Technical Note No: 4

Sub: APRRP-CC Pavements – Early age Cracks in CC pavements-Causes and Remedial measures- Reg.

Ref: 1) Inspection of works in Prakasam and Nellore Districts by PMC Team.

2) Enquiry by the EE PIU Kadapa about Cracks observed in CC pavement.

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Background: During inspection of APRRP works by PMC Team it was observed that the CC roads are experiencing cracks in most of the panels of CC pavements executed by PIUs in the field. (Fig-1).

The main causes for formation of early age cracks are due to the following lapses identified during discussions with PIU staff.

1. No Initial and Intermediate Curing adopted in the field.
2. Only final curing is done with ponding beyond the stipulated time.
3. Initial cutting of joints is not under taken by the contractors within the stipulated time of 24 hours.
4. Usage of excess water as against the Design mix recommendations for the convenience of masons.
5. In some cases, concreting taken place when the ambient temperature is more than 35^0 C.

Fig1. Cracks observed in APRRP CC roads

Introduction: Cracks in concrete are of common occurrence and these develop when stresses in the concrete exceeds its strength. The dimensional changes occur due to shrinkage (Plastic, Drying, etc.) or expansion caused due to thermal movement or chemical actions. In cement concrete it is believed that one-third of shrinkage takes place in the first 10 days, half within one month and the remaining half in about a year. Shrinkage cracks in concrete may thus continue to occur and widen up to about a year.

Various forms of Shrinkage:

a) **Plastic Shrinkage:** After the concrete has been placed in forms, concrete undergoes a volumetric contraction while it is in plastic state (before the concrete has set). This is known as Plastic Shrinkage. This plastic shrinkage sometimes results in the formation of cracks. **This happens if concrete surface loses water faster than the rate of bleeding**. These cracks occur within a few hours (i.e between one-two hours) of placing concrete. (Fig 2).

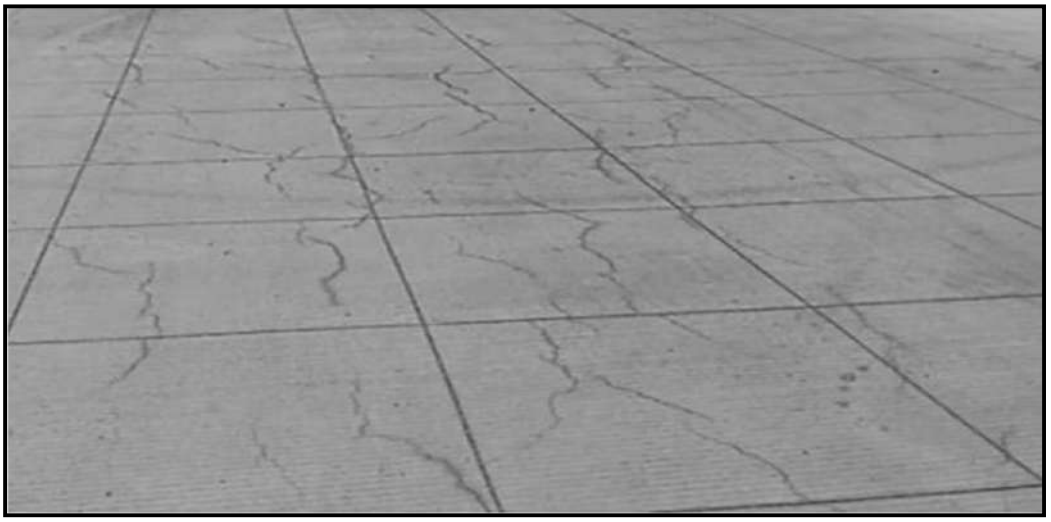

Fig 2. Plastic shrinkage cracks in CC pavement

b) **Drying Shrinkage:** After hardening, concrete starts drying. **The excess water,** called water of convenience would have been added to get adequate workability and finish ability. Cement paste shrinks more than mortar and mortar shrinks more than concrete. Concrete made with smaller size aggregate shrinks more than the concrete made with bigger size aggregate. This takes place in the first few months. (Fig 3).

Fig 3. Drying shrinkage cracks in CC pavement

c) Crazing: Crazing is the development of fine random cracks on the surface of the concrete caused by shrinkage of the surface layer. They generally occur in the over floated or over toweled surface layer of concrete slabs and in the formed surfaces of concrete. Generally, craze cracks develop at an early age and are apparent the day after placement. The crazing is more prominently seen when the surface is wet. (Fig 4).

Fig 4. Crazing cracks in CC Pavements

The generally observed reasons for appearance of Crazing cracks are

- Poor or **inadequate curing**
- Too wet a mix, excessive floating produces an excessive concentration of cement paste and fines at the surface.
- Finishing while there is bleed water present on the surface
- Sprinkling cement on the surface to dry up bleeds water. This concentrates fines on the surface

Factors affecting Shrinkage

The initial shrinkage in concrete depends on number of factors, e.g. cement and water content, size of aggregate and aggregate-cement ratio, excessive fines, use of admixtures, composition of cement, temperature, humidity and curing etc.

Prevention of Shrinkage Cracks

- **Plastic shrinkage**
  - The fresh concrete should be protected from direct sunrays and strong winds for at least 24 hours.
  - Avoid use of warm water and warm aggregate in order to keep the temperature of fresh concrete low.
  - In hot weather, lower the temperature of the fresh concrete by using chilled mixing water or replace some of this water with crushed ice.
  - Concrete should not be done when Ambient temperature is more than 35^0 C. Temperature of green concrete should not be more than 30^0 C.
  - Cover the freshly placed concrete with tarpaulins or plastic sheet to prevent evaporation of bleed water. (Fig 5).

Fig 5. Concrete slabs covered by Plastic sheet

  - Start curing as soon as possible after placing of concrete but before the surface water - sheen fully disappears.

- The Use of sufficient proportions of synthetic or steel fibers in concrete can provide improved control of plastic cracking. (Fig 6).

Fig 6. Poly Propylene Fibers (4.5 to 14 Kg/Cum)

- **<u>Drying</u> Shrinkage:**
- Use minimum water content. To compensate for the reduction in workability, plasticizers can be used. (Fig.7).

Fig 7. EXCESS WATER in THE MIX (Wrong Method of placing concrete)

WATER as per design mix in the Concrete (Correct Method of placing concrete)

- Do not use admixtures known to increase drying shrinkage, e.g., those containing calcium chloride.
- Provide adequate and early curing to exposed surfaces.
- **Crazing:**
- Start curing the concrete as soon as possible.
- Use of moderate slump (75mm to 125mm).
- Never sprinkle or trowel dry cement or a mixture of cement and fine sand into the surface of the plastic concrete to absorb water. Remove bleed water by dragging a hose pipe across the surface.
- Do not perform any finishing operation while bleed water is present on the surface.

As seen from the above causes for cracks in concrete which is mainly due to one single parameter i.e curing. To adopt proper curing to minimize the cracks in concrete is explained below.

When to Start Curing of Concrete:

· **Initial Curing:** During the initial setting sometimes bleed water is evaporating from the surface faster than it is rising out from the concrete. When all the water gets evaporated from the surface, you need to do some initial curing to minimize the moisture loss. During this period, if you do not start the curing it may lead to plastic shrinkage cracks. (Fig 8 & 9).

Fig 8. Slab is ready for Initial Curing

Fig 9. Initial Curing with Sprinkling of Water

Intermediate Curing: During this period, evaporation may need to be reduced, but the concrete is not yet be able to tolerate the direct application of water or the mechanical damage resulting from the application of plastic sheets. In this stage liquid forming membrane compound can be used effectively to reduce evaporation loss. Texturing should be done before application of curing compound. (Fig 10)

Fig 10. Texturing and Intermediate Curing with Application of Curing Compound

Joint Cutting: In case the slab is constructed continuously with a view to cut joints with concrete saw, this exercise should be done soon after the concrete sets. Normally, in summer

when ambient temperature is more than 30^0C initial cutting may be carried after 4-8 hours of laying and in winter when ambient temperature is less than 30^0C initial cut may be done at 8-12 hours of laying. (Fig 11). In any case initial cut of all the transverse and longitudinal joints shall be completed within 24 hours to avoid the random cracking. Subsequently widening of joint groove will be done after 14-16 days of casting concrete. No sealing of joints shall be undertaken before 21 days of construction.

Fig 11. Sawing Depth H/3 to H/4

Fig 12. Cracks due to late sawing of Initial cut of CC road

· **Final Curing** (i.e. Actual Curing that we Normally do): After cutting of joints final Curing can be done by application of wet covering. i.e. Ponding method, Saturated burlap. In short, the curing should start after minimum six hours (Final setting time of cement) and not less than 24 hours. (Fig 13 & 14).

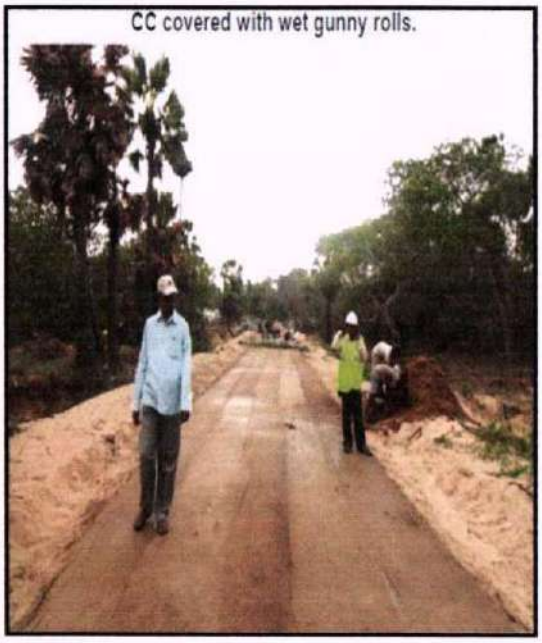

Fig 13. Wet Gunny Bags

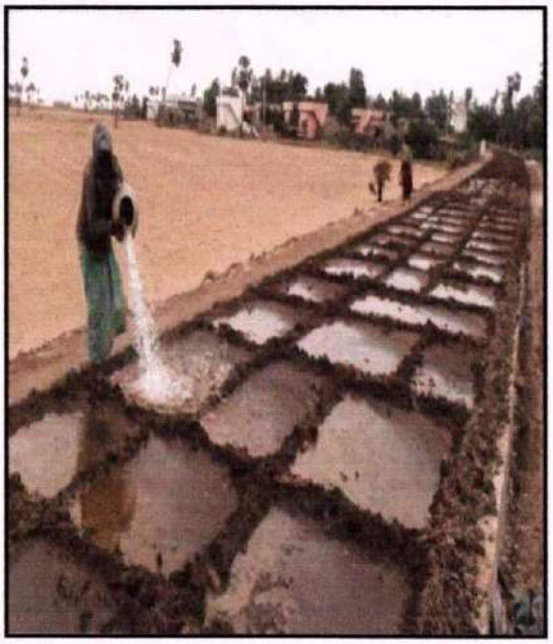

Fig 14. Ponding

Conclusion:

These cracks although non-structural do not endanger the safety, but affect the aesthetics of the structure. Although the cracking cannot be eliminated totally, it can be minimized by understanding the reason for such cracks. Most of these shrinkage problems are either due to the properties/qualities of materials and workmanship viz. adequate water -cement ratio, compaction etc.

The selection and use of suitable materials with good construction practices reduce the shrinkage and the resultant cracks thus enhancing the service life and reducing the life cycle cost.

KPR 30/7

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References:

1) IRC: SP:62-2014- Guidelines for design and construction of cement concrete pavements for low volume Roads (First Revision)
2) Ultra Tech Mailer.
3) IRC: 15:2017- Code of practice for construction of Jointed Plain Concrete Pavements (Fifth Revision).