

Tensile strength test of concrete engineering essay



Concrete is a widely used construction material in the world. It is one of the most versatile, durable and environmental friendly material. Most importantly concrete is good at compression and is completely non-combustible, which makes it popular in this industry. But concrete has low tensile strength causing concrete to behave in brittle manner. This nature in concrete has lead to numerous test and research in order to increase the tensile properties of concrete.

History of concrete dates back several thousand years to the day of the ancient Egyptians, the Greeks and the Romans. These early concrete compositions were based on lime although the Romans are known for their development of pozzolanic cement and lightweight concrete based on pumice. The credit for the introduction of steel as reinforcement is variously attributed to Lambot in 1855 for ferrocement boats, to Monier in 1867 and to Hennebique in 1897 who built the first reinforced concrete frame building. But the Notable steps forward in this century have been the introduction of pre-stressed concrete by Freyssinet in the 1940s and the motorway-building boom of the 1960s involving concrete pavements and bridges. Although the vast majority of concrete structures have performed satisfactorily for many years such progress has not been made without its problems.

1. 1 HIGH STRENGTH CONCRETE

High strength is a concrete which has a cylinder compressive strength greater than 6000psi or 42 MPa. Generally, for building high rise structures, concrete with cylinder compressive strength over 140 MPa is used. In some laboratories in United States and Europe, a concrete with strength over 315

MPa has been produced, however, the problem with such strength is that it reduces the ductility of structure. Higher strength concretes leads to cost effective structural systems. Using such concrete, overall weight of the systems on the foundation reduces, resulting in size reduction, increase in available occupancy space, and thus cost of components.

Many factors are taken into account for making a high strength concrete. Generally, such a concrete contains a higher Portland cement, strong aggregates, and a low water/cement ratio. Now-a-days, addition of super plasticizers, blast furnace slag, polymers, water reducing admixtures or silica fume are common

1. 2 HISTORICAL DEVELOPMENT OF HIGH STRENGTH CONCRETE

In last half decade, the compressive strength of commercial concrete has tripled approximately from 5, 000 psi to 14, 000 psi. In 1950s, a ready mixed concrete of design strength of 5000 psi was called as high strength. A decade later, Washington state highway department specified 6000 psi strength concrete for prestressed girders. High strength concrete made constructions such as 311 South Walker Drive concrete building; East Huntington, W. V., and other long span cable stayed bridges. Increased use of mineral admixtures and chemicals in 1960s lead to an increase in attainable strength. In 1973, Japan national railway built three high strength concrete bridges and they were found to meet all expectation by serving for over 20 years.

Chicago city played a very important role in the evolution of commercial high strength concrete. The inventors of micro-silica concrete (MSC) realised that <https://assignbuster.com/tensile-strength-test-of-concrete-engineering-essay/>

Chicago inner city development would be quite beneficial, which indeed was, and hence, with appointing high strength concrete pioneer, William Schmidt, they targeted an increase up to 6000 psi for a new 40 story tall Outer Drive East Condominium Project, using normal weight concrete. In 1972, the first 7500 psi concrete was used for a 52 story tall Mid-continental Plaza. Later, in 1974, 9000 psi concrete was supplied to 74 stories tall Water Tower Place, which was the tallest building at that time.

In late 1980s, very high strength concrete as being successfully developed in many parts of North America. One of the best examples is Two Union Square in Seattle which is a 220 m tall, 58 story building. The original concrete specified for them was 14000 psi at 28 days, however, to incorporate a static modulus of elasticity of 50 Gpa, the concrete was upgraded to a compressive strength around 19000 psi. A test conducted after 4 years found that the compressive strength and modulus of elasticity were 19900 psi and 5.6 Gpa, respectively. Now-a-days, 14000 psi at 56 days is commonly used in many metropolitan cities.

1.3 MOTIVE FOR DEVELOPMENT of High strength concrete

Modern methods have improved the quality of concrete by many folds. Aspects such as, long term failure studies, development of effective and powerful instrumentation, molecular structure of material, increased need of materials better for larger structures and increased ductility, and decrease of cost effectiveness of traditional material have redefined concrete.

