Relationship between the Strength and Durability of Conventional Concrete: An Overview

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***Abstract*- Although the strength of concrete has direct relationship with durability, but it does not completely signify that this statement is always prove right. This aspect should be sensitively taken into consideration while designing a concrete mix. As we know that, the strength of concrete is depends on the water-cement (W/C) ratio used for making concrete mix. There is such kind of relation between strength and water-cement (W/C) ratio, like for making a high strength concrete, low water-cement (W/C) ratio is required. This shows that at higher water-cement (W/C) ratio the concrete mix obtained is of low strength. In low water-cement (W/C) ratio, cement content is high in comparison to water content, and when cement content is high then it results in greater cracking tendencies because of increased thermal and drying shrinkage. High strength concretes are more sensitive to cracking than moderate or low strength concrete. At drying stage micro cracks are developed in concrete structure, which are due to drying shrinkage but are not susceptible to decrease in strength and durability. When water-cement (W/C) ratio is high then it results in higher permeability in concrete structure, which affects the strength and durability of concrete. High permeability is more sensitive to early stage deterioration of concrete, due to ingress of moisture, carbonation, sulphate attacks etc., all these ill effects makes the concrete less durable. This article is overviewed the relationship between the strength and durability of conventional concrete. This relationship signifies that higher strength of concrete can withstand long term durability is uncertain, it all depends on the better quality of product of hydration, reduced permeability, proper curing etc.**

***Index terms*- Durability, Hydration, Permeability, Shrinkage, Strength, Water-Cement Ratio.**

I.INTRODUCTION

Concrete is a basic building material which is most commonly used in many civil engineering projects like, buildings, bridges, dams, highways, towers etc. It is a composite material and can vary to a very great extent in it's quality properties and performance. A good quality concrete should satisfy strength and durability parameters, because these are important characteristics of making long term serviceable concrete structures. So, it is necessary to have consideration of these aspects, while designing a concrete mix.

II. STRENGTH OF CONCRETE

The strength of concrete is primarily the most essential and useful property of concrete. Strength of concrete is it's resistance against breaking by external load applications. The designed concrete is tested against compressive, flexural, shear and tensile strengths, as per the requirements of structure. In most structural applications concrete is employed primarily to resist compressive stresses. The strength of concrete is usually measured in terms of compressive strength. The compressive strength of concrete is one of the most desirable property, which is used as a qualitative measure for other properties of hardened concrete. The other strengths like flexural, shear and tensile are also an important intrinsic properties to determine the quality of concrete, but these are work specified. All these strengths are the scales of the quality of concrete.

III. DURABILITY OF CONCRETE

Concrete is said to be durable, if it withstands the conditions for which it has been planned or designed, without deterioration, over a period of intended service life. Durability is the resistance of concrete to a variety of physical or chemical attacks due to internal or external causes. The internal causes are alkali aggregate reaction, volume change due to

differences in thermal properties, drying shrinkage and permeability of concrete. The external causes may be due to weathering, occurrence of extreme temperature variations, abrasion, environmental penetration by water, chlorides, sulphates, carbon dioxide (CO2) etc. In the formation of durable concrete, the various properties of hardened concrete play a significant role.

IV. STRENGTH AND DURABILITY RELATIONSHIP

The strength of concrete has direct relationship with durability, but it is not a sufficient statement in this regard, else more is required to understand about this concept, and this aspect should be sensitively taken into consideration while designing a concrete mix. When we discuss about high strength concrete mix design, then designer consider using of high strength cement, very low water-cement (W/C) ratio through the use of increased cement content and reduced water content. The above steps result in higher thermal shrinkage, drying shrinkage, modulus of elasticity and lower creep coefficients. With higher quantity of cement content, the concrete exhibits greater cracking tendencies because of increased thermal and drying shrinkage. As the creep coefficient is low in such concrete, there will not be much scope for relaxation of stresses. Hence, high strength concretes are more sensitive to cracking than moderate or low strength concrete.

