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A REVIEW REPORT ON PLASTIC SHRINKAGE OF CONCRETE & SELF COMPACTING CONCRETE

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ABSTRACT

Plastic cracking is one of the major problems in concrete. During the summer, dry months of the year it is by no means scarce to find cracks appearing on the surface of the concrete within a little duration of its placement. Plastic cracking is very divergent from the cracks which come on account of thermal movement. They notice to roughly follow their straining element, eg. Changein the concrete section. An integrated appeal to the bridle of cracking processes and damage of concrete, including the kinetics of crack accretion depending on the time and the magnitude of the external load is proposed. After casting up to 24 hours cracking may become problematic in any concrete structure. It can destruction the aesthetics of the concrete member and decrease the durability and serviceability by facilitating the entrance of dangerous material. Plastic shrinkage cracking create most commonly in concrete with a large surface area such as in slab and floor. As the moisture is removed, the surface concrete decrement, resulting in tensile stresses in the weak material.To prevent cracks in concrete reduce water content & proper concrete mix design, curing, compaction etc.

Keywords: accretion, appeal, bridle, divergent, plastic shrinkage concrete, scarce, etc.

I. INTRODUCTION

During first few hours after concrete has been placed, concrete plastic shrinkage is occurring. Cracking is one of the big issues in concrete.It is well-established that during the first few hours after casting, while still in a plastic state, concrete is prone to shrink if the rate at which water evaporates from the surface exceeds the rate at which it is replaced by bleed water from below. Plastic shrinkage cracking of concrete is a widespread problem in concrete construction, particularly in thin applications such as highway pavements, slabs cast on grade, surface repairs, overlays, patching, and shotcrete tunnel linings. Ideally, proper curing and finishing practices can eliminate plastic shrinkage cracking. However, such practices are often not reliably followed. Alternatively, the addition of relatively small amounts (i.e. typically less than 0.5% by volume) of short fibres to concrete has been found to significantly reduce, if not completely eliminate, restrained plastic shrinkage cracking since concrete has various physical and chemical properties it is prone to cracking. The main causes of cracking are as follows:

- Ageing – Carbonation
- Foundation problems
- Weathering Actions
- Improper or modified use of the structure

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- Poor maintenance
- Progressive loading
- Deficiencies in design
- Poor quality of concrete material
- Improper concrete mix
- Movement of concrete arising from physical properties
- Poor workmanship and negligence
- Over trowelling and impermeable formwork
- Reduced continuity of the structural member
- Defects and errors in construction practices
- Improper structural repairs or modification
- Chemical attacks by Chlorides and Sulphates
- Differential thermal stress – Heat of hydration of cement.

Fig.1 Plastic shrinkage cracking at concrete surface

Plastic shrinkage and its probable cracking, the main topic of this research, occurs shortly after casting, while the concrete still is in its plastic phase, Figure 1.1. The phenomenon is defined as the shrinkage of young concrete which occurs due to rapid and excessive drying. The cracking occurs when the concrete surface dries and shrinks so fast, that the induced tensile strains exceed the strain capacity of the very young concrete. It may clearly affect the aesthetics, durability and serviceability of the structure by accelerating the ingress of harmful materials that might cause damage in future, e.g. corrosion of the reinforcement. Plastic shrinkage cracking mainly occurs in horizontal concrete elements with large surface to volume ratio (e.g. slabs, pavements, industrial floors). As a result of water evaporation, hydraulic pressure (capillary pressure) builds-up in the pore system which in turn causes the concrete to shrink. If the concrete is restrained (e.g. by the formwork, reinforcement, change of sectional depth, difference in shrinkage in different parts of the concrete, etc.) and it has not gained enoughtensile strength, the shrinkage will lead to cracking.

Prevention is better than heal it is always better to prevent cracking to a certain or a possible extent than to think of repairs in the future due to various reasons. The settling concrete is restrained and cracks form at the surface. They may become visible very early, ie while finishing is proceeding, but are often not noticed until some hours

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after placement. The amount of settlement tends to be proportional to the depth of concrete, ie the deeper the section the greater the settlement.As plastic shrinkage cracking is dependent on evaporation rate, settlement and capillary pressure, the concrete mix design, the duration of the dormant period, and the environmental conditions (concrete and air temperature, relative humidity and wind speed) ultimately determine the risk of cracking.

Table-1 Classification of Cracks

Type of Cracking	Form of Crack	Primary Cause	Time of Appearance
Plastic settlement	Over and aligned with reinforcement, subsidence under reinforcing bars	Poor mixture design leading to excessive bleeding, excessive vibrations	10 min to 3 h
Plastic shrinkage	Diagonal or random	Excessive early evaporation	30 min to 6 h
Thermal expansion and contraction	Transverse	Excessive heat generation, excessive temperature gradients	1 day to 2–3 weeks
Drying shrinkage	Transverse, pattern or map cracking	Excessive mixture water, inefficient joints, large joint spacings	Weeks to months
Freezing and thawing	Parallel to the surface of concrete	Lack of proper air-void system, non durable coarse aggregate	After one or more winters
Corrosion of reinforcement	Over reinforcement	Inadequate cover, ingress of sufficient chloride	More than 2 years
Alkali–aggregate reaction	Pattern and longitudinal cracks parallel to the least restrained side	Reactive aggregate plus alkali hydroxides plus moisture	Typically more than 5 years, but weeks with a highly reactive material
Sulfate attack	Pattern	Internal or external sulfates promoting the formation of ettringite	1 to 5 years

II.CAUSES OF CRACKING:

Concrete structures do not frequently fail due to lack of strength, rather due to inadequate durability or due to improper maintenance techniques. The most common cause ofpremature deterioration is attributed to the development of cracks (Mehta, 1992; Hobbs, 1999). Cracking can occur in concrete pavements and structures for several reasons that can primarily be grouped into either mechanical loading or environmental effects. It should also be noted that for most practical structures, reinforcement is used to bridge and hold cracks together when they develop, thereby assuring load transfer while adding ductility to a relatively brittle material. Therefore not all cracking causes concern. Reinforced concrete elements are frequently designed on the assumption that cracking should take place under standard loading conditions. Mechanical loads induce strains

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that can exceed the strain capacity (or strength capacity) of concrete, thereby causing cracking. Concrete may be particularly susceptible to cracking that occurs at early-ages when concrete has a low tensile capacity. If the loads are applied repeatedly or over a long period of time, fatigue and creep can affect the strain (or strength) development that can lead to failure or reduce stresses.

III.MECHANISM OF PLASTIC SHRINKAGE:

Three drying phases.9 During Phase I, sedimentation can occur as the denser cement and aggregate particles settle and water rises to the surface. This layer of bleed water is free to evaporate at a rate similar to that of bulk water.10Phase II begins when the layer of bleed water evaporates and liquid-vapor menisci form at the surface and within theconcrete.11 a capillary pressure develops that is inversely proportional to the radius of curvature at a given meniscus. The pressure rearranges cement particles (consolidation), forcing more pore solution to the top surface of the concrete. The net internal pressure drop can produce further particle rearrangement (consolidation), forcing more pore solution to the top surface of the concrete. For concretes with prewetted LWA, the water will be drawn out of the LWA before it is drawn out of the paste because LWA generally contains larger pores than the paste. It would thus also be expected that a reduction in the settlement would occur as water is provided from the rigid LWA rather than from the fluid, deformable cement paste. When the pressure can no longer be reduced due to a rearrangement of the particles in the system and the drying front recedes from the surface toward the interior of the concrete, the concrete is susceptible to cracking. The transition that occurs at this point is referred to as the critical point, 10 as it represents the point in time when the concrete is most susceptible to cracking.12, 13During Phase III, the drying front penetrates into the interior of the concrete and the continuous liquid path between the surface and the interior is lost. Evaporation and settlement rates slow.

IV.PLASTIC SHRINKAGE IN CEMENTITIOUS MATERIAL:

The total shrinkage that any concrete element experiences during its lifespan is, as known, caused by various contracting mechanisms. Among others, phenomena such as evaporation, hydration and/or carbonation can participate in the total shrinkage of the cementitious materials (Esping 2007). However, the effect of these phenomena on the concrete's total shrinkage is strongly time-dependent and hence, the total shrinkage of concrete can be dividedinto: (a) early-age shrinkage which represents the shrinkage in the first 24 hours after mixing, and (b) long-term shrinkage for the time beyond .Figure 2.1 illustrates the governing mechanisms of the total shrinkage in cementitious materials and the way they influence the early-age and long-term shrinkage. It ought to be noted that long-term shrinkage is not the topic of this research. Instead, early-age shrinkage and its driving mechanisms (especially plastic shrinkage) are particularly investigated.

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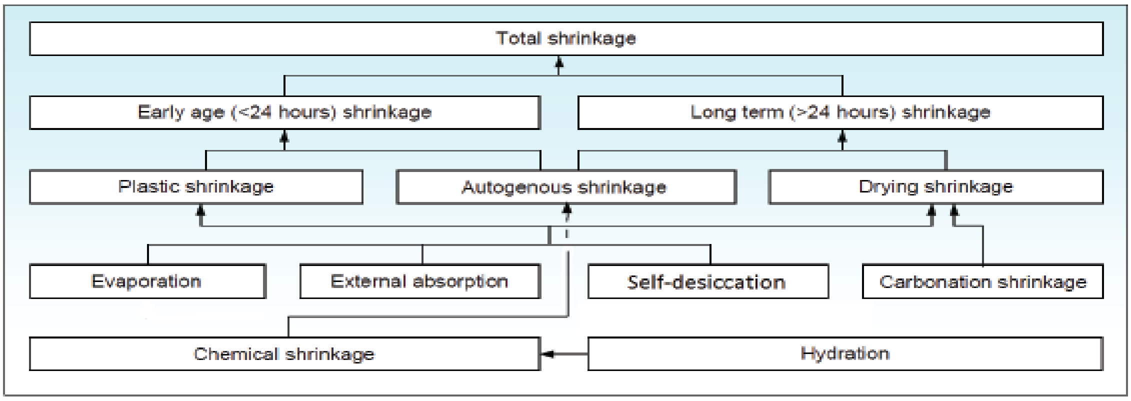

Fig.3 Illustration of the governing mechanisms of the total shrinkage in cementitious materials.

V.MAIN FACTORS AFFECTING PLASTIC SHRINKAGE CRACKING:

Fig 3 summarizes the process of plastic shrinkage cracking and the factors which can affect the phenomenon. A deep comprehension on how these factors influence the whole cracking process can lead to invention of new crack preventative methods. Some of the factors are briefly described in the following.

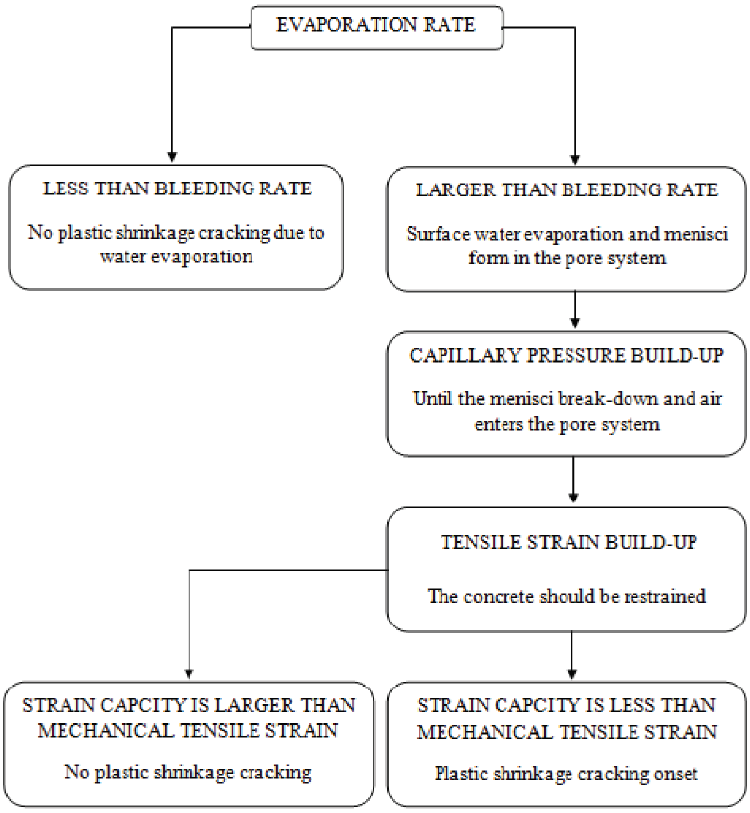

Fig.4 Plastic shrinkage cracking flowchart.

a. Water/Cement Ratio:

Water/cement ratio significantly affects the plastic shrinkage cracking tendency. Assumingconstant mixture constituents, higher w/c ratio causes more bleeding water and vice versa. Incase of high w/c ratio, thus, it takes longer time for the surface water layer to disappear due toevaporation and consequently delays the capillary pressure build-up in the pore system. However, this is highly dependent on the concrete mix. A lower amount of cement in SCC with low w/c ratio often is compensated with more fines (e.g. filler) in order to avoid segregation and reduction of durability and serviceability.

b. Additives:

Several studies have been carried out to find new admixtures in order to reduce the plastic shrinkage of concrete. These admixtures show high practicality in reducing evaporation rate, settlement, negative capillary pressure and plastic shrinkage formation. For instance, it has been concluded that cellulose-based viscosity modifying agent (stabilizer) causes reduction of the evaporation rate in cementitious material. Accelerator (ACC) and retarders have a strong influence on the plastic shrinkage cracking tendency.Some experiments showed that accelerator admixtures cause higher plastic shrinkage and total crack area, while retarders act contrary. On the other hand, superplasticizer (SP) reduces the need for water in the concrete mixtures i.e. less bleed water. This reduction of surface water may however not increase the risk of cracking.

c. Fibres:

Fibres (steel and/or polypropylene) often have been used in concrete mixtures in order to reduce the width of the plastic shrinkage cracks, through stitching the concrete surface particles together. Experiments performed by Sivakumar and Santhanam show that a combination of steel and polypropylene fibres (hybrid fibres), can reduce the width of the plastic shrinkage cracks up to 55%. However, despite of the lower crack width, parallel cracksmay form around the main crack. This phenomenon can be due to the transfer of the shrinkage stresses, through the fibres, to the surrounding areas.

d. Fines Content:

Fines such as fly ash, silica fume, slag, etc. lead to a larger total specific surface area of the binder, and narrower pores. Consequently, the water that is supposed to be transported to the concrete surface will be trapped inside and adsorbed by the fine particles, resulting in lower bleeding rate compared to a concrete with lower volume of fines. Cohen et al. (1990) concluded that higher surface area of the particles leads to higher tensile capillary pressureand eventually higher probability of plastic shrinkage crack formation. Moreover, experiments showed that silica fume increases the crack tendency in the concrete, despite of the evaporation reduction. Accordingly, using high proportion of fine material in the concrete mixture is not favorable as regards to plastic shrinkage cracking.

e. Depth of the Concrete Section:

A deeper concrete member typically experiences more settlement. As a result, more water is being transported to the concrete surface trough the pore system leading to a larger water accumulation on the surface. This means that the surface water layer evaporation takes longer time, causing delay in capillary pressure build-up.

f. Curing Measures:

Plastic shrinkage cracks can be avoided through several post-casting curing measures. These measures in general aim at reduction of the surface water evaporation. For instance, sealing the concrete surface (e.g. covering the concrete with plastic sheet) decreases the evaporation rate and consequently can lead to a crack-free concrete. In another case, experiments have shown that evaporation of the surface water can be suppressed through spraying aliphatic alcohols over the fresh concrete surface (Cordon & Thorpe 1965, Hedin 1985).

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Compensating the evaporated water (rewetting) is another way to protect the fresh concrete against plastic shrinkage cracking.

VI. CONCLUSION

Plastic shrinkage is the phenomenon that may change under certain conditions & circumstances of the concrete. The area of any cracks increases with increase in rate of evaporation of surface water of concrete for any water cement ratio. Greater the cement to aggregate ration more the crack area & maximum crack width. Depending on the ambient atmospheric conditions crack width is also decide. The addition of low volume fractions of short flax fibres to Portland cement mortar specimens was found to be effective in reducing the cracking that results from restrained plastic shrinkage under conditions that produce high evaporation rates. Addition of fibres can effectively control the plastic shrinkage cracks of the concrete.If we replace the sand with prewetted LWA can provide a significant reduction in settlement and plastic shrinkage cracking of mortars and concretes.. If a sufficient volume of prewetted LWA is provided, plastic shrinkage cracking can be reduced or eliminated under the exposure conditions. Cracks in SCC produced by rapid hydrating cements are mainly autogenous, while thoseproduced by slow hydrating cements are mainly subjected to plastic shrinkage cracking. A shrinkage reducing admixture and a paraffin-based curing compound were effective in preventing cracking. Based on the observed evaporation, settlement, capillary pressure and cracking behavior, the mechanisms for crack prevention were identified. As plastic shrinkage cracking is dependent on evaporation rate, settlement and capillarypressure, the concrete mix design, the duration of the dormant period, and the environmental conditions (concrete and air temperature, relative humidity and wind speed) ultimatelydetermine the risk of cracking.

VII. LITERATURE REVIEW

1.S.R.R. Senthilkumar, et.al Tamilnadu College of Engineering, India. "Prediction And Prevention Of Plastic ShrinkageCracking In Cementitious Composites"

A. For any concrete mix with any water to cement ratio the total crack area and maximum width ofcrack increases with the increase in rate of free surface water evaporation.

B. The rate of change of total crack area is rapidly increases with increase in cement to aggregateratio under higher free surface water evaporation loss, whereas it is moderately increases underlower free surface water evaporation.

C. The quantitative difference in maximum width of crack is moderate for any particular concrete mixwith different water to cement ratios subject to any environmental conditions.

D. Plastic shrinkage cracking is greatly influenced by the cement to aggregate ratio. Greater thecement to

2. Emma Boghossian et.al. AMEC Americas Limited, Vancouver, British Columbia, Canada.

He observed that, The addition of low volume fractions of short flax fibres to Portland cement mortar specimens was found to be effective in reducing the cracking that results from restrained plastic shrinkage under conditions that produce high evaporation rates. Tests showed that when flax fibres were added at a volume fraction of 0.1%, the total projected area of cracks forming on the surface of specimens within the first 24 h was reduced by more than 95% relative to plain mortar specimens, and maximum crack widths were reduced by more than 90% to less than 0.18 mm.

3. Andreas Leemann et.al. Impact of admixtures on the plastic shrinkage cracking of self-compacting concrete.

Plastic shrinkage cracking of SCC was measured with a setup that permitted a continuous recording of settlement, mass loss and capillary pressure of specimens placed into a wind tunnel at controlled temperature and relative humidity. Additionally, bleeding was determined on separate specimens stored at the same temperature, but covered with a lid permitting the accumulation of bleeding water and the determination of its amount. Finally, isothermal calorimetry was performed on cement pastes with compositions corresponding to the tested SCC.The mechanisms that lead to cracking of the reference concrete can be described as follows. Before settlement of the fresh concrete stops, the capillary pressure started to decrease due to the formationof water menisci at the surface of the concrete. As soon as the plasticity of the concrete was lost, due to consolidation of the concrete under the capillary pressure and the loss of water, the settlementrate decreased and almost stopped and the deformation became isotropic.

4. Ryan Henkensiefken et.al. Plastic Shrinkage Cracking in Internally Cured Mixtures.

The replacement of sand with prewetted LWA can provide a significant reduction in settlement and plastic shrinkage c racking of mortars and concretes. If a sufficient volume of prewetted LWA is provided, plastic shrinkage cracking can be reduced or eliminated under the exposure conditions employed in this study. The water movement from the LWA to the nearby cement paste, both prior to and after setting, has been verified using X-ray absorption measurements. The supply of water by the rigid but porous LWA reduces the settlement accompanying evaporation and the magnitude of the capillary stresses that are developed during drying as the water-filled pores in the LWA are generally larger than those in the hydrating cement paste.

5. FaezSayahi, Plastic Shrinkage Cracking in Concrete.

Plastic shrinkage cracking is a complex interaction of several variables that may change under different circumstances and conditions at the very early ages. These variables have a direct influence on the evaporation, capillary pressure build-up rate and the duration of dormant period. The explanations offered in this thesis and the appended papers for the plastic shrinkage cracking mechanism and the role of each mixture constituent in the process facilitates gaining a comprehensive and clear vision of the phenomenon. However, considerably more information is needed to gain a clear view on the influence of each constituent, which hopefully can lead to innovation of new crack preventive measures.

6. Andreas Leemann et. al. Impact of admixtures on the plastic shrinkage cracking of self-compacting concrete.

Plastic shrinkage cracking of SCC was measured with a setup that permitted a continuous recording of settlement, mass loss and capillary pressure of specimens placed into a wind tunnel at controlled temperature and relative humidity. Additionally, bleeding was determined on separate specimens stored at the same temperature, but covered with a lid permitting the accumulation of bleeding water and the determination of its amount. Finally, isothermal calorimetry was performed on cement pastes with compositions corresponding to the tested SCC.

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7. Ryan Henkensiefken et. al. Plastic Shrinkage Cracking in Internally Cured Mixtures Made with Pre-wetted Lightweight Aggregate.

It has been demonstrated that the replacement of normal weight sand with pre-wetted LWA can provide a significant reduction in settlement and plastic shrinkage cracking of mortars and concretes. If a sufficient volume of pre-wetted LWA is provided, plastic shrinkage cracking can be reduced or eliminated under the exposure conditions employed in this study. The water movement from the LWA to the nearby cement paste both prior to and after setting have been verified using x-ray absorption measurements. The provision of water by the rigid but porous LWA reduces the settlement accompanying evaporation and also reduces the magnitude of the capillary stresses that are developed during drying since the water-filled pores in the LWA are generally larger than those in the hydrating cement paste. It should be noted that the water from the LWA employed to reduce plastic shrinkage cracking is unavailable to alleviate the later problems associated with self-desiccation and drying.

8. Shubham Sunil Malu, Plastic Cracking of Concrete

Concrete when fresh is weak as a newborn child and therefore needs all attention and protection on its exposed surface till it has gained reasonable strength. If initial protection and curing are neglected in addition to improper concrete mix, the structure will be like a weak child having inherent defects throughout its life. Plastic settlement cracks mostly occurs in certain concrete sections where the presence of reinforcement or ties, or the shape of the section itself, impedes the settlement of the mix after compaction. They can be avoided only by improved mix design, or by revibration of the concrete after placing. Plastic shrinkage cracks are much less predictable than settlement cracks. The only way to avoid them, especially in windy warm weather, is to cover the concrete with a polyethylene sheet almost immediately after placing, compacting and finishing the concrete. Early curing of concrete is also desirable.

9. Faez Sayahi et. al. Plastic Shrinkage Cracking In Self-Compacting Concrete: A Parametric Study

High capillary pressure build-up rate, only when accompanied with high evaporation, significantly increases the cracking tendency. This can be amplified further by a long dormant period. The main driving force behind plastic shrinkage cracking in concretes with high w/c ratio is evaporation alongside high capillary pressure build-up rate and long dormant period. On the other hand, autogenous shrinkage, probably, is the main reason behind crack formation in concretes with low w/c ratio. The optimum w/c ratio is between 0.45 and 0.55. Any concrete with w/c ratio out of this range is more prone to early age cracking.

10.Paul J. Uno Plastic Shrinkage Cracking and Evaporation Formulas

Plastic shrinkage is normally associated with concrete slab problems—primarily plastic shrinkage cracking. Researchers such as Menzel, Lerch, Bloem, Powers, and others were instrumental in providing methods for predicting the likelihood of plastic shrinkage cracking due to evaporation and concrete bleeding. The author has provided some further formulas, a simpler nomograph, and a set of guidelines which should assist the cement and concrete industry in minimizing the onset of plastic shrinkage cracking.

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[9] Shubham Sunil Malu, Plastic Cracking of Concrete

[10] Sayahi et. al. Plastic Shrinkage Cracking In Self-Compacting Concrete: A Parametric Study

[11] Paul J. Uno Plastic Shrinkage Cracking and Evaporation Formulas.