



MAHARISHI MARKANDESHWAR UNIVERSITY (MULLANA)

Major Project Report

On

Variation in compressive strength of  
reinforced concrete blocks

In Partial Fulfillment for the award of  
degree of  
B.Tech (Civil)

Under The Guidance of  
Er. Deepak Kumar  
Civil Engineering Department  
MMEC

**Submitted by**  
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# **CERTIFICATE**

This is to certify that the work recorded in this project entitled “**Variation in compressive strength of reinforced concrete blocks**” submitted for the Bachelor Degree of Civil Engineering of M.M.University, Ambala, is a faithful record of research work under guidance and supervision.

The assistance and help received during the course of investigation and source of literatures have been fully acknowledged.

## **Supervisor**

Er. Deepak kumar  
Associate professor,CivilEngg.dept  
M.M.University,  
Mullana-Ambala

## **Head**

Dr.VikasGarg  
Civil Engg.Dept.  
M.M.University,  
Mullana-Ambala

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Vivek sharma (11082627)

Vivek singh negi (11082626)

Gaurav kumar(11082649 )

Sachit sandhu (11082635)

Akshay kumar(11082647)

Devansh sharma (11082630)

Shobhit kalra (11082669)

Ritin goel(11082644)

# INTRODUCTION

**Concrete** is a composite construction material composed primarily of aggregate, cement and water. There are many formulations that have varied properties. The aggregate is generally a coarse gravel or crushed rocks such as limestone, or granite, along with a fine aggregate such as sand. The cement, commonly Portland cement, and other cementitious materials such as fly ash and slag cement, serve as a binder for the aggregate. Various chemical admixtures are also added to achieve varied properties. Water is then mixed with this dry composite which enables it to be shaped (typically poured) and then solidified and hardened into rock-hard strength through a chemical process known as hydration. The water reacts with the cement which bonds the other components together, eventually creating a robust stone-like material. Concrete has relatively high compressive strength, but much lower tensile strength. For this reason is usually reinforced with materials that are strong in tension (often steel). Concrete can be damaged by many processes, such as the freezing of trapped water.

Concrete is widely used for making architectural structures, foundations, brick/block walls, pavements, bridges/overpasses, motorways/roads, runways, parking structures, dams, pools/reservoirs, pipes, footings for gates, fences and poles and even boats. Famous concrete structures include the Burj Khalifa (world's tallest building), the Hoover Dam, supporting structures for the Panama Canal and the Roman Pantheon.

Concrete technology was known by the Ancient Romans and was widely used within the Roman Empire. After the Empire passed, use of concrete became scarce until the technology was re-pioneered in the mid-18th century.

The environmental impact of concrete is a combination of negative and positive effects; the manufacture of concrete certainly releases large quantities of carbon dioxide, but concrete structures can have a long service life. Furthermore, concrete has a high thermal mass and very low permeability, so it is suitable for energy efficient housing. Also, recycling when concrete structures are demolished, is increasingly common

## **Types of concrete**

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There are many types of concrete, designed to suit a variety of purposes coupled with a range of compositions, finish and performance characteristics.



**A highway paved with concrete.**



**Regular concrete paving blocks**



**Concrete in sidewalk stamped with contractor name and date it was laid**

## **Regular concrete**

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Regular concrete is the lay term describing concrete that is produced by following the mixing instructions that are commonly published on packets of cement, typically using sand or other common material as the aggregate, and often mixed in improvised containers. This concrete can be produced to yield a varying strength depending on the purpose, ranging from blinding to structural concrete respectively. Many types of pre-mixed concrete are available which include powdered cement mixed with an aggregate, needing only water.

Typically, a batch of concrete can be made by using 1 part Portland cement, 2 parts dry sand, 3 parts dry stone, 1/2 part water. The parts are in terms of weight – not volume. This would make 1-cubic-foot (0.028 m<sup>3</sup>) of concrete. The sand should be mortar or brick sand (washed and filtered if possible) and the stone should be washed if possible. Organic materials (leaves, twigs, etc.) should be removed from the sand and stone to ensure the highest strength.

## **High-strength concrete**

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High-strength concrete has a compressive strength generally greater than 6,000 pounds per square inch . High-strength concrete is made by lowering the water-cement (W/C) ratio to 0.35 or lower. Often silica fume is added to prevent the formation of free calcium hydroxide crystals in the cement matrix, which might reduce the strength at the cement-aggregate bond.

