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CONCEPTUAL STUDY OF THE EFFECT OF GEL SPACE RATIO ON THE STRENGTH OF CONCRETE

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ABSTRACT
This study is focused on understanding the basic theory related to the strength of concrete. The concrete is best in compression, it shows little bit tension too. Therefore, study emphasized on compressive strength of concrete and it's responsible factors. The main factors are water-cement ratio and gel-space ratio, which are responsible for attaining the strength of concrete at an early age. The strength can be more correctly related to the solid products of hydration of cement to the space available for formation of hydrated products of cement. The proper quantity of water is essential for hydration of cement, because as the concrete get hardened and drying, there is formation of capillaries in the microstructure of concrete due to the shrinkage, and temperature stresses, that reduce the concrete strength. Therefore, it is essential to understand the relationship between the strength and gel-space ratio.

KEY WORDS : *Strength of Concrete, Compressive Strength, Water-Cement Ratio, Gel-Space Ratio.*

1. INTRODUCTION

Concrete is prominently used in the field of construction. It is world's most versatile, durable, economic and sustainable construction material. It is a composite material which consist mixture of Portland cement, sand and aggregates. Water is required to make a homogeneous mix. It has a unique property as it becomes hard, strong and durable after get dry. Concrete get it's desirable strength when it mixes properly while making fresh concrete, compacted properly during casting, attaining hardness and strength when cured properly.

2. STRENGTH OF CONCRETE

Strength of concrete is its resistance to rupture. Generally, when we discuss the strength of concrete, it is assumed that compressive strength is under consideration. Therefore, however, other strengths to consider besides compressive strength, depending on the loading applied to the concrete are as flexure or bending and tension are applied under certain conditions and must be resisted by the concrete or by steel reinforcement in the concrete. The strength of concrete are the measure of compressive strength, flexural strength and modulus of elasticity and measure of tensile strength of concrete is splitting tensile strength of concrete. All these indicate strength with reference to a particular method of testing.

2.1 Compressive Strength :

The compressive strength of concrete is one of the most important and useful property of concrete. In most structural applications concrete is considered primarily to resists compressive stresses. In those cases where strength in tension or in shear is primary importance, the compressive strength is frequently used as a measure of these properties. The measure of compressive strength is important because the concrete is quite good to bear compressive loads, i.e. strong in compression. Hence, the compressive strength test is performed to determine the strength of concrete at different mix combinations.

When concrete fails under compressive load, the failure is essentially a result of crushing and shear failure. It can be assumed that the concrete in resisting failure generates both cohesion and internal friction. The cohesion and internal friction developed by concrete in resisting failure is related to water-cement ratio and gel-space ratio.

3. FACTORS AFFECTING STRENGTH OF CONCRETE

For a given cement and acceptable aggregates, the strength that may be developed by workable, properly placed mixture of cement, aggregate and water (under the same mixing, curing and testing conditions) is influenced by following factors –

a) Water-cement ratio
b) Aggregate-cement ratio
c) Grading, surface texture, shape, strength, and stiffness of aggregates particles
d) Maximum size of aggregate

In the above it can be further inferred that water-cement ratio primarily affects the strength, whereas other factors indirectly affect the strength of concrete by affecting the water-cement ratio. But, instead of relating the strength to water/cement ratio, the strength can be more correctly related to the solid products of hydration of cement to the space available for formation of this product.

3.1. Effect of Water-Cement Ratio :

Strength of concrete primarily depends upon the strength of cement paste, and strength of cement paste depends upon the dilution of paste. The strength of paste increases as the cement content increases and decreases when air and water content increases.

Abrams (1918) water-cement ratio law states that the strength of concrete is only dependent upon water-cement ratio provided the mix is workable. It state in generalized form –

$$S = \frac{A}{B^x}$$

where, x = water-cement ratio by volume and for 28 days results

A = constant = 14000 lbs/sq in = 984.296 kg/cm^2

B = constant = 7

But, in as early as 1897 Feret, who formulated – a general rule defining the strength of the concrete paste and concrete in terms of volume fractions of the constituents by the equation –

$$S = K\left(\frac{c}{c+e+a}\right)^2$$

where, S = strength of concrete

c, e, and a = volume of cement, water and air respectively

K = constant

From above equation it is understood that the volume of air is also included because it is not only the water-cement ratio but also the degree of compaction, which indirectly means the volume of air filled voids in the concrete is taken into account in estimating the strength of concrete.

