Characteristic strength of concrete- Formula, Uses, and calculation

What is characteristic strength of concrete?

The characteristic strength of concrete is the definite theoretical value of the material in which, when the material has actually tested the probability of getting higher results higher than that value is 95% or say the probability of getting the result lower than that value 5 %.

Thus, the characteristic strength is the value of design material along with consideration of its probable variability.

In the field of engineering, the actual value in a site or field can be very different from theoretical or designed value due to many reasons. No two-designed material may have the same characteristics and property although they have been made with the same specification and condition.

Lab Test of Concrete
Thus, it has adopted the probability and statistics approach method, in which some definite results of certain numbers of experiments collected, recorded as data, and analyzed. Based on it, the next probable numerical value of the other samples are predicted along with some risk factors or uncertainty percentage.

The characteristic strength formula is simply given as;

Characteristic strength = mean strength of samples – 1.64* standard deviation value of such sample's strength

This equation of the characteristic strength is derived from normal distribution curve of probability and statistical approach, which is formed by numerous samples made under same condition along with the same specification.

Characteristic strength of concrete formula

The strength of concrete generally represents the compressive strength of concrete, as concrete has maximum compressive strength and is its unique feature.

Therefore, in concrete the characteristic strength of concrete literally means Characteristic compressive strength unlike in other materials like steel or wood, etc. so most of the design of the concrete structure is done by adopting the value of compressive strength.

And also compressive strength is well used to relate much property of concrete such as elasticity modulus, water tightness, porosity, wear resistance, fire resistance, etc. the tensile strength of concrete is usually 10 percent of the compressive strength, as concrete is very weak in tension.

In addition, the characteristic strength of concrete formula is given by

$$f_{ct} = 0.35 * \sqrt{f_{ck}}$$

So, whenever we say characteristic of concrete, it means the probable range of concrete compressive strength along with percentage of certainty.

The concrete is generally graded along with its characteristic compressive strength value. For example, concrete of grade M15, concrete of grade M20, concrete of grade M 25 etc. Here represents mix and the numerals represent the characteristic compressive strength of the concrete. The design of concrete and structure is carried out on basis of reference of these values.

How to calculate characteristic strength of concrete

The number of similar sample test specimens, which is formed of a certain designed proportion of aggregates under similar environmental conditions, are made. The condition is managed to attain similar to the field condition as much as possible.

The general specimens sample is of dimension is 150mmX150mmX150mm cube and sometimes 150 mm diameter along with a height 300 mm cylinder. Then the samples are well cured and then tested for the determination of the compressive strength.

The test is normally carried out after 28 days. Here, the test literally means the compressive strength test performed under UTM.

The results of all testing will be collected as statistical data and then will be represented by a histogram in which, the

number of specimens falling indefinite interval of strength made as to the frequency on the Y-axis and the value of the strength of concrete on the x-axis are represented.

The standard deviation for the such discrete data can be given by;

$$s = \left[\frac{\sum_i^n (fi - fm)^2}{n-1}\right]^{1/2}$$

Or,

$$s = \left[\frac{n\sum_i^n fi^2 - (\sum_i^n fm)^2}{n(n-1)}\right]$$

Where f_i=strength of i th specimen,

n= number of speciemen

fm is mean strength of samples

Thus if the given discrete data is successfully converted to continuous series by the help of the differential calculus then such histogram can be trace into the fine (dashed) curve which gives the bell-shaped as shown in fig 1. In addition, this bell-shaped curve is known as the Normally distribution curve or Gaussian distribution curve.

The curve has a peak of frequency at the middle representing the tested sample has an average strength of the respective value at the curve will be nearly symmetrical. And dome shape or slope of the curve will represent the variation in the strength of other samples.

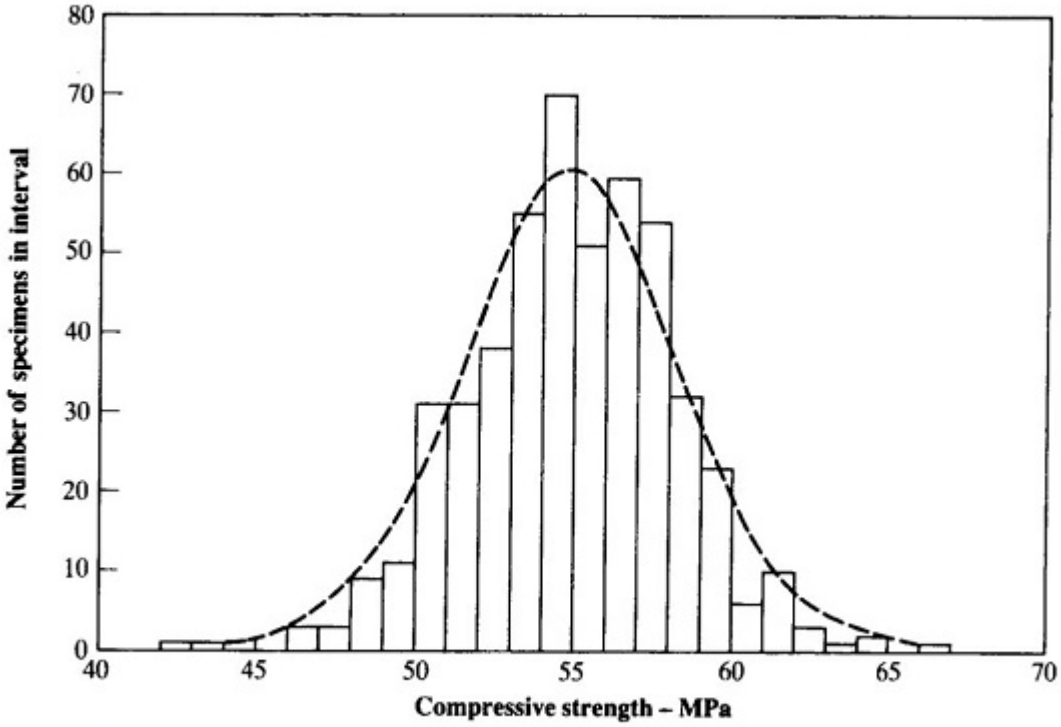

fig 1 A histogram of strength values

Thus, the curve now can be completely analogs with the theoretical normal distribution curve as shown in figure 2. and from the approach of probability and statistics and engineering knowledge we can generalize the formula for characteristic strength determination.

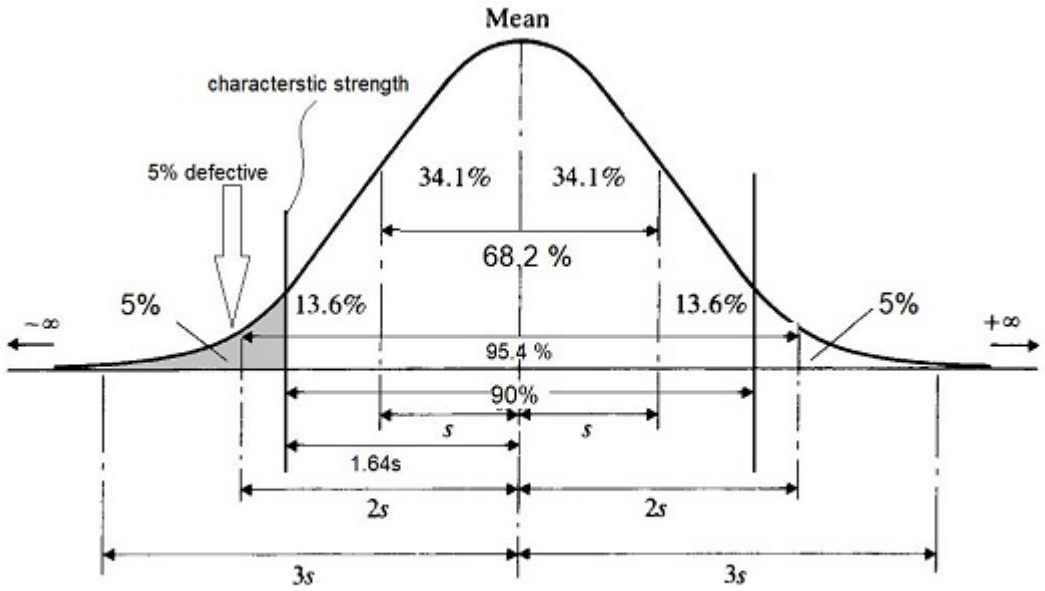

fig 2 : Normal distribution curve; percentage of specimens in intervals of one standard deviation shown

The extremely less frequency with the very less or very high

strengths can be neglected in a practical approach. By analysis of the graph (fig 2), the probable value of any sample can be determined. For example; the value of the strength of the new sample might lie between f_m-2s and f_m+2s,

Giving maximum value of compressive strength (f_{max}) = f_m+2s

And minimum probable value of compressive strength (f_{min})=f_m-2s,

if only 95.4 percent of middle area of graph is only significantly considered.