The high early strength concrete has high cement content and low water content. On account of low water content, only surface hydration of cement particle would have taken place leaving considerable amount of un-hydrated core of cement grains. This un-hydrated core of cement grains has strength in reverse. When micro cracks have developed, the un-hydrated core gets hydrated, getting moisture through micro cracks. The hydration products so generated seal the cracks and restore the integrity of concrete for long term durability. The cement paste formed due to hydration, is of good quality in case of low water-cement ratio is used as compare to the quality of cement paste formed using high water-cement ratio is used. The weak transition zone between aggregate and hydrated cement paste does not exists in case of low water-cement ratio concrete. Un-hydrated cement particles are also present in low water-cement ratio concrete for any eventual healing of micro cracks. The micro structure of concrete with very low water-cement (W/C) ratio, is much stronger and less permeable. The interconnected network of capillaries is so fine that water cannot flow any more through them. But however, it is difficult to conclude whether the micro cracks developed in high early strength concrete reduces the long term durability or the delayed hydration of un-hydrated core of cement grains would heal up the micro cracks and thereby improve long term durability along with the better quality of product of hydration, higher strength, reduced permeability.

V. MAJOR FACTORS AFFECTING THE STRENGTH AND DURABILITY OF CONCRETE

The following major factors affect the strength and durability of concrete are –

1 Water-cement (W/C) ratio and water content
2 Permeability of concrete
3 Interaction between permeability, volume change, and cracking of concrete
4 Mix design
5 Aggregate-cement ratio

A. Water-Cement (W/C) Ratio and Water Content -

Strength of concrete is primarily depends on the water cement ratio, means the content of cement and water in the mix, or in other words the cement paste is responsible for strength. The strength of paste increases as the cement content increases and decreases when air and water content increases, means high strength attains at low water-cement (W/C) ratio. So, it is desirable for achieving high strength of concrete mix keep lower the water-cement (W/C) ratio, and also it makes the concrete impermeable and more durable.

With low water-cement ratio the permeability decreases to such a level that these concretes are impervious to water. The capillaries in such type of concrete are so fine that water cannot flow any more through them. The low water-cement (W/C) ratio concrete are less sensitive to carbonation, external chemical attack and other detrimental effects that causes lack of durability of concrete. It is clear that use of higher water-cement (W/C) ratio results in higher permeability in concrete structure. So, for a durable concrete, use of lowest possible water-

cement (W/C) ratio is the fundamental requirement to produce dense and impermeable concrete

A water-cement (W/C) ratio of 0.5 – 0.6 is considered normal. The lower water-cement (W/C) ratio of 0.4 is generally specified if a higher quality concrete is desired. The practical range of the water-cement (W/C) ratio is from about 0.30 to over 0.60. The ratio of 0.30 is very stuff (unless super-plasticizers are used), and a ratio of 0.60 makes a wet and fairly weak concrete. The simplest way to think about the water-cement (W/C) ratio is to think that the amount of water in a concrete mix, the more dilute paste will be. This not only affects cement compressive strength, it also affects the porosity and the shrinkage of concrete. The generalized relationship between free water-cement ratio and compressive strength is shown by graph below –

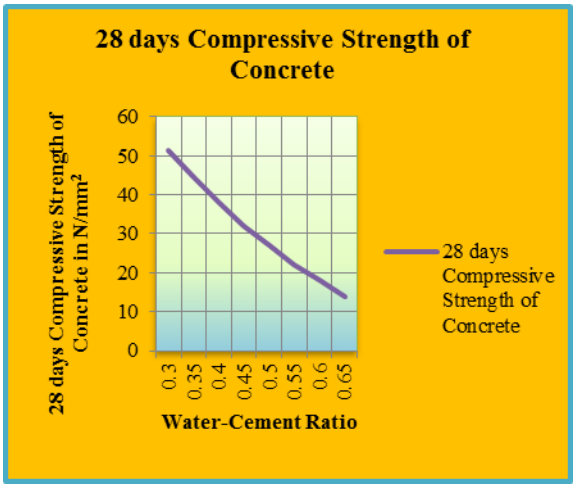

Fig. 1 Generalized relation between free water-cement ratio and compressive strength of concrete

B. Permeability of Concrete -

Another important point of consideration is the permeability of concrete. It has direct repercussion on durability than that of water-cement ratio. Micro cracks at transition zone are considering factor for permeability whereas water-cement ratio may not get involved directly. Micro cracks in the initial stage are so small that they may not increase the permeability. But propagation of micro cracks with time due to drying shrinkage, thermal shrinkage and externally applied load result in increasing the permeability of concrete. Permeable concrete is responsible to lower strength at maturity. The relationship between permeability and water-cement (W/C) ratio is shown below –

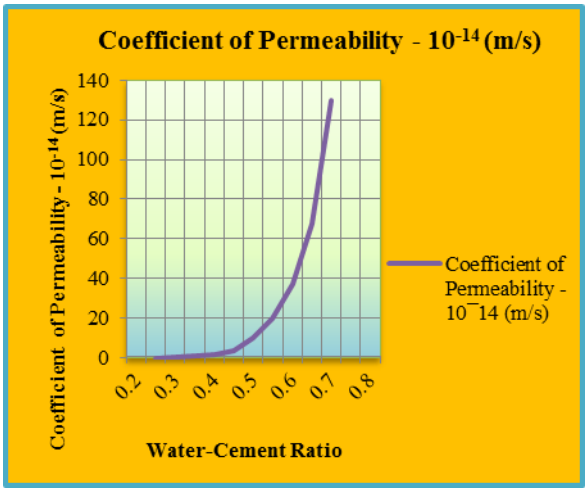

Fig. 2 Relation between permeability and water-cement ratio

C. Interaction between Permeability, Volume Change and Cracking of Concrete –

Permeability, volume change and cracking of concrete are responsible for lack of durability of concrete. The permeability of concrete is often referred as the main cause for lack of durability. But it is also considered that volume change that takes place in an otherwise impervious concrete due to heat of hydration or internal manifestation can crack the concrete affecting durability. Micro cracks in transition zone even in initially impermeable concrete, can start the cycle of deterioration process in concrete.

D. Mix Design -

The fundamental requirement of a concrete mix is that it should be satisfactory both in the fresh as well as in the hardened state, possessing minimum desirable properties like workability, strength and durability. Besides these requirements, it is essential that the concrete mix is prepared as economically as possible by using the least possible amount of cement content per unit volume of concrete; with due regard to the strength and durability requirements.

E. Aggregate-Cement Ratio -

The aggregate/cement ratio affects the strength of concretes in the high strength range to a significant degree and this is one of the reasons for considering the design of high strength concrete separately. It is important to note that mixes with very low water/cement and aggregate/cement ratios, having

extremely high cement content of the order of 450-550 kg/m3 exhibits retrogression of strength, especially when large size aggregates are used. The reduction of strength is attributed to the loss of aggregate-cement bond due to stresses induced by shrinkage. For a constant water/cement ratio, a leaner mix leads to a higher strength. This pattern of behaviour is due to the absorption of water by aggregates leading to a reduction in the effective water-cement ratio of the mix.

Besides all above, other factors which are also significantly effect on the strength and durability of concrete, such as workability, use of admixtures, curing of concrete, environmental interactions etc.

VI. CONCLUSION

It is observed that the water-cement (W/C) ratio plays a remarkable role in understanding the strength and durability relationship. It is prime factor and a parent aspect of generating an impermeable or permeable concrete, drying shrinkage and volume change. The permeability of concrete is responsible for developing micro cracks in concrete, which are responsible for lowering strength and durability at serviceable life of concrete structures. Thus, it is concluded that the strength is the early stage property of concrete, but the durability is long term property of concrete, which is effective in relation to the early stage strength of concrete. And it is not necessary that a high strength concrete can withstand more durable in all exposure conditions at the end of it's serviceability. A low strength concrete may also be durable for a particular duration, which shall depend on the exposure conditions. All this depends on the selection of proper water-cement (W/C) ratio, grading of aggregates, workability, workmanship, curing of concrete etc.

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