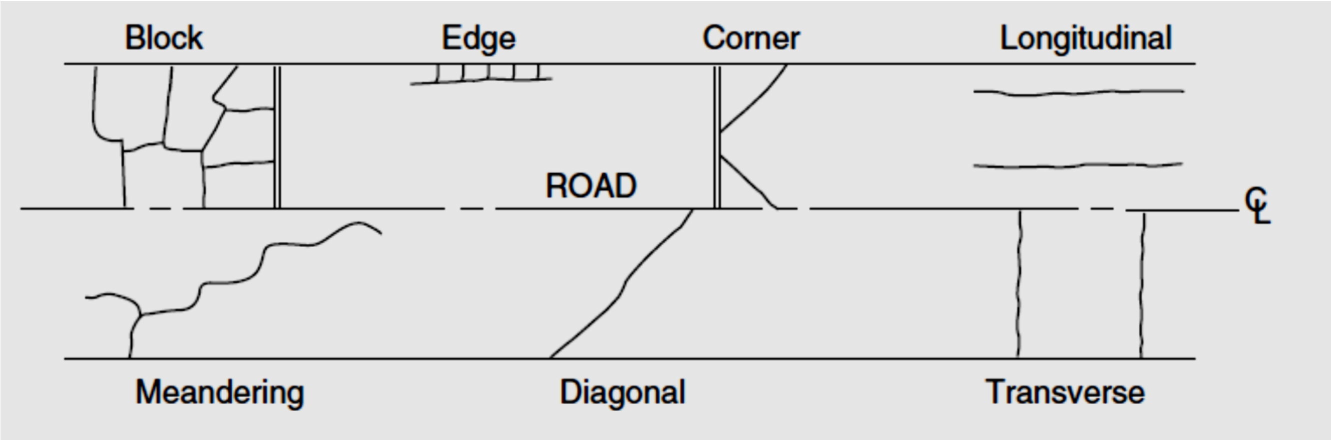


Figure (6-C) Sketch of cracks in rigid pavement

2-1 Block Cracks

Interconnected cracks that form a series of rectangular blocks over the entire pavement are known as block cracks (see Figure 7-C).

Causes: Possible causes for block cracking are:

a) inadequate slab thickness,
b) loss of subbase or subgrade support, and
c) subgrade settlement.

Figure (7-C) Block cracks in rigid pavement

2-2 Longitudinal Cracks

Single or a number of parallel cracks appear longitudinally along the pavement, as shown in Figure (8-C).

Causes: Possible causes for longitudinal cracks are:

a) lateral shrinkage,
b) insufficient slab thickness,
c) differential settlement,
d) longitudinal joint too shallow or too close to traffic lane, and
e) poorly constructed joints.

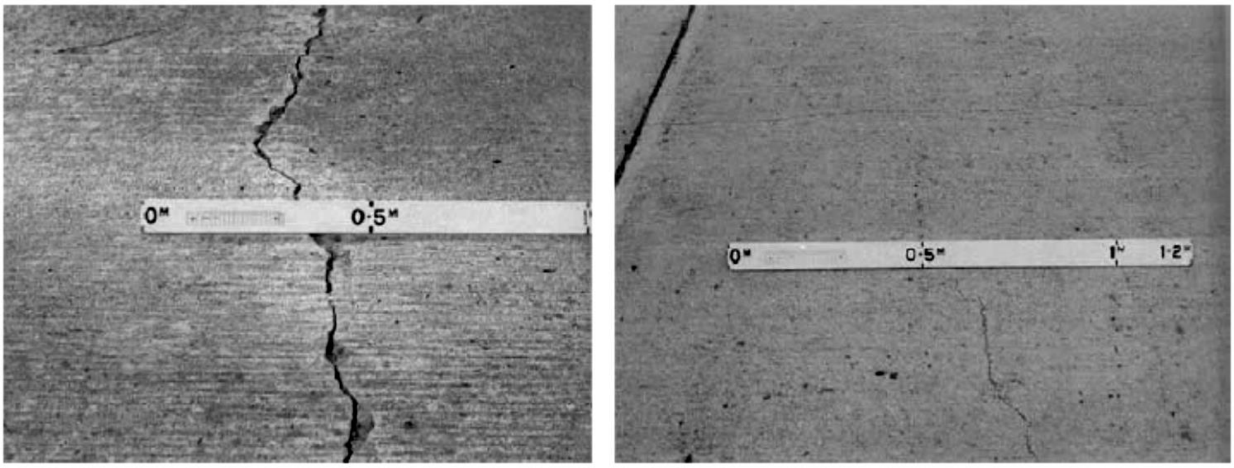


Figure (8-C) Longitudinal cracks in rigid pavements

2-3 Transverse Cracks

As shown in Figure (9-C), transverse cracks run transversely across the slab. Transverse cracks generally start near construction joints.