These days, concrete structural systems build from 15000-20000 psi concretes can be found quite easily. However, factors such as newer

components or admixtures, microstructural studies, better material selection proportioning, long term performance, blended cement compositions, placement techniques and others; provide an ample scope of improvement. For e. g., use of slags and pozzolans as cementitious replacements contribute to energy conservation and disposal of industrial by-products, besides higher strength. Improved cements such as densified cements (DSP) and macrodefect free cements (MDF) and composite advancements, for e. g., slurry infiltrated fiber concrete (SIFCON), have allowed the builders to achieve concrete with strengths up to 300 MPa. A very nice example of such concrete use is the undersea tunnel connecting British Isles and France.

1. 4. APPLICATIONS OF HIGH STRENGTH CONCRETE

The use of high strength concrete has been increasing considerably high in construction world because of both technical and economical advantage. The use of HSC provides more economical construction due to reduced member cross-section and dimensions. HSC has been extensively used in high rise building and highway bridges. Major area of use has been high rise buildings. Tall construction feature whose construction would have been not possible in terms of durability and long term performance have been successfully constructed using HSC. The use of HSC helps in the reduction in structural member size, reinforcement percentage increasing floor space and decreasing dead weight. One of the examples of high rise building is the Mercantile Exchange building in Chicago which used 9000psi concrete.

The other application of HSC is in prestressed Bridge girders. The use of HSC would allow using greater spans for a given number of girders as compared

to NSC. Again for a given span, use of HSC provides economical cost by reduction in labour cost in the production of girders, transportation cost, erection cost and overhead expenses. Japanese I-shaped, box and rectangular section bridge girders have been constructed using 8500psi concrete where the spans are between 100 to 280 ft. One of the examples is Bennett Bay Bridge, Idaho which has which 1730ft segmental girder with two centre spans of 520ft and end span of 320ft.

1. 5 DISADVANTAGES OF HIGH STRENGTH CONCRETE

HSC has brought about a lot of construction possibilities which would not have been possible with NSC. However HSC comes with some disadvantages too mainly because of lack of research and information about its behaviour in real construction field. As HSC is composed of mineral and chemical admixture, increased quality control is required. In codes minimum thickness and cover have been specified preventing realization of full benefit of using HSC. It can be difficult to cure adequately due to self-desiccation of low water/cement ratio mixes. HSC possess increased permeability which makes curing difficult as it prevents applied curing water from compensating any initial moisture loss. These are the disadvantages relating the use of HSC in real construction filed.

1. 6 RESEARCH OBJECTIVES

The main objective of this research is to determine the true uniaxial tensile strength of concrete by carrying out a series of cylinder splitting test, modulus of rupture test and cylinder compression test. The research aims to utilise the simple correction factors proposed by Raoof and Lin (1999) which <https://assignbuster.com/tensile-strength-test-of-concrete-engineering-essay/>

aims to overcome the shortcomings associated with the closed form formula used in the Brazilian concrete splitting test.

Many experimental tests on various concrete mixes had been already carried out for the verification of the proposed correction factor. The criteria for this research were based on 3 days compressive and tensile strength of high strength concrete with total of 16 batches using two types of coarse aggregate. Also few batches testing were done for normal strength and self compacting concrete. In this research effect of constituent materials will also be studied. The purpose of this research is to compare and contrast the use of correction factors with the results the results obtained from previous experiments.

1. 7 RESEARCH SCOPE

The scope of this research included computation of splitting tensile strength, compressive strength and modulus of rupture on normal, high and self compacting concrete. The mineral admixtures, which have been used for this research project, were comprised of silica fume, fly ash. The superplasticiser and viscosity modifying admixture that was used in this research were Sika ViscoCrete10 and structure 480 respectively. All the admixtures used in this research are used in real life applications.