From the fig. 1.1 below it can be seen that the lower water-cement ratio could be used when the concrete is vibrated to achieve higher strength, whereas comparatively higher water-cement ratio is required when concrete is hand operated. In both situations when the water-cement ratio is below the practical limit the strength of the concrete falls rapidly due to introduction of air voids. The strength at any water-cement ratio depends on the degree of hydration of cement and its chemical and physical properties, the temperature at which the hydration takes place, the air content in case of air entrained concrete, the change in the effective water-cement ratio and the formation of fissures and cracks due to bleeding or shrinkage. The fig. 1.2 below showing the relation between cement-water ratio and compressive strength –

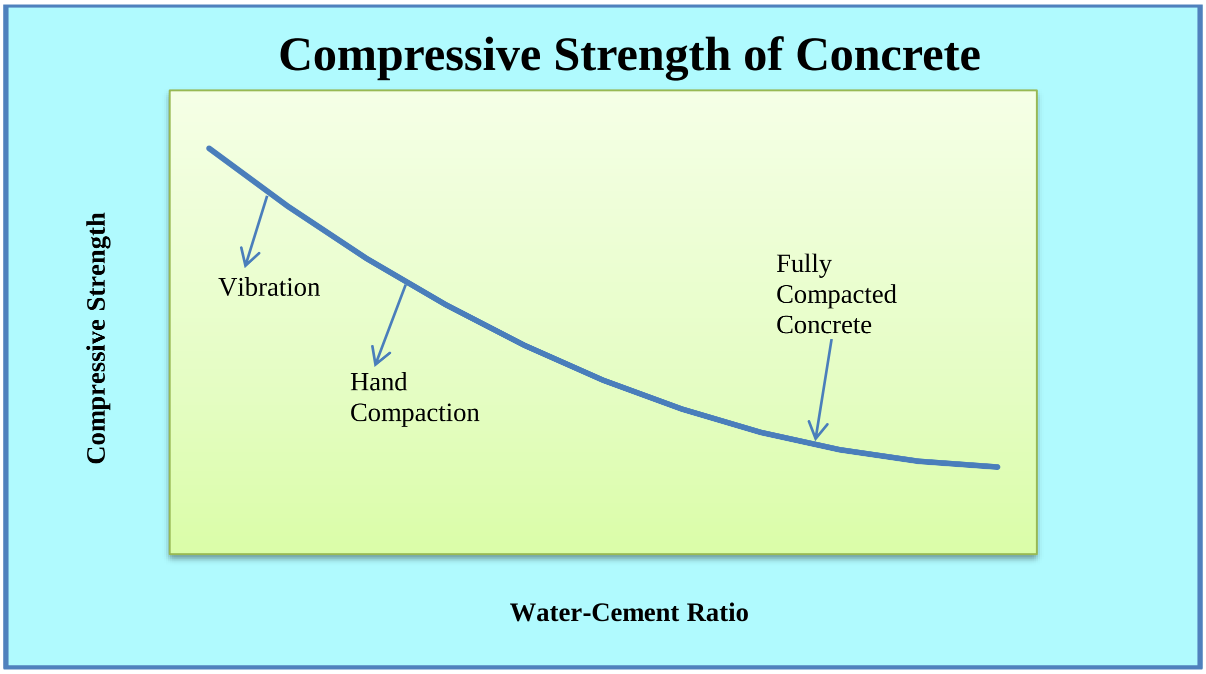

Fig. 1.1. The relation between strength and water-cement ratio of concrete

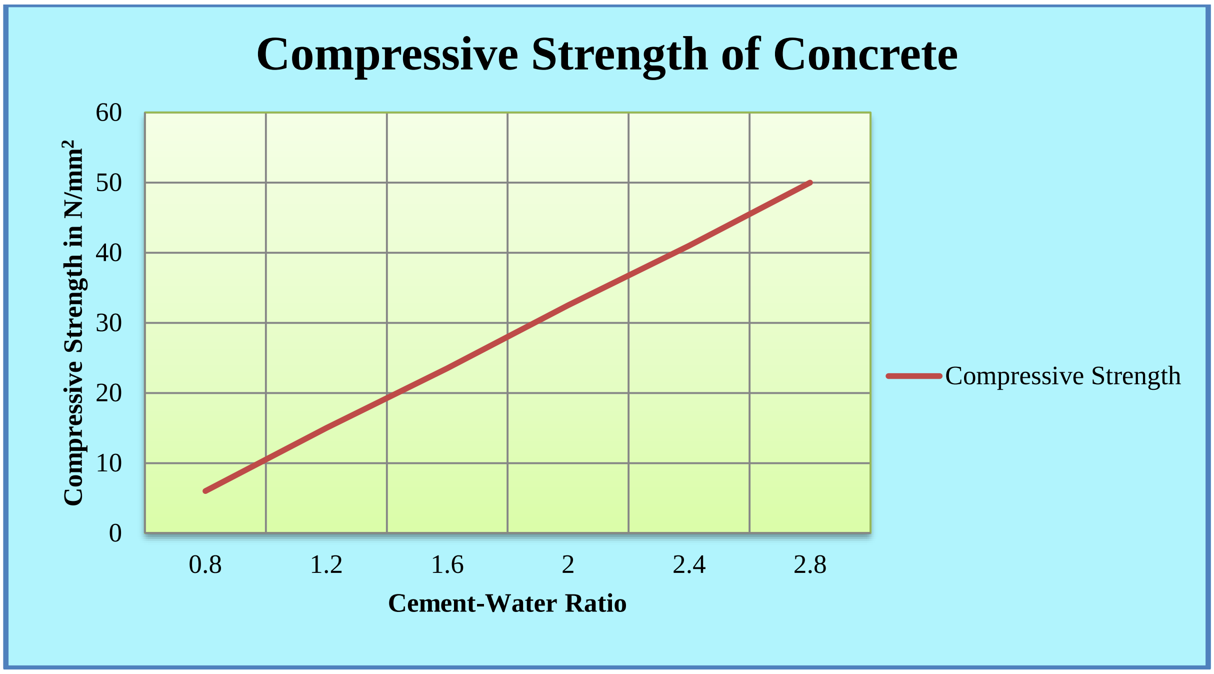

Fig. 1.2. The relation between strength and cement-water ratio

Many researches showed that the theory of attaining strength by the concrete based only on water-cement ratio is not completely sufficient itself, there is also need to understand the concept of strength in terms of the relationship between strength and gel-space ratio.

3.2. Effect of Gel-Space Ratio :