Causes: Shrinkage, rocking action, and insufficient slab thickness are possible causes for these cracks. Late saw cutting of construction joint can also cause these cracks.

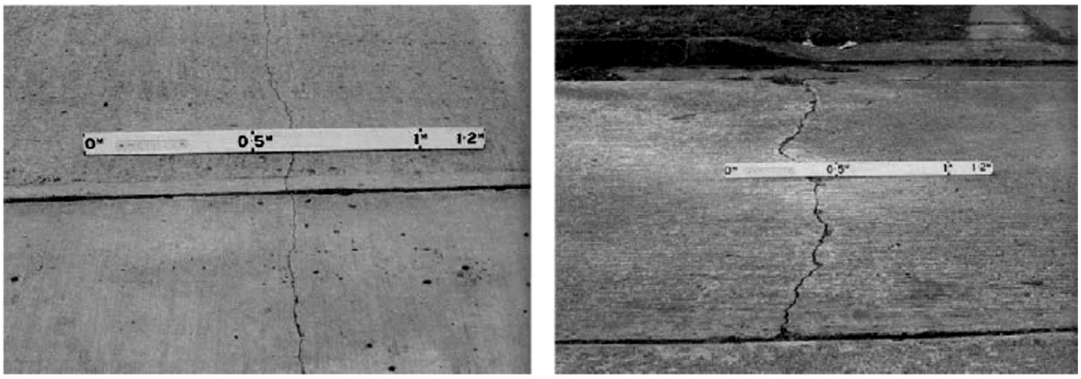


Figure (9-C) Transvers cracks in rigid pavements

2-4 Diagonal Cracks

Diagonal cracks are single cracks run diagonally across the slab, as may be seen in Figure (10-C).

Causes: (1) Settlement, (2) shrinkage in the slab, (3) inadequate slab thickness, and (4) rocking actions are possible causes for diagonal cracks in the rigid pavement.

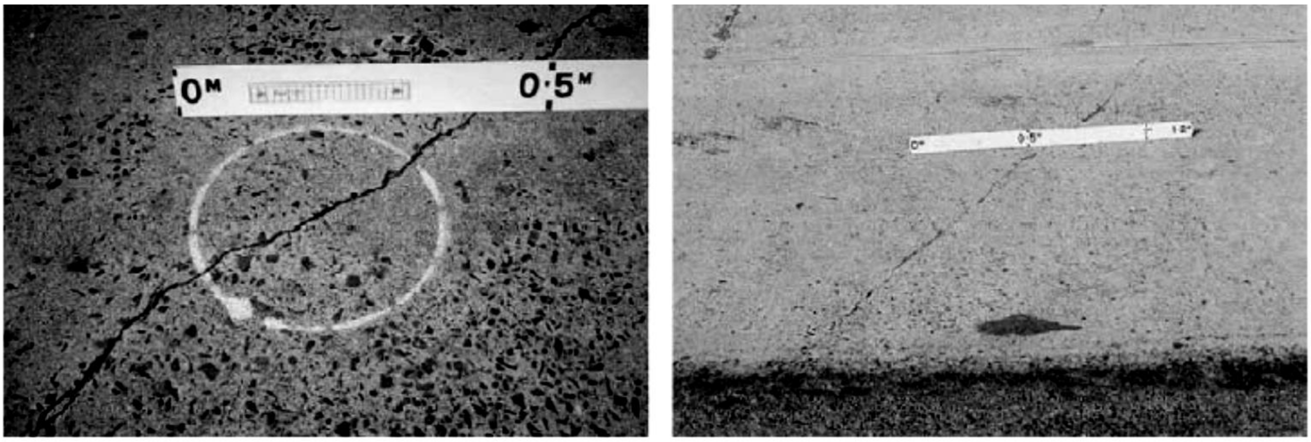


Figure (10-C) Diagonal cracks in rigid pavements

2-5 Corner Cracks

As seen in Figure (11-C), corner cracks appear at the corners of slabs diagonally from a longitudinal edge to a transverse joint.

The causes for corner cracks are: (1) inadequate slab thickness, (2) loss of support of subbase or subgrade, (3) overloading, (4) curling of corners, and (5) poor joint design.