2. LITERATURE REVIEW

High strength concrete has been classified as one of the advanced construction materials. High strength concrete has both economical as well as durability benefits. It helps in the reduction in formwork area and cost

with the accompanying reduction in shoring and stripping time due to high early age gain in strength. The composition of high strength concrete constitutes of mineral admixtures which provides a base for the use of waste products.

2. 1 PREVIOUS RESEARCH WORK ON HIGH STRENGTH CONCRETE

High strength concrete uses various mineral admixtures such as silica fume, fly ash, granulated blast furnace slag and superplasticiser which increase the strength of High strength concrete. Most applications of high-strength concrete have used the strength property of the material. However, high strength concrete may carry various other characteristics that can be of great advantage for construction industry. Various researches have been carried out on high strength concrete in order to study other characteristics of HSC.

Some research work that had been carried out on high strength concrete has been summarised below:

M. Mazloom A. A. Ramezaniapour, J. J. Brooks(2004): carried out in joint collaboration between UK and Iranian university presented experimental work on short- and long-term mechanical properties of high-strength concrete containing different levels of silica fume. In this research the cement was replaced by silica fume with 0%, 6%, 10% and 15%. The researchers found that as the proportion of silica fume is increased the workability of concrete decreased but its short-term mechanical properties such as 28-day compressive strength and secant modulus improved. The mix portion used in this research is shown in the table below.

For each mix, the following specimens were made: 24 samples of 100 mm cubes for compressive strength; eight 80 x 270 (diameter x length) mm cylinders for creep; four 80x270mm and four 150x300mm cylinders for shrinkage; two 80x270 mm and two 150x300mm cylinders for swelling. From the test carried it was also established that the percentages of silica fume replacement did not have a noticeable effect on total shrinkage. Moreover the compressive strength of the concrete mixes containing silica fume did not increase after the age of 90days.

K. Lahlou, P.-C. Ai'tcin & O. Chaallal (1992): This research presents the behaviour of High-strength concrete under confined stress. The investigation was carried out on three 28 day strength levels: 50, 80 and 115 MPa where the actual mixes used resulted in strength of 47, 78 and 115MPa. The study showed that improved confinement provides increased compressive strength. As a result a new ultrahigh-strength concrete of strength 250MPa was produced.

Other outcome of the research was that the confinement efficiency increased with the increase in the compressive strength of the concrete.

Zhen-jun He, Yu-pu Song (2010): this is one of the most recent researches carried out in china to study the failure criterion and triaxial strength of HSC before and after high temperature. HSC is susceptible to spalling, or even explosive spalling when subjected to rapid temperature rise as in the case of a fire. Though high strength concrete has been greatly used but very little research has been carried about the effect of high temperature on the concrete structure

Triaxial tests were performed at all kinds of stress ratios after exposure to normal and high temperatures of 20, 200, 300, 400, 500, and 600 °C, using a large static-dynamic true triaxial machine. The study showed that no explosive spalling was observed during the high temperature temperatures ranging from 200 °C to 600 °C.

Also there was no change in the failure modes with the increase in the temperature where the failures under uniaxial tension were tension failure. The uniaxial compressive strength of plain HSHPC was not decreased after 200 and 300 °C. The brittleness-stiffness of HSHPC specimens between 200 °C and

300 °C is higher than that above 400 °C. The temperature around 400 °C is critical to the ultimate strength that decreases rapidly. The increasing extent of the triaxial to uniaxial compressive strength depends on the stress states, the stress ratios, and the brittleness-stiffness of HSHPC after different temperatures.

M. I. Khan, C. J. Lynsdale (2002): the corrosion of steel reinforcement is a common cause of deterioration in reinforced concrete. The use of blended cements or supplementary cementing materials decreases the permeability, thereby increasing the resistance of concrete to deterioration by aggressive chemicals.