The strength can be more correctly related to the solid products of hydration of cement to the space available for formation of this product. Powers and Brownyard have established the relationship between the strength and gel-space ratio. Power had experimentally showed that the strength of concrete bears a specific relationship with gel-space ratio. He found the relationship –

Relationship between strength and gel-space ratio = $240\ x^3$

Where, x = gel-space ratio and 240 – represents the intrinsic strength of the gel in N/mm^2 for the type of cement and specimen used. The strength calculated by Power's expression holds good for an ideal case.

The gel-space ratio is defined as the ratio of the volume of the hydrated cement paste to the sum of volumes of the hydrated cement and of the capillary pores. The relationship between the strength and gel-space ratio is independent of age. Gel-space ratio can be calculated at any age and for any fraction of hydration of cement.

a) Calculation of gel-space ratio for complete hydration

$$\text{Gel-Space Ratio} = x = \frac{\text{Volume of gel}}{\text{Space available}} = \frac{0.657C}{0.319C+W}$$

b) Calculation of gel-space ratio for partial hydration

$$\text{Gel-Space Ratio} = x = \frac{\text{Volume of gel}}{\text{Space available}} = \frac{0.657C\alpha}{0.319C\alpha+W}$$

where, C = weight of cement in g
W = volume of mixing water in ml
α = fraction of cement that has hydrated