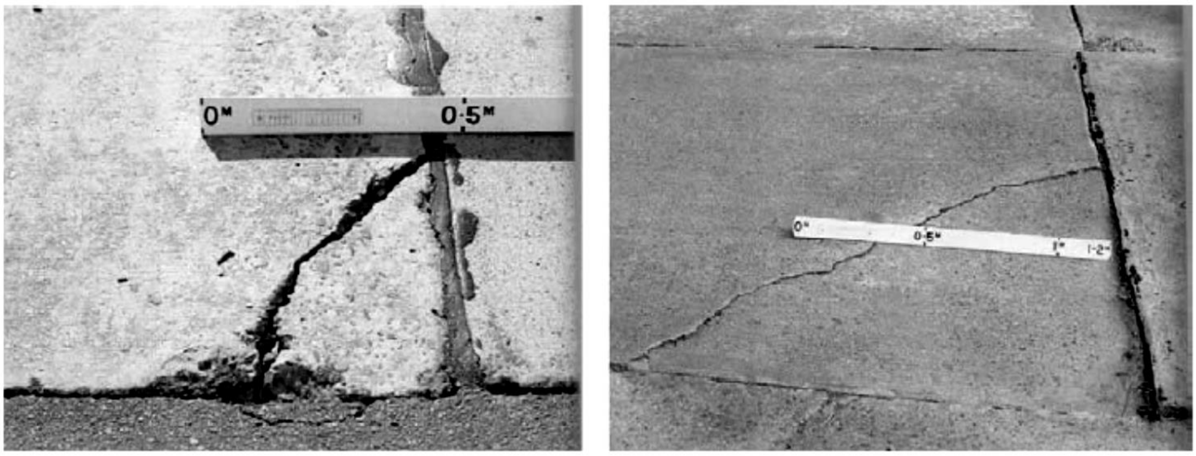


Figure (11-C) Corner cracks in rigid pavements

2-6 Meandering Cracks

Similar to flexible pavements, meandering cracks in rigid pavements are irregular single cracks that run in any direction (see Figure 12-C).

Causes: (1) Rocking action, (2) settlement, (3) shrinkage, and (4) inadequate slab thickness.

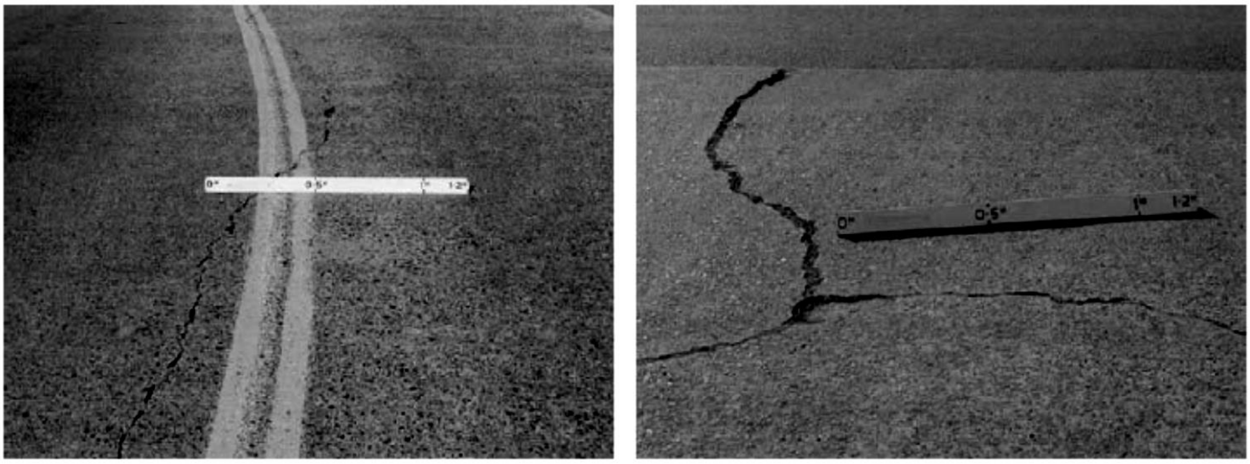


Figure (12-C) Meandering cracks in rigid pavements

2.6 Durability ("D") Cracking

This distress usually appears as a pattern of cracks running parallel and close to a joint or linear crack. Since the concrete becomes saturated near joints and cracks, a dark-colored deposit can usually be found around fine "D" cracks (Figure 13-C).

Causes: "D" Cracking is caused by freeze-thaw expansion of the large aggregate which, over time, gradually breaks down the concrete.