Similarly,

If only 68.2 percent of graph is significantly considered then,

Maximum probable value of compressive strength (f_{max}) = f_m+s

And minimum probable value of compressive strength (f_{min})=f_m –s

Thus we can generalize the maximum and minimum probable value for the material on the basis of how much area from graph is to be considered significantly which can be given by;

$f_{max}/f_{min} = f_m \pm k \cdot s$;

where, k =probability factor

The probability factor value for different area consideration is given as in fig 3.

Probability of strength values in the range $f_m \pm ks$ and below $f_m - ks$ for normal distribution

Probability factor k	Significant area consideration	Lower Percentile position of the area
1.00	68.2	15.9 (1 in 6)
1.64	90.0	5.0 (1 in 20) ⇒ requied position for the characterstic strength
1.96	95.0	2.5 (1 in 40)
2.33	98.0	1.0 (1 in 100)
3.00	99.7	0.15 (1 in 700)

fig 3: determination of value of k

As we know from the definition of characteristic strength, the characteristic strength is the marginal value below which only 5 percent of the total samples are considered to occur.

Thus, from the above curve, we will only consider 90 percent of the area (note that, 5 percent of area giving less than (fm-k·s) value and 5 percent of area giving more than (fm+k·s) value is needed to be removed from the total area of the curve as per general calculation formula) as significant and thus minimum value would be our characteristic value of the concrete. Which is given by

$f_{ck} = f_m - k \cdot s$; k =1.64

or $f_{ck} = f_m - 1.64 * s$

thus this way characteristic strength of concrete is determined.

Where characteristic strength are use?

The characteristic strength of the concrete is used as the

standard values in performing the designs of structure. As the design is always based upon, the assumption of the worst condition that may actually happen in the site, the characteristic strength of concrete represents the minimum value at the site condition that must be present.

For the Nominal mix method of concrete, the characteristic strength of concrete is fixed on the basis of standard ratio proportion of aggregates and cement as per IS code 465:2000 clause 9 and table 9, that are obtained after several tests conducted in making standard codes and specification.

For the Design mix method of concrete, the characteristic strength of concrete required in concrete are initially assumed as a constant, and the targeted strength of concrete is determined by using the converse formula of characteristic strength ;

i.e. $f_{targeted} = f_{ck} + 1.64 * s$

and the assumption of standard deviation value “s” is taken as

1.5 for M10 – M15

4 for M20 – M25

5 for M30 – M50

As per IS code 456:2000, clause 9.2.4.2 and table 11

And, the remaining design of concrete for targeted strength is designed on basis of code and specification explained by the DOE method, ACI method, and IS method.

What is Characteristic load in on structure?

The characteristic load is also defined as a certain value of the applied loads in structure in which the probability of

load being applied greater than that load, is only 5% (i.e. applying load less than that value is 95%).

Formula for Characteristic load

Characteristic load = Average load + 1.64 * standard deviation in load applied

The concept of the characteristic load is similar to the characteristic strength. It is also derived similar to characteristic strength, after the study of different kinds of load that had been applied in structure for a certain interval of time.

Again, I would like to repeat the fact that the design of the structure is made on basis of the worst condition that may cause real practice and field of the structure.

Therefore, for this, the characteristic load is taken as the maximum definite probable value that may apply with field along with risk percentage. The characteristic loads are assigned after the study of the loads that may be applied over the entire lifetime of the structure.

The load is generally dependent upon their types as live load, dead load, seismic load, wind load, etc.

Moreover, the characteristic load is also called working load or service load as they are directly used value for the design approach of the Working Stress method. In this approach, characteristic load are not altered and are not allowed to cross the limit of allowable stress in the material.

However, in the design approach of the Limit State Method, characteristic loads are multiplied with the factor of safety (greater than 1) in order to achieve the design load. On the basis of such a design load, the remaining design procedure are carried out.

I hope this article remains helpful for you.

Happy Learning – Civil Concept

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