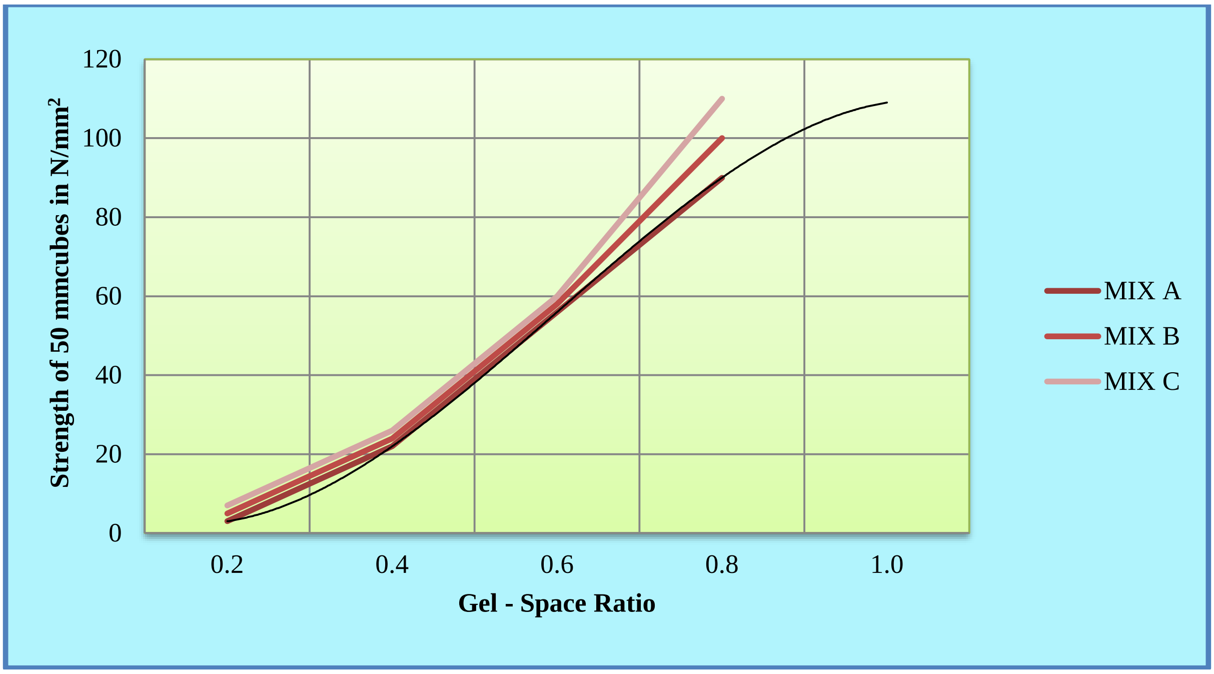

Fig. 1.3. The relationship between compressive strength of mortar and gel-space ratio

3.3. Gain of Strength with Age :

The concrete develops strength with continued hydration. The rate of attain of strength is faster to start with and the rate gets decreased with the age. It is generally to assume the 28 days strength as the full strength of concrete. Actually concrete attains strength beyond 28 days also. Hence, the increase in strength beyond 28 days is taken into consideration in design of structures. The increased in strength beyond 28 days used to get immersed with the factor of safety. Thus, the designers have been trying to reduce the factor of safety and make the structure more economical by better understanding of material.

3.4. Effect of Maximum Size of Aggregate on Strength :

It is fact that the larger the aggregate the lower is the total surface area and therefore the lower is the requirement of water for the given workability. For, this reason a lower water-cement ratio can be used which will result in higher strength. The use of larger size of aggregate did not contribute to the higher strength as expected from the theoretical considerations due to the following reasons –

- The larger maximum size aggregate gives lower surface area for development of gel bonds which is responsible for lower strength of the concrete.
- Bigger aggregate causes a more heterogeneity in the concrete which will prevent the uniform distribution of load when stressed.
- Large size aggregate have internal bleeding so the transition zone will become much weaker due to the development of micro cracks. It causes lower compressive strength.
- It has been observed that the high strength concrete is adversely affected by the use of large size aggregate, where as in weaker concrete the influence of size of aggregate get reduced.
- In lean concrete mixes larger aggregate gives highest strength while in rich mixes it is smaller aggregate which yield higher strength.

4. CONCLUSION

It is clear from the above study that gel-space ratio plays an important role in attaining compressive strength of concrete. Generally, it is assumed that water-cement ratio is the only major factor which affects the strength of concrete but it is one side of coin only. The other aspect, in fact the strength of concrete is more correctly related to the gel-space ratio and others factor too also. The relationship between the strength and gel-space ratio is independent of age. The gel-space ratio is depends on the hydration of cement and its hydrated products. It means space available for formation of hydrated products when hydration process begins. The gel-space ratio gives also gives the account of theoretical strength of concrete at per cent hydration of cement. But, there is a lot of difference between the theoretical strength and its actual strength of concrete. Actual strength of concrete is much lower than the theoretical strength estimated on the basis of molecular cohesion and surface energy of a solid assumed to be perfectly homogeneous and flawless. The reduction of the strength is due to the presence of flaws. Therefore, while forming good concrete mix proper quantity of water is essential for hydration of cement, which directly depends on gel-space ratio. Thus concept of gel-space ratio is mandatory to understand the concept of attaining strength of concrete.

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