Low W/C ratios and the use of silica fume make concrete mixes significantly less workable, which is particularly likely to be a problem in high-strength concrete applications where dense rebar cages are likely to be used. To compensate for the reduced workability, superplasticizers are commonly added to high-strength mixtures. Aggregate must be selected carefully for high-strength mixes, as weaker aggregates may not be strong enough to resist the loads imposed on the concrete and cause failure to start in the aggregate rather than in the matrix or at a void, as normally occurs in regular concrete.

In some applications of high-strength concrete the design criterion is the elastic modulus rather than the ultimate compressive strength.

## **Stamped concrete**

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Stamped concrete is an architectural concrete which has a superior surface finish. After a concrete floor has been laid, floor hardeners (can be pigmented) are impregnated on the surface and a mold which may be textured to replicate a stone / brick or even wood is stamped on to give an attractive textured surface finish. After sufficient hardening the surface is cleaned and generally sealed to give a protection. The wear resistance of stamped concrete is generally excellent and hence found in applications like parking lots, pavements, walkways etc.

## **High-performance concrete**

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High-performance concrete (HPC) is a relatively new term used to describe concrete that conforms to a set of standards above those of the most common applications, but not limited to strength. While all high-strength concrete is also high-performance, not all high-performance concrete is high-strength. Some examples of such standards currently used in relation to HPC are:

- Ease of placement
- Compaction without segregation
- Early age strength
- Long-term mechanical properties
- Permeability
- Density
- Heat of hydration
- Toughness
- Volume stability
- Long life in severe environments
- Depending on its implementation, environmental

## **Ultra-High-performance concrete**

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Ultra-High-performance concrete is a new type of concrete that is being developed by agencies concerned with infrastructure protection. UHPC is characterized by being a steel fibre-reinforced cement composite material with compressive strengths in excess of 150 MPa, up to and possibly exceeding 250 MPa. UHPC is also characterized by its constituent material make-up: typically

fine-grained sand, silica fume, small steel fibers, and special blends of high-strength Portland cement. Note that there is no large aggregate. The current types in production (Ductal, Taktl, etc.) differ from normal concrete in compression by their strain hardening, followed by sudden brittle failure. Ongoing research into UHPC failure via tensile and shear failure is being conducted by multiple government agencies and universities around the world.

### **Self-consolidating concretes**

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After identifying the defects in concrete in Japan were mainly due to a) high water cement ratio to increase workability, b) poor compaction mostly happened due to the need of speedy construction in 1960s-70s, Professor Hajime Okamura envisioned the need of a concrete that is highly workable and does not rely on the mechanical force for compaction. During the 1980s, Professor Okamura and his PhD student Kazamasa Ozawa (currently professor) at the University of Tokyo, Japan developed a concrete called Self Compacting Concrete (SCC) that was cohesive but flowable and took the shape of the formwork without use of any mechanical compaction. SCC is known as self-consolidating concrete in the United States. SCC is characterized by:

- extreme fluidity as measured by *flow*, typically between 650–750 mm on a flow table, rather than slump(height)
- no need for vibrators to compact the concrete
- placement being easier.
- no bleed water, or aggregate segregation
- Increased Liquid Head Pressure, Can be detrimental to Safety and workmanship

SCC can save up to 50% in labor costs due to 80% faster pouring and reduced wear and tear on formwork.

As of 2005, self-consolidating concretes account for 10-15% of concrete sales in some European countries. In the US precast concrete industry, SCC represents over 75% of concrete production. 38 departments of transportation in the US accept the use of SCC for road and bridge projects.

This emerging technology is made possible by the use of polycarboxylates plasticizer instead of older naphthalene based polymers, and viscosity modifiers to address aggregate segregation.



## **Vacuum concretes**

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The use of steam to produce a vacuum inside of concrete mixing truck to release air bubbles inside the concrete is being researched. The idea is that the steam displaces the air normally over the concrete. When the steam condenses into water it will create a low pressure over the concrete that will pull air from the concrete. This will make the concrete stronger due to there being less air in the mixture. Obviously this needs to be done in a sealed container.

## **Shotcrete**

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Shotcrete (also known by the trade name Gunitite) uses compressed air to shoot concrete onto (or into) a frame or structure. The greatest advantage of the process is that shotcrete can be applied overhead or on vertical surfaces without forming. It is often used for concrete repairs or placement on bridges, dams, pools, and on other applications where forming is costly or material handling and installation is difficult. Shotcrete is frequently used against vertical soil or rock surfaces, as it eliminates the need for formwork. It is sometimes used for rock support, especially in tunneling. Shotcrete is also used for applications where seepage is an issue to limit the amount of water entering a construction site due to a high water table or other subterranean sources. This type of concrete is often used as a quick fix for weathering for loose soil types in construction zones.

There are two application methods for shotcrete.

- dry-mix – the dry mixture of cement and aggregates is filled into the machine and conveyed with compressed air through the hoses. The water needed for the hydration is added at the nozzle.
- wet-mix – the mixes are prepared with all necessary water for hydration. The mixes are pumped through the hoses. At the nozzle compressed air is added for spraying.

For both methods additives such as accelerators and fiber reinforcement may be used.

## **Pervious concrete**

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Pervious concrete contains a network of holes or voids, to allow air or water to move through the concrete.

This allows water to drain naturally through it, and can both remove the normal surface-water drainage infrastructure, and allow replenishment of groundwater when conventional concrete does not.

It is formed by leaving out some or all of the fine aggregate (fines). The remaining large aggregate then is bound by a relatively small amount of Portland cement. When set, typically between 15 % and 25 % of the concrete volume is voids, allowing water to drain at around 5 gal/ft<sup>2</sup>/ min (70 L/m<sup>2</sup>/min) through the concrete.

### **Roller-compacted concrete**

Roller-compacted concrete, sometimes called rollcrete, is a low-cement-content stiff concrete placed using techniques borrowed from earthmoving and paving work. The concrete is placed on the surface to be covered, and is compacted in place using large heavy rollers typically used in earthwork. The concrete mix achieves a high density and cures over time into a strong monolithic block. Roller-compacted concrete is typically used for concrete pavement, but has also been used to build concrete dams, as the low cement content causes less heat to be generated while curing than typical for conventionally placed massive concrete pours.

### **Glass concrete**

The use of recycled glass as aggregate in concrete has become popular in modern times, with large scale research being carried out at Columbia University in New York. This greatly enhances the aesthetic appeal of the concrete. Recent research findings have shown that concrete made with recycled glass aggregates have shown better long term strength and better thermal insulation due to its better thermal properties of the glass aggregates.

### **Asphalt concrete**

Strictly speaking, asphalt is a form of concrete as well, with bituminous materials replacing cement as the binder.

### **Rapid strength concrete**

This type of concrete is able to develop high resistance within few hours after being manufactured. This feature has advantages such as removing the formwork early and to move forward in the building process at record time, repair road surfaces that become fully operational in just a few hours.

### **Polymer concrete**

Polymer concrete is concrete which uses polymers to bind the aggregate. Polymer concrete can gain a lot of strength in a short amount of time. For example, a polymer mix may reach 5000 psi in only four hours. Polymer concrete is generally more expensive than conventional concretes.

### **Geopolymer or green concrete**

Geopolymer concrete is a greener alternative to ordinary Portland cement made from inorganic aluminosilicate (Al-Si) polymer compounds that can utilise 100% recycled industrial waste (e.g. fly ash and slag) as the manufacturing inputs resulting in up to 80% lower carbon dioxide emissions. Greater chemical and thermal resistance, and better mechanical properties, are said to be achieved by the manufacturer at both atmospheric and extreme conditions.

Similar concretes have not only been used in Ancient Rome (see Roman concrete) as mentioned but also in the former Soviet Union in the 1950s and 1960s. Buildings in Ukraine are still standing after 45 years so that this kind of formulation has a sound track record.

### **Refractory Cement**

High-temperature applications, such as masonry ovens and the like, generally require the use of a refractory cement; concretes based on Portland cement can be damaged or destroyed by elevated temperatures, but refractory concretes are better able to withstand such conditions. Materials may include calcium aluminate cements, fire clay, ganister and minerals high in aluminum.

### **Gypsum concrete**

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Gypsum concrete is a building material used as a floor underlayment used in wood-frame and concrete construction for fire ratings, sound reduction, radiant heating, and floor leveling. It is a mixture of gypsum, Portland cement, and sand.

## Reinforced concrete

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Reinforced concrete is concrete in which the undesirably low tensile strength and elasticity of the concrete component are averted by including reinforcing structures of high tensile strength in the mass of the concrete. Such structures usually are reinforcing bars of steel (rebar) and also usually, are embedded passively in the concrete before it sets. Such reinforcing structures are designed to take up working stresses that otherwise would have placed the concrete mass under unacceptable tension. Modern concrete reinforcing structures however, may contain non-steel materials with high tensile strength, and also may be permanently stressed before or after the mass sets, so as to improve the behaviour of the final structure under working loads.

For a strong, ductile and durable construction the reinforcement needs to have the following properties:

- High strength
- High tensile strain
- Good bond to the concrete
- Thermal compatibility
- Durability in the concrete environment

In most cases reinforced concrete uses steel rebars that have been inserted to add strength.

### Use in construction



Concrete is reinforced to give it extra tensile strength; without reinforcement, many concrete buildings would not have been possible.

Reinforced concrete can encompass many types of structures and components, including slabs, walls, beams, columns, foundations, frames and more.

Reinforced concrete can be classified as precast or cast in-situ concrete.

Designing and implementing the most efficient floor system is key to creating optimal building structures. Small changes in the design of a floor system can have significant impact on material costs, construction schedule, ultimate strength, operating costs, occupancy levels and end use of a building.

### **Behaviour of reinforced concrete**

Concrete is a mixture of coarse (stone or brick chips) and fine (generally sand or crushed stone) aggregates with a binder material (usually Portland cement). When mixed with a small amount of water, the cement hydrates to form microscopic opaque crystal lattices encapsulating and locking the aggregate into a rigid structure. Typical concrete mixes have high resistance to compressive stresses however, any appreciable tension (e.g., due to bending) will break the microscopic rigid lattice, resulting in cracking and separation of the concrete. For this reason, typical non-reinforced concrete must be well supported to prevent the development of tension.

If a material with high strength in tension, such as steel, is placed in concrete, then the composite material, reinforced concrete, resists not only compression but also bending and other direct tensile actions. A reinforced concrete section where the concrete resists the compression and steel resists the tension can be made into almost any shape and size for the construction industry.

### **Characteristics**

Three physical characteristics give reinforced concrete its special properties.

First, the coefficient of thermal expansion of concrete is similar to that of steel, eliminating large internal stresses due to differences in thermal expansion or contraction.

Second, when the cement paste within the concrete hardens this conforms to the surface details of the steel, permitting any stress to be transmitted efficiently

between the different materials. Usually steel bars are roughened or corrugated to further improve the bond or cohesion between the concrete and steel.

Third, the alkaline chemical environment provided by the alkali reserve (KOH, NaOH) and the portlandite (calcium hydroxide) contained in the hardened cement paste causes a passivating film to form on the surface of the steel, making it much more resistant to corrosion than it would be in neutral or acidic conditions. When the cement paste exposed to the air and meteoric water reacts with the atmospheric CO<sub>2</sub>, portlandite and the Calcium Silicate Hydrate (CSH) of the hardened cement paste become progressively carbonated and the high pH gradually decreases from 13.5 – 12.5 to 8.5, the pH of water in equilibrium with calcite (calcium carbonate) and the steel is no longer passivated.

As a rule of thumb, only to give an idea on orders of magnitude, steel is protected at pH above ~11 but starts to corrode below ~10 depending on steel characteristics and local physico-chemical conditions when concrete becomes carbonated. Carbonation of concrete along with chloride ingress are amongst the chief reasons for the failure of reinforcement bars in concrete.

The relative cross-sectional area of steel required for typical reinforced concrete is usually quite small and varies from 1% for most beams and slabs to 6% for some columns. Reinforcing bars are normally round in cross-section and vary in diameter. Reinforced concrete structures sometimes have provisions such as ventilated hollow cores to control their moisture & humidity.

Distribution of concrete (in spite of reinforcement) strength characteristics along the cross-section of vertical reinforced concrete elements is inhomogeneous.

### **Mechanism of composite action of reinforcement and concrete**

The reinforcement in a RC structure, such as a steel bar, has to undergo the same strain or deformation as the surrounding concrete in order to prevent discontinuity, slip or separation of the two materials under load. Maintaining composite action requires transfer of load between the concrete and steel. The direct stress is transferred from the concrete to the bar interface so as to change the tensile stress in the reinforcing bar along its length. This load transfer is achieved by means of bond (anchorage) and is idealized as a continuous stress field that develops in the vicinity of the steel-concrete interface.

## **Anchorage (bond) in concrete**

Because the actual bond stress varies along the length of a bar anchored in a zone of tension, current international codes of specifications use the concept of development length rather than bond stress. The main requirement for safety against bond failure is to provide a sufficient extension of the length of the bar beyond the point where the steel is required to develop its yield stress and this length must be at least equal to its development length. However, if the actual available length is inadequate for full development, special anchorages must be provided, such as cogs or hooks or mechanical end plates. The same concept applies to lap splice length mentioned in the codes where splices (overlapping) provided between two adjacent bars in order to maintain the required continuity of stress in the splice zone.

## **Anti-corrosion measures**

In wet and cold climates, reinforced concrete for roads, bridges, parking structures and other structures that may be exposed to deicing salt may benefit from use of epoxy-coated, hot dip galvanised or stainless steel rebar, although good design and a well-chosen cement mix may provide sufficient protection for many applications. Epoxy coated rebar can easily be identified by the light green colour of its epoxy coating. Hot dip galvanized rebar may be bright or dull grey depending on length of exposure, and stainless rebar exhibits a typical white metallic sheen that is readily distinguishable from carbon steel reinforcing bar.

Another, cheaper way of protecting rebars is coating them with zinc phosphate. Zinc phosphate slowly reacts with calcium cations and the hydroxyl anions present in the cement pore water and forms a stable hydroxyapatite layer.

Penetrating sealants typically must be applied some time after curing. Sealants include paint, plastic foams, films and aluminum foil, felts or fabric mats sealed with tar, and layers of bentonite clay, sometimes used to seal roadbeds.

Corrosion inhibitors, such as calcium nitrite [ $\text{Ca}(\text{NO}_2)_2$ ], can also be added to the water mix before pouring concrete. Generally, 1–2 wt. % of [ $\text{Ca}(\text{NO}_2)_2$ ] with respect to cement weight is needed to prevent corrosion of the rebars. The nitrite anion is a mild oxidizer that oxidizes the soluble and mobile ferrous ions ( $\text{Fe}^{2+}$ ) present at the surface of the corroding steel and causes it to precipitate as an insoluble ferric hydroxide ( $\text{Fe}(\text{OH})_3$ ). This causes the

passivation of steel at the anodic oxidation sites. Nitrite is a much more active corrosion inhibitor than nitrate, a less powerful oxidizer of the divalent iron.

## **Common failure modes of reinforced concrete**

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Reinforced concrete can fail due to inadequate strength, leading to mechanical failure, or due to a reduction in its durability. Corrosion and freeze/thaw cycles may damage poorly designed or constructed reinforced concrete. When rebar corrodes, the oxidation products (rust) expand and tends to flake, cracking the concrete and unbonding the rebar from the concrete. Typical mechanisms leading to durability problems are discussed below.

### **Mechanical failure**

Cracking of the concrete section can not be prevented; however, the size of and location of the cracks can be limited and controlled by reinforcement, placement of control joints, the curing methodology and the mix design of the concrete. Cracking defects can allow moisture to penetrate and corrode the reinforcement. This is a serviceability failure in limit state design. Cracking is normally the result of an inadequate quantity of rebar, or rebar spaced at too great a distance. The concrete then cracks either under excess loading, or due to internal effects such as early thermal shrinkage when it cures.

Ultimate failure leading to collapse can be caused by crushing of the concrete, when compressive stresses exceed its strength; by yielding or failure of the rebar, when bending or shear stresses exceed the strength of the reinforcement; or by bond failure between the concrete and the rebar.

### **Carbonation**

Carbonation, or neutralisation, is a chemical reaction between carbon dioxide in the air with calcium hydroxide and hydrated calcium silicate in the concrete.

When designing a concrete structure, it is normal to state the concrete cover for the rebar (the depth within the object that the rebar will be). The minimum concrete cover is normally regulated by design or building codes. If the reinforcement is too close to the surface, early failure due to corrosion may occur. The concrete cover depth can be measured with a cover meter. However, carbonated concrete only becomes a durability problem when there is also sufficient moisture and oxygen to cause electro-potential corrosion of the reinforcing steel.



One method of testing a structure for carbonation is to drill a fresh hole in the surface and then treat the cut surface with phenolphthalein indicator solution. This solution will turn [pink] when in contact with alkaline concrete, making it possible to see the depth of carbonation. An existing hole is no good because the exposed surface will already be carbonated.



Concrete wall cracking as steel reinforcing corrodes and swells. The rust formed as the iron corrodes has a lower density than the metal, so it expands as it forms, cracking the decorative cladding off the wall, as well as damaging the structural concrete. The breakage of material from the surface is called spalling.



**Detailed view of spalling.**

The apparently thin layer of concrete between the steel and the surface suggests that the design fell foul of carbonatation, or similar problems of corrosion from external exposure

## **Non-steel reinforcement**

There is considerable overlap between the subjects of non-steel reinforcement and fiber-reinforcement of concrete. The introduction of non-steel reinforcement of concrete is relatively recent; it takes two major forms: non-metallic rebar rods, and non-steel (usually also non-metallic) fibers incorporated into the cement matrix. For example there is increasing interest in glass fiber reinforced concrete (GFRC) and in various applications of polymer fibers incorporated into concrete. Although currently there is not much suggestion that such materials will in general replace metal rebar, some of them have major advantages in specific applications, and there also are new applications in which metal rebar simply is not an option. However, the design and application of non-steel reinforcing is fraught with challenges; for one thing, concrete is a highly alkaline environment, in which many materials, including most kinds of glass, have a poor service life.

In particular FRP rods are useful for structures where the presence of steel would not be acceptable. For example, MRI machines have huge magnets, and accordingly require non-magnetic buildings. Again, toll booths that read radio tags need reinforced concrete that is transparent to radio. Also, where the design life of the concrete structure is more important than its initial costs, non-steel reinforcing often has its advantages where corrosion of reinforcing steel is a major cause of failure. In such situations corrosion-proof reinforcing can extend a structure's life substantially.

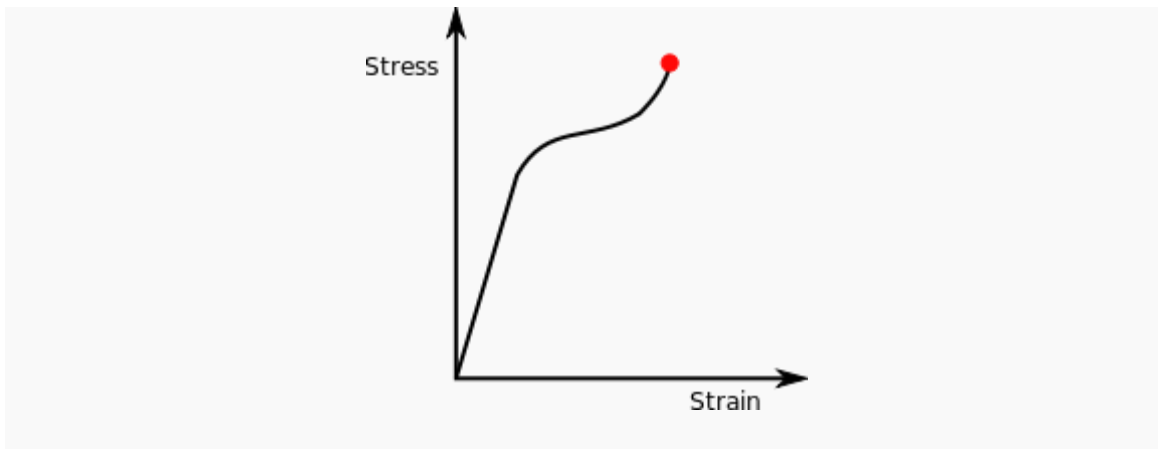
The material properties of FRP or GRP bars differ markedly from steel, so there are differences in the design considerations. FRP or GRP bars have relatively higher tensile strength but lower stiffness, so that Deflections are likely to be higher than for equivalent steel-reinforced units. Structures with internal FRP reinforcement typically have an elastic deformability comparable to the plastic deformability (ductility) of steel reinforced structures. Failure in either case is more likely to occur by compression of the concrete than by rupture of the reinforcement. Deflection is always a major design consideration for reinforced concrete. Deflection limits are set to ensure that crack widths in steel-reinforced concrete are controlled to prevent water, air or other aggressive substances reaching the steel and causing corrosion.

One drawback to the use of FRP reinforcement is the limited fire resistance. Where fire safety is a consideration, structures employing FRP have to maintain their strength and the anchoring of the forces at temperatures to be expected in the event of fire. For purposes of fireproofing an adequate thickness of cement concrete cover or protective cladding is necessary. The disadvantages are not on the side of the FRP however, addition of  $1 \text{ kg/m}^3$  of polypropylene fibers to concrete has been shown to reduce spalling during a simulated fire.

## Compressive Strength

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By definition, the compressive strength of a material is that value of uniaxial compressive stress reached when the material fails completely. The compressive strength is usually obtained experimentally by means of a **compressive test**. The apparatus used for this experiment is the same as that used in a tensile test. However, rather than applying a uniaxial tensile load, a uniaxial compressive load is applied. As can be imagined, the specimen (usually cylindrical) is shortened as well as spread laterally. A Stress–strain curve is plotted by the instrument and would look similar to the following:



The compressive strength of the material would correspond to the stress at the red point shown on the curve. Even in a compression test, there is a linear region where the material follows Hooke's Law. Hence for this region  $\sigma = E\epsilon$  where this time E refers to the Young's Modulus for compression.

This linear region terminates at what is known as the yield point. Above this point the material behaves plastically and will not return to its original length once the load is removed.

## Compression

When a specimen of material is loaded in such a way that it extends it is said to be in **tension**. On the other hand if the material compresses and shortens it is said to be in **compression**.

On an atomic level, the molecules or atoms are forced apart when in tension whereas in compression they are forced together. Since atoms in solids always try to find an equilibrium position, and distance between other atoms, forces arise throughout the entire material which oppose both tension or compression.

The phenomena prevailing on an atomic level are therefore similar. On a macroscopic scale, these aspects are also reflected in the fact that the properties of most common materials in tension and compression are quite similar.

The major difference between the two types of loading is the strain which would have opposite signs for tension (positive—it gets longer) and compression (negative—it gets shorter).

Another major difference is tension tends to pull small sideways deflections back into alignment, while compression tends to amplify such deflection into buckling.

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## Various tests used to determine the compressive strength of reinforced concrete

### 1) Cube Test



compacting of concrete cubes

This is the conventional method of testing the compressive strength of concrete. This can be described as a “destructive” method of testing as casted concrete cubes are crushed to determine the compressive strength.



In this testing procedure concrete cubes are casted in a standard way such that they represent the batches of concrete used for concreting. The cubes are of the size 150x150x150mm and each cube is casted in three layers with specified compaction to each layer. Cubes are properly cured and crushed at the ages of 7, 28 etc. Three cubes are crushed at a time and their mean crushing strength is taken as the compressive strength of concrete.

## 2) Impact Hammer Test



This is a test specially designed for non-destructive testing of concrete structures. Using this test large areas can be tested for compressive strength

consuming less time and money. Possibility of determination of concrete quality between different sections is also an advantage of this test.

The testing is done by pressing a impact plunger against a solid surface of concrete. The maximum height of rebound is recorded and a rebound number is obtained according to the scale of Impact Hammer. This rebound number can then be converted in to compressive strength via conversion tables provided with the equipment. These conversion values vary with the angle of testing and therefore angular corrections should be applied when necessary.

### 3) Ultrasonic test



**Ultrasonic Test**

Ultrasonic test for concrete is a field test for quality control and inspection of concrete structures. It uses measurement of the speed of ultrasonic pulses through the concrete to correlate concrete strength to standard strength. Using this test we can identify non-homogeneous conditions in the structure such as honeycombs, voids, cracks and frozen concrete.

First the instrument is calibrated using a standard calibration bar and the receiving and the transmitting ends are coated with a thin uniform grease layer. The concrete surface is cleaned well to make it dust free and uniformly distributed grease layer is applied on the concrete surface as well. The transmitting and receiving ends of the apparatus is then placed on marked locations of the structure and the machine is turned on to get the reading.

## **Following procedure was used for testing the Compressive strength of reinforced Concrete Cubes**

### **APPARATUS**

Compression testing machine

### **PREPARATION OF CUBE SPECIMENS**

The proportion and material for making these test specimens are from the same concrete used in the field.

### **SPECIMEN**

6 cubes of 15 cm size Mix. M15 or above

### **MIXING**

Mix the concrete either by hand or in a laboratory batch mixer

#### **HAND MIXING**

(i) Mix the cement and fine aggregate on a water tight none-absorbent platform until the mixture is thoroughly blended and is of uniform color

(ii) Add the coarse aggregate and mix with cement and fine aggregate until the coarse aggregate is uniformly distributed throughout the batch.

(iii) Add steel and iron bars respectively to the varied specimens during the formation of concrete blocks.

(iv) Add water and mix it until the concrete appears to be homogeneous and of the desired consistency

### **SAMPLING**

(i) Clean the moulds and apply oil

(ii) Fill the concrete in the moulds in layers approximately 5cm thick

(iii) Compact each layer with not less than 35 strokes per layer using a tamping rod (steel bar 16mm diameter and 60cm long, bullet pointed at lower end)

(iv) Level the top surface and smoothen it with a trowel

### **CURING**

The test specimens are stored in moist air for 24 hours and after this period the specimens are marked and removed from the molds and kept submerged in clear fresh water until taken out prior to test.

### **PRECAUTIONS**

The water for curing should be tested every 7 days and the temperature of water must be at  $27 \pm 2^\circ\text{C}$ .

### **PROCEDURE**

(I) Remove the specimen from water after specified curing time and wipe out excess water from the surface.

(II) Take the dimension of the specimen to the nearest 0.2mm

(III) Clean the bearing surface of the testing machine

(IV) Place the specimen in the machine in such a manner that the load shall be applied to the opposite sides of the cube cast.

(V) Align the specimen centrally on the base plate of the machine.

(VI) Rotate the movable portion gently by hand so that it touches the top surface of the specimen.

(VII) Apply the load gradually without shock and continuously at the rate of  $140\text{kg}/\text{cm}^2/\text{minute}$  till the specimen fails

(VIII) Record the maximum load and note any unusual features in the type of failure.



## NOTE

Minimum three specimens should be tested at each selected age. If strength of any specimen varies by more than 15 per cent of average strength, results of such specimen should be rejected. Average of these specimens gives the crushing strength of concrete. The strength requirements of concrete.

## REPORT

- a) Identification mark
- b) Date of test
- c) Age of specimen
- d) Curing conditions, including date of manufacture of specimen
- f) Appearance of fractured faces of concrete and the type of fracture if they are unusual.

### Percentage strength of concrete at various ages:

The strength of concrete increases with age. Table shows the strength of concrete at different ages in comparison with the strength at 28 days after casting.

Age	Strength per cent
1 day	16%
3 days	40%
7 days	65%
14 days	90%
28 days	99%

## **CALCULATIONS**

Size of the cube =15cm x15cm x15cm

Area of the specimen (calculated from the mean size of the specimen )=225cm<sup>2</sup>

Characteristic compressive strength( $f_{ck}$ )at 7 days

Expected maximum load = $f_{ck} \times \text{area} \times f.s$

Similar calculation should be done for 14 day compressive strength

Compressive strength = (Load in N/ Area in mm<sup>2</sup>)

## **RESULTS**

### **Compressive strength of plain concrete block dated 21 feb using M20 concrete.**

- 1 .Mix the cement and fine aggregate thoroughly.
2. Add the coarse aggregate and mix with cement until it is uniformly distributed throughout the batch.
3. Add water and mix it until the concrete appears to be homogeneous and of desired consistency.
4. Fill the concrete in mould in layers and compact each layer by using a tamping rod.
5. Specimen was stored in moist air for 24 hrs. after which it was stored in clear fresh water.
6. Curing was done for 14 days.
- 7 . Compressive strength of concrete blocks for normal M20 at 14 days curing is

**16 N/ mm<sup>2</sup>.**

### **Compressive strength of concrete block having steel reinforcement (5%) dated 28 feb. using M20 concrete.**

- 1 .Mix the cement and fine aggregate thoroughly.
2. Add the coarse aggregate and mix with cement until it is uniformly distributed throughout the batch.
3. Add steel bars of 30mm length and 1mm in diameter and mix it thoroughly.
3. Add water and mix it until the concrete appears to be homogeneous and of desired consistency.

4. Fill the concrete in mould in layers and compact each layer by using a tamping rod.
5. Specimen was stored in moist air for 24 hrs. after which it was stored in clear fresh water.
6. Curing was done for 14 days.
7. Compressive strength of concrete blocks having steel bars with 5% reinforcement for normal M20 at 14 days curing is **18.6 N/ mm<sup>2</sup>**.

**Compressive strength of concrete block having iron reinforcement (5%) dated 6 march using M20 concrete.**

1. Mix the cement and fine aggregate thoroughly.
2. Add the coarse aggregate and mix with cement until it is uniformly distributed throughout the batch.
3. Add iron bars of 30mm length and 1mm in diameter and mix it thoroughly.
3. Add water and mix it until the concrete appears to be homogeneous and of desired consistency.
4. Fill the concrete in mould in layers and compact each layer by using a tamping rod.
5. Specimen was stored in moist air for 24 hrs. after which it was stored in clear fresh water.
6. Curing was done for 14 days.
7. Compressive strength of concrete blocks having iron bars with 5% reinforcement for normal M20 at 14 days curing is **18.4 N/ mm<sup>2</sup>**.

**Compressive strength of concrete block having both iron & steel reinforcement (5%) dated 16 march using M20 concrete.**

1. Mix the cement and fine aggregate thoroughly.
2. