Creep of Concrete

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***Abstract* - This paper summarizes various aspects of the prediction of concrete creep to be discussed in respect to the age of concrete, mix proportion and Reinforcement. The creep of concrete, which originates from the calcium silicate hydrates (C-S-H) in the hardened Portland cement paste (which is the binder of mineral aggregates), is fundamentally different from the creep of metals and polymers. Unlike the creep of metals, it occurs at all stress levels and, within the service stress range, is linearly dependent on the stress if the pore water content is constant. Unlike the creep of polymers and metals, it exhibits multi-months aging, caused by chemical hardening due to hydration which stiffens the microstructure.**

***Keywords* - Creep, Concrete, Age of concrete, mixproportions, Reinforcement**

I. INTRODUCTION

Concrete creep is defined as: deformation of structure under sustained load. Basically as long term pressure or stress on concrete can make it change shape. This deformation usually occurs in the direction the force is being applied. Like a concrete column getting more compressed, or a beam bending. Creep does not necessarily cause concrete to fail or break apart. Creep is factored in when concrete structures are designed. When in influence on Aggregates, they undergoes very little creep. It is really the paste which is responsible for the creep. However, the aggregate influences the creep of concrete through a restraining effect on the magnitude of creep. The paste which is creeping under load is restrained by aggregate which do not creep. The stronger the aggregate the more is the restraining effect and hence the less is the magnitude of creep. The modulus of elasticity of aggregate is one of the important factors influencing creep. In case of mix proportions the amount of paste content and its quality is one of the most important factors influencing creep. A poorer paste structure undergoes higher creep. Therefore, it can be said that creep increases with increase in water/cement ratio. In other words, it can also be said that creep is inversely proportional to the strength of concrete. Broadly speaking, all other factors which are affecting the water/cement ratio are also affecting the creep. In view of age at which a concrete member is loaded will have a predominant effect on the magnitude of creep. This can be easily understood from the fact that the quality of gel improves with time. Such gel creeps less, whereas a young gel under load being not so stronger creeps more. What is said above is not a very accurate statement because of the fact that the moisture content of the concrete being different at different age also influences the magnitude of creep.

II. NATURE OF CREEP

Elastic deformations occur immediately when concrete is loaded. Nonelastic deformations under sustained loading increase with time. Consequently since concrete is frequently subjected to dead loading, which is sustained loading, it usually is subjected to both types of deformations. the nonelastic deformation, rightly called creep, increases at a decreasing rate during the period of loading. It has been shown that significant amount of creep takes place during the first seconds after loading and yet creep may carry on for 25 years Approximately, one-fourth to one-third of the total creep takes place in the first month of sustained loading, and about one-half to three-fourths of the total creep occurs during the first half year of sustained loading in concrete sections of moderate size. When the sustained load is removed, there is some recovery but the concrete does not usually return to its original state. The elastic and creep recoveries are less than the deformation under load because of the increased age of the concrete at the time of unloading.

Creep may be due to giving-in of internal voids, viscous flow of the cement-water paste, crystalline flow in aggregates, and flow of water out of the cement gel due to external load and moisture. The last cause is generally believed to be the most important. The magnitude and rate of creep for most concrete structures are intimately related to the drying rate, but creep is also important in massive structures where little or no drying of the concrete takes place. In these structures, most of the creep is believed due to the flow of the absorbed water from the gel (seepage) caused by external pressure.

`Creep strain, being caused by sustained load (or if the rate of loading is slow) unlike shrinkage which is independent of load, is expressed as a strain per unit compressive stress causing it. The ultimate magnitude of creep on a unit-stress basis, p.s.i, usually ranges from 0.2 to 2.0 (* 10-6) and ordinarily is about 1 millionth per unit of length. This value is about three times the elastic deformation of concrete having a secant modulus of elasticity of 3 million psi.