The investigation carried out by Khan and Lynsdale (2002) aimed at developing HSC and carryout investigation into the optimisation of blended cementitious system for the development of HSC. PFA at 0%, 20%, 30% and 40% (by weight) was incorporated as partial cement replacement. To these

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blends, 0%, 5%, 10% and 15% SF replacement levels were incorporated to make various binary and ternary cementitious combinations. Cube compressive strength and cylinder splitting strength test was carried out and the oxygen permeability was measured using the given equation:

From the experimental results it was noticed that as curing age increases, the reduction in strength with increasing PFA content becomes less apparent, especially for PFA contents < 30%. As SF is incorporated at 10%, the overall level of strength is increased. Research showed that the incorporation of PFA showed slight reduction in oxygen permeability as compared to the use of silica fume at the later age. The depth of carbonation was also slightly reduced by the inclusion of SF. There was a significant and linear increment in the depth of carbonation with the increase in PFA content. Experimentally there was an 0.3mm of carbonation depth increment for every 10% increase in PFA.

J. J. Brooks, M. A. Megat Johari, M. Mazloo (2000): Chemical admixtures play a vital role in the production of High-strength concrete. Metakaolin (MK) is one of the new admixture commercially introduced. It is very important to know the setting characteristics of concrete as it helps in the scheduling of concrete construction operations. In this research the effect of chemical admixtures and shrinkage reducing admixtures (SRA) on the setting time of HSC was investigated using the penetration resistance method (ASTM C 403). The penetration resistance (P) of all the different concrete mixes was expressed as $P = ae^{bt}$ i. e. P was expressed as the exponential function of time.

The general effect of the admixture retarded the setting times of HSC while the SRA had significant retarding effect when used in combination with superplasticiser. As a whole the conclusive statement is that increasing the levels of SF, FA provides greater retardation in the setting time of HSC.

2. 2 PREVIOUS WORK ON TENSILE STRENGTH PROPERTIES OF HIGH STRENGTH CONCRETE

Tensile strength of concrete is one of the basic and very important properties of concrete. The knowledge of tensile strength is very important in designing concrete structure. Various tests have been carried out in order to determine the tensile strength of concrete. Traditional direct tensile strength test are not commonly acceptable as it suffers many drawbacks. In these tests there is huge stress concentration near the grips and non uniform distribution within the sample. Researches have shown that results from such experiment are low and coefficient of variation is low. Hence more research has been carried out in order to find the true uniaxial tensile strength of concrete.

Zhuhai lin and Laurence Wood (2003): After the proposal of correction factor by Raoof and Lin (1999), further research into the correction factor was carried out by Lin and Wood in 2003. In this research assuming uniaxial tensile strength and properties of the concrete, the Brazilian cylinder splitting test was analyzed by the isoparametric nonlinear finite strip element. The result from the research showed that at the onset of cylinder failure the tensile strength along the vertical diameter of cylinder was smaller than the assumed uniaxial tensile strength which means the splitting

test underestimates the uniaxial tensile strength of concrete. The study also showed the effect of width of packing strip together with the ratio of (f_t/f_c) for the compressive strength constant at 30 N/mm^2 and showed a linear relationship. According to Lin and Wood the range of correction factor for 30 N/mm^2 is about 1.09 to 1.40 for packing strip of 12mm, 1.10 to 1.44 for 13mm width, 1.09 to 1.41 for 14mm and 1.09 to 1.39 for 15mm packing strip width

V. Ramakrishnan, Y. Ananthanayayana, K. C. Gopal : As we already mentioned that different test have shown different values of tensile strength for the same concrete mix. V. Ramakrishnan and his associated carried out a research to compare the results in the various tests and to study the uniformity of the results. In this research over 600 specimens were tested for 28 days target strength.

A comparative analysis of tensile strength test was carried out and the results were compared against cube compressive strength as shown in the plot above. After laboratory work it was found that modulus of rupture does not give the true tensile strength but only gives the highest value of tensile strength and lies between 1.3 to 2 times the cylinders splitting strength. The cylindrical splitting test was taken satisfactory as it gave more uniform and consistent results than other tensile strength tests.

M. F. M. Zain et al: computation of correction factor for the determination of true tensile strength of HSC depends upon the compressive strength of HSC. It is very important to show the relationship between tensile splitting test and compressive strength of HSC. Zain and associates carried out a research

in 2002 in order to determine the relation of splitting tensile strength of concrete with compressive strength, water/binder (W/B) ratio and concrete age. After the investigation a relationship between tensile strength, compressive strength and concrete by age was proposed which is . Plot for this relation is given below.

The relation given above for the prediction of tensile strength of concrete was compared with French code, ACI code and CEB/FIP code and found to be very close. Hence this equation can be helpful in estimating the Splitting tensile strength of HSC.

S Bhanja, B Sengupta(2005): Our research aims to use silica fume as one of the mineral admixture on HSC mixes. Many researches have been carried out to investigate the mechanical effect of silica fume on HSC but very few are carried out in order to analyse the effect of silica fume on tensile strength of concrete. S. Bhanja (2005) carried out research to develop a better understanding on the isolated contribution of silica fume on the tensile strength of concrete. In this experiment 32 mixes with silica fume binder ratio from 0. 0 to 0. 3 were tested for 28 days strength. From the research it was found out that the use of silica fume improves the tensile strength of concrete and depends upon the water cementitious material ratio of mix. Flexural strength showed greater development than splitting tensile strength. Two expressions were developed to establish the relationship between flexural strength, split tensile strength and compressive strength of silica fume concrete.

It was also established that increase in tensile strength beyond 15% of silica replacement was almost irrelevant.

2. 3. TENSILE STRENGTH TESTING OF HIGH STRENGTH CONCRETE

Although concrete is not normally designed to resist direct tension, the knowledge of tensile strength is of value in estimating the load under which the crack will develop. One of the most well known mechanical properties of concrete is that the tensile strength is 8 to 10 times less than compressive strength. Because of such a low tensile strength, the crack can be seen on the surface of concrete structure. Tension failure is still one of the most important issues because it influences the serviceability significantly. Tensile strength is one of the most important parameters used to evaluate tensile failure of a concrete. Tension tests are needed for concrete as complement to standard compression test in order to obtain a better assessment of structural performance.

According to various research and literature review carried out it has been revealed that direct tension test are unsuitable as the results from such tests suffer from inconsistencies due to several uncontrolled variables. It is difficult in this test to avoid stress concentration near the grips and non-uniform stress distribution within the sample. Evans and Wright confirm that the results obtained in the direct tension test of concrete are low and the coefficient of variation is great. Hence this type of test is no longer accepted as reliable. The splitting test is rather simple to perform, does not require other equipment than that needed for the compression test, and gives an approximately similar value of the " true" tensile strength of concrete

(Neville, 1971). According to investigation of splitting tensile strength carried out by O, Neil (2002) , the addition of silica fume, high-range water reducing admixtures and special curing conditions the tensile strength of the concrete was higher than that of conventional concrete.

The tensile tests that are commonly used and that has been used in this project are detailed in full below:

2. 3. 1. MODULUS OF RUPTURE OR FLEXURE TEST

A direct application of a pure tension force, free from eccentricity is difficult, and is further complicated by secondary stresses induced by the grips or by embedded studs. Because of these difficulties, it is preferable to measure the tensile strength of concrete by subjecting a plain concrete beam to flexure. This is in fact one of the two standard tension tests. The theoretical maximum tensile stress reached in the bottom fibre of the test beam is known as the modulus of rupture. The value of modulus of rupture depends on the dimensions of the beam and, above all, on the arrangement of loading. Two systems are used: a central point load, which gives a triangular bending moment; and symmetrical two-point loading, which produces a constant bending moment between the load points. Since concrete consists of elements of varying strength, it is to be expected that two-point loading will yield a lower value of the modulus of rupture than when one point load is applied. The centre- point loading has been discontinued both in United Kingdom and the U. S.

Figure 4 Two point flexure test

BS 1881: Part 4: 1970 prescribes third-point loading on 150 by 150 by 750mm beams supported over a span of 600mm but when the maximum size of aggregate is not more than 25mm, 100 by 100 by 500mm beams with a span of 400 mm may be used.

There are four possible reasons why the modulus of rupture test yields a higher value of strength than a direct tensile test made on the same concrete. The first one is related to the assumption of the shape of the stress block. The second one is that accidental eccentricity in a direct tensile test results in a lower apparent strength of the concrete. The third is offered by an argument similar to that justifying the influence of the loading arrangement on the value of the modulus of rupture. Fourthly, in the flexure test, the maximum fibre stress reached may be higher than direct tension because the propagation of a crack is blocked by less stressed material nearer to the neutral axis. Thus the energy available is below that necessary for the formation of new crack surfaces.

The requirement for ASTM Standard C 78 - 75 are similar to those of BS 1881: part 4: 1970. If fracture occurs within the central one-third of the beam the modulus of rupture is calculated on the basis of ordinary elastic theory, and is therefore equal to $PL / (bd^2)$.

Where P = the maximum total load on the beam

L = span

b = width of the beam

d = depth of the beam.

If however fracture occurs outside the load points, e. g. at a distance a from the near support, a being measured along the centre line of the tension surface of the beam, then the modulus of rupture is given by $3pL/(bd^2)$. This means that the maximum stress at the critical section, and not the maximum stress on the beam, is considered in the calculations.

2. 3. 2. CYLINDER SPLITTING TEST

The splitting tensile test is used worldwide to measure the tensile strength of concrete. In splitting test a cylindrical or prismatic specimen is compressed along two diametrically opposed generators as shown in the in Figure 5 to prevent multiple cracking and crushing at the points of loading, the load is distributed through two bearing strips whose width differs in the various standards. If the material behaviour is linear-elastic, this geometry leads to nearly uniform tensile stress along the plane of loading, and the expected rupture mode is the splitting of the specimen in two halves across that plane. In the case of concentrated loads, the maximum tensile stress on this plane can be calculated by

$$\sigma_{f \max} =$$

Where $\sigma_{f \max}$ is the maximum tensile stress in the specimen when the applied load is P , D and B are the specimen depth and thickness respectively.

Figure 5 Specimen positioned in a testing machine for determination of splitting tensile strength.

Following the standards the maximum tensile stress at failure is a material property called splitting tensile strength. If the load-bearing strips are narrow enough to consider the loading concentrated, and the material behaviour is linearly-elastic -brittle is close to the tensile strength determined by ideal uniaxial tensile test. The tensile strength is evaluated in the standards by

$f_{st} =$

Where P_u is the maximum load recorded during the test. The splitting tensile strength is then calculated on the assumption of a hypothetical load bearing strip of zero width.

One of the main advantages of the splitting test is that only external compressive loads are required. A cylindrical or prismatic specimen is compressed along two diametrically opposed generators so that a neatly uniform tensile stress is induced in the loading plane. To avoid local failure in compression at the loading generators, two thin strips, usually made of plywood, are placed between the loading platens and the specimen to distribute the load. The specimen fails by splitting because of the induced tensile stress state. The maximum value of the tensile stress, computed at failure from the theory of elasticity, is the splitting tensile strength, ordinarily assumed in the standards to be a material property.

The splitting test is simple to perform and gives more uniform results than other tension tests. The strength determined in the splitting test is believed to be closer to the true tensile strength of concrete than the modulus of rupture the splitting strength is 5 to 12 percent higher than the direct tensile strength. It has been suggested, however, that in the case of mortar and

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lightweight aggregate concrete, the splitting test yields too low a result. With normal aggregate, the presence of large particles near the surface to which the load is applied may influence the behaviour. According to Minders et al, 2003 as the age and strength increase the ratio of tensile to compressive strength decreases (figure). Probably due to the effect of drying shrinkage cracks air curing when compared with moist curing reduces the tensile strength more than the compressive strength.