Effects: This type of distress may eventually lead to disintegration of the entire slab.

Figure (13-C) Durability Cracking.

3- Joint Seal and Spalling

3-1 Joint Seal Defects

Joint seal defects are the most common defects in jointed concrete pavements. They can be easily identified when seal is lost leaving a gap between the joints or when sealant extrudes from the joint, as shown in Figure (14-C).

Causes: (1) Sealant construction quality, (2) ageing of sealant, (3) too much or too little sealant in the joint, and (4) poor sealant performance are primary causes for joint seal defects, (5) though rocking and pumping actions may also cause these defects.

Effects: Defective seal joints permit water to enter in the pavement structures and allow incompressible rubbish to lodge in the joint. Incompressible material keeps the joint permanently open and limits the horizontal expansion of slabs. As a result, high stresses are developed in the pavement.

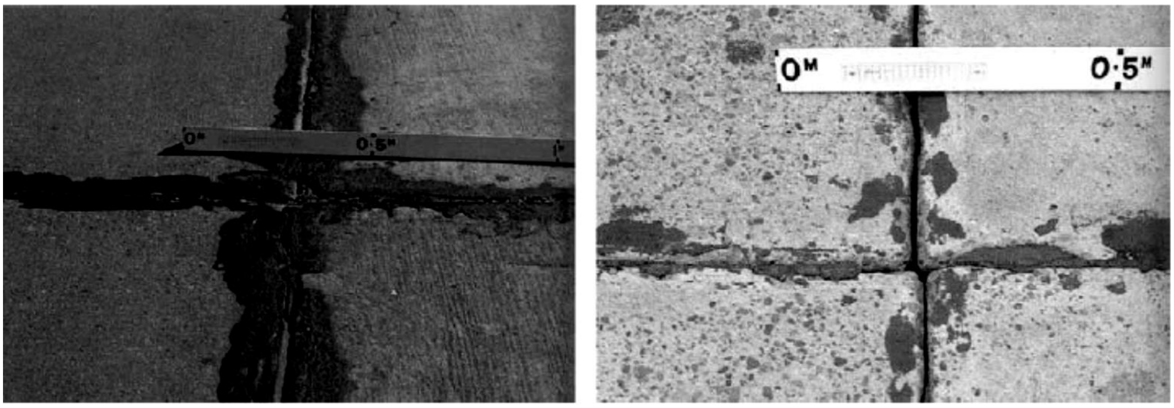


Figure (14-C) Joint seal defects in rigid pavement

3-2 Spalling

Spalling is found when small pieces of concrete, usually in angular shape, are separated from the pavement surface. As seen in Figure (15-C). Spalling generally occurs at joints, edges, corners or cracks, or directly over reinforcing bars.

Causes: (1) Infiltration of incompressible particles into joints or cracks, (2) corrosion of reinforcement bars or dowels, (3) misalignment of dowels, (4) subbase movement, and (5) poor quality concrete aggregate.

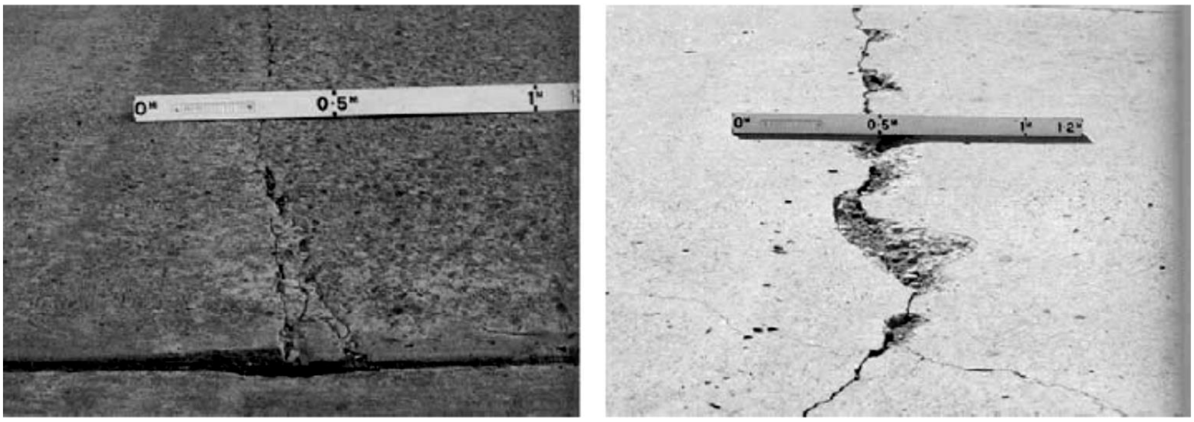


Figure (15-C) Spalling in rigid pavements

4- Surface Defects

Surface defects in rigid pavements include (1) scaling, (2) skid resistance, (3) pothole, and (4) patching.

4-1 Scaling or Raveling

As shown in Figure (16-C), raveling or scaling is a condition when mortar and aggregate are lost through progressive breakdown of slab surface due to (1) poor aggregate quality, (2) inadequate curing, (3) local cement deficiency, or (4) overworking of surface during construction.

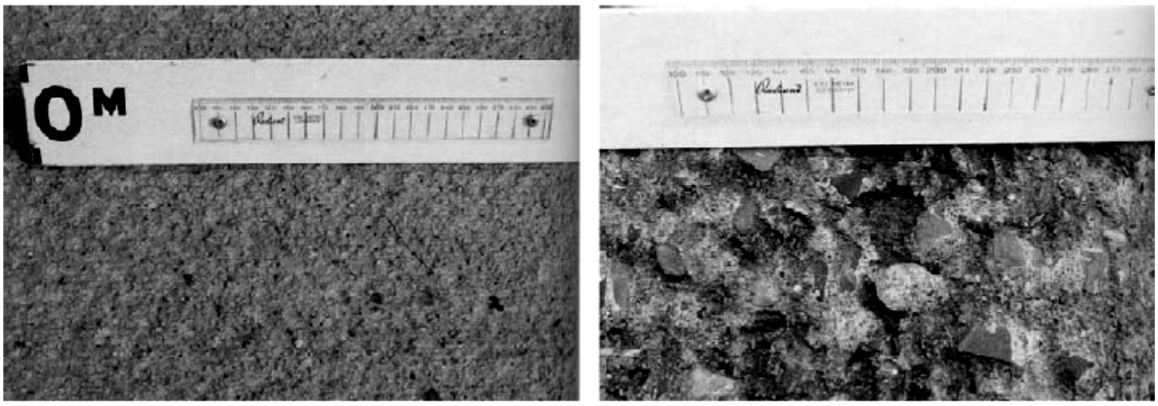


Figure (16-C) Scaling and raveling in rigid pavements

4-2 Skid Resistance

Smooth, polished or glassy appearances indicate lack of skid resistance (see Figure 17-C).

Causes: (1) Loss of skid resistance can occur from low microtexture and macrotexture of the aggregates, as well as due to (2) spillages, (3) poor construction finishing, and (4) poor quality mortar that worn by traffic.

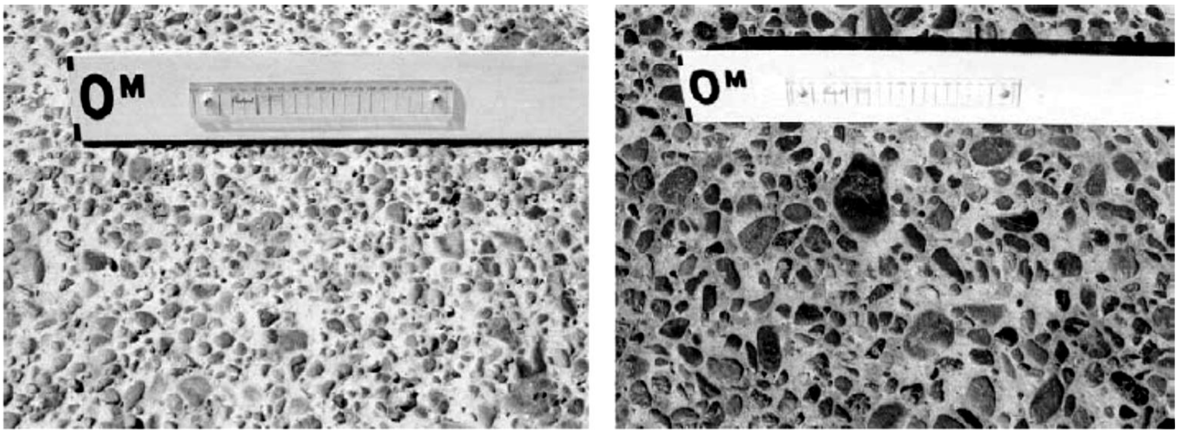


Figure (17-C) Low skid resistant concrete surface

4-3 Pothole

Potholes in rigid pavement are bowl-shaped cavity in the surface (see Figure 18-C).

Causes: Potholes are developed due to (1) localized cracks, (2) freeze – thaw action, and (3) rebars too close to the surface. (4) Traffic and water in the cavity accelerate the development of pothole.

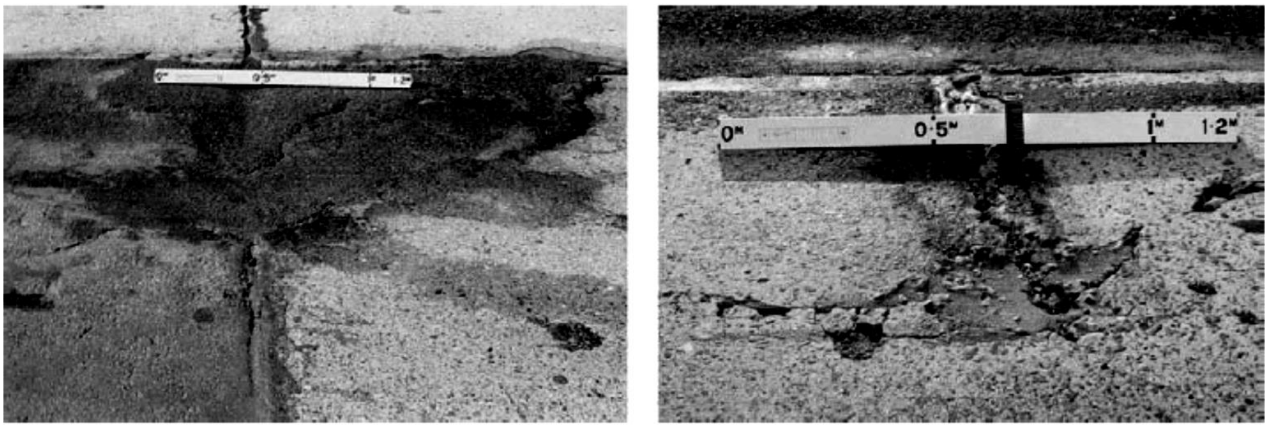


Figure (18-C) Potholes in rigid pavements

4-4 Patch

Original material from localized area of the concrete surface is removed and replaced with asphalt or concrete material to repair localized distresses (see Figure 19-C). Variety of distresses may occur at the patches including cracking, spalling, and distortion.

Figure (19-C) Patches in rigid pavements

5- Edge Defects

As seen in Figure (20-C), shoulder drop-off is the most common pavement edge defect found in concrete pavements. Shoulder drop-off is characterized as the differential settlement between the shoulder and the edge of the slab that may **cause due to** (1) incorrect geometry, (2) poor shoulder drainage, and (3) loose shoulder materials.

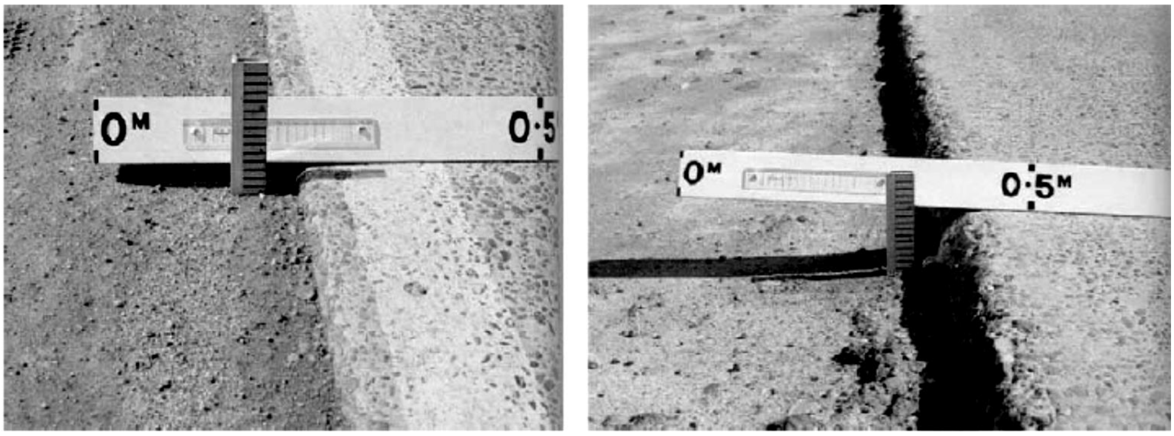


Figure (20-C) Edge detects in rigid pavements