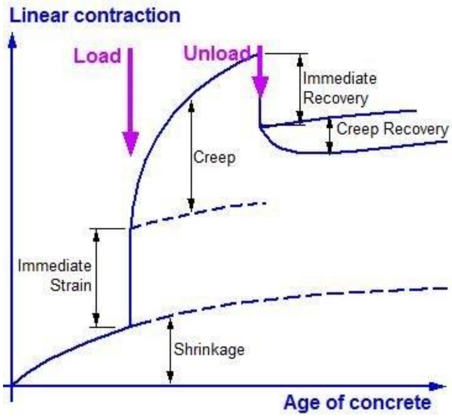

Fig 1 Elastic and creep deformation of mass concrete under constant load followed by load removal

In order to visualize the effects of both elastic and creep deformation at a given time, the sustained modulus of elasticity, defined as to the sum of the elastic and creep deformation at a given time, may be used. Tests have shown that the modulus of elasticity of concrete after 2 years of sustained loading varied between one-half of the initial secant modulus of elasticity. A reduced value of short-time secant or chord modulus of elasticity is frequently used in design to take creep into account.

Creep, unlike shrinkage, which is generally undesirable, may be either desirable or undesirable depending on the circumstances. It is desirable in that it generally promotes better distribution of stresses in reinforced-concrete structures. It is undesirable if it causes excessive deformation and deflections that may necessitate costly repairs or if it results in large lasses of prestressed-concrete members.

Young's Modulus of elasticity of concrete decreases with time, which in turn increases long term deflections. It is at best only an intelligent guess as to the combined effects of creep, humidity, temperature and host of other variables (unavoidable in the making of concrete) on the reduction of modulus of elasticity of concrete. However, under temperate weather conditions and using normal materials and construction practices, the finally reduced elastic modulus value may be effectively taken as 40 to50 per cent of the initial (secant) modulus value.

Where concrete is partly partly cast in situ, the differential creep effect usually nearly balances the differential shrinkage effect.

Where a concrete structure is built part by part, even if each stage is cast in situ (e.g.span-by-span bridge –beck construction), the actual long term distributions of dead load bending moment and shear equalise themselves by creep and finally very nearly agrees with the distributions that would result if the structure was continuously cast in situ in one single operation Therefore, the dead load moment and shear value at any section, in a span by span construction, may be taken as a corresponding to the actually constructed scheme and the other as if the whole structure were cast in situ in one continuous operation. This point should be noted very carefully by the designer if he wants to understand what creep does to his initially assumed moment and shear distributions.

III. EFFECTS OF CREEP

Creep affects strain and defluxions and often also stress distribution, but the effects vary with the type of structure.

The influence of creep on the ultimate strength of a simply supported reinforced concrete beam subjected to a sustained load is not significant, but the defluxion increases considerably and may in many cases be a critical consideration in design. According to Glanville and Thomas, there are two distinct "neutral surfaces" in a beam subjected to sustained loading one of zero stress, the other of zero strain This arises from the fact that an increase in the strain in concrete leads to an increased stress in the steel and a consequent lowering of the natural axis and an increasing depth of concrete is brought into compression. As a result the elastic strain distribution changes, but the creep strain distribution changes, but the creep strain is not cancelled out, so that at the level of the new stress-neutral-axis a residual tensile strain will remain. At some level above this axis there is a line of zero strain at any time although there is a stress acting. This is an interesting example of the influence of the stress history on strain at any time.

In reinforced concrete columns, creep results in a gradual transfer of load from the concrete to the reinforcement. Once the steel yields, any increase in load is taken by the concrete, so that the full strength of both the steel and the concrete is developed is developed before failure takes place. In statically indeterminate structures creep may relive stress concentration induced by shrinkage, temperature changes, or movement of support in all concrete structures creep reduces internal stresses due to non-uniform shrinkage so that there is a reduced in cracking. In calculating creep effects in structures it is important to realize that the actual time-dependent deformation is not the "free" creep of concrete but a value modified by the quantity and position of reinforcement.

On the other hand, in mass concrete, creep in itself may be a cause of cracking when a restrained concrete mass undergoes a cycle of temperature changes due to the development of the heat of hydration and subsequent cooling. Creep relieves the compressive stress induced by the rapid rise in temperature so that the remaining compression disappears as soon as some cooling has taken place. On further cooling of concrete, tensile stresses develop and, since the rate of creep is reduced with age, cracking may occur even before the temperature has dropped to the initial (placing) value For this reason the rise in temperature in the interior of a large concrete mass must be controlled by the use of low cement content precooling of mix ingredients, limiting the height of concrete lifts and cooling of concrete by pipes embedded in the concrete mass (as is done in the case of dams).

Another instance of the adverse effects of the structure due to increase in deformation. Even when creep does not affect the ultimate strength of s structure its effects may be serious as far as the performance of the structure is concerned. This is for instance, the case in the foundation block of a very large turbo-generator: differential movement of the supported of indeterminate structure due to 'creep' and 'the change in the slope of the beams (which may be even 50m long) due to shrinkage' would upset the alignment of the shaft of the generator. Likewise, in very tall building, differential creep also structural effects in beams and slabs.The loss of prestress due to creep is well known and, indeed, accounts for failure of all early attempts of prestressing. It was only the introduction of high tensile steel, whose elongation is several times the contraction of concrete due to creep andshrinkage, which made prestressing a successful proposition.

IV. CREEP AS EFFECTED BY CONSTITUENTS, PROPORTIONS, AND MANUFACTURE OF CONCRETE

Concrete made with low-heat cement creep more than concrete made with normal cement, probably because of its influence on the degree of hydration. This desirable characteristic explains, at least in part, the relative freedom from cracking of mass concrete structures as they cool to normal temperatures. The effect of cement fineness on creep appears to be variable. Pozzolanic additions to cement generally increase creep, Approved air-entraining agents added in the proper amounts appear to have no appreciable effect on creep. As creep is an important factor, proprietary compounds should not be used unless their effects have been previously evaluated.

Under comparable conditions creep and shrinkage generally decease when well-graded aggregates with low void contents are used and when the maximum size of the coarse aggregate is increased. Hard, dense aggregate with low absorption and a high modulus of elasticity are desirable when low shrinkage and creep are wanted. The mineral composition of the aggregate is important, and generally increasing creep may be expected with aggregates in the following order: limestone, quartz, granite, basalt, and sandstone.

Creep of concrete increase as the water-cement ratio increase. In addition it appears that if two concrete mixtures have the same water-cement ratio, the mixture having the greater volume of cement paste will creep the most. In general, lean concrete mixture exhibit considerably greater creep then do rich concrete mixture because the water-cement ratio effect of increasing creep for the lean mixture is more important then the paste effect of decreasing creep.

The tendency of concrete to creep decreases as cement hydration increases, and consequently water-cured concrete should creep less then air-cured concrete. However, the shrinkage or swelling produced the initial curing period also influences creep. Size effects are also important in curing because small specimens respond more rapidly more rapidly to moisture changes than large concrete members.

V. EFFECTS OF EXPOSURE AND LOADING CONDITIONS ON CREEP

The rate and ultimate magnitude of creep increases as the humidity of atmosphere decreases.The relation between relative humidity and creep is not linear concrete under sustained load in air at 70% relative humidity will have an ultimate about twice as large as concrete in air at 100% relative humidity.The ultimate creep in air at 50% relative humidity will be about three times as large.Protection of concrete members from rapid drying is beneficial in reducing the rate and ultimate amount of creep.

The rate and magnitude of creep generally decreases as the size of concrete increases. It has been estimated that the creep of mass concrete may beabout one-fourth of that obtained with small specimens stored in moist air. Witha given material and sustained load the rate of magnitude of creep decrease as the age at which the sustained load is sustained supplied increases, as long as hydration continues.creep is also approximately proportional to sustained stress within the range of usual working stresses. Sustained stresses above the working stresses produce creep that increases progressively faster rate as the magnitude of the sustained stress is increased.

Most creep information for plain concrete has been obtained for sustained compressive loading.However, test information for creep under sustained tension, bending,torsion,and biaxial and tri-axial-stress conditions generally shows the same behavior pattern! The ultimate tensile creep, reduced to a 1-p.s.i. stress basis, is about the same as the ultimate compressive creep on the same basis.

A test method to determine the creep characteristics of moulded concrete cylinders subjected to sustain longitudinal compressive load is provided in ASTM standard C512.The method is intended to compare concrete specimens tested under controlled conditions, but it does notprovided a mean for calculating deflections of reinforced-concrete members in structures. Total creep strain (per p.s.i) is given by the equation:

$$\epsilon = \frac{1}{E} + F(K)\log(t+1)$$

ϵ = total creep strain per psi

E= instantaneous elastic modulus, psi,

F (K) = Creep rate, calculated as the slope of astraight line representing the creep curve on a semi log plot (logarithmic axis represents time),

t = time after loading, days

The Quantity 1/E is the initial elastic strain per psi, and the second term in the equation represents the creep strain per psi for any given period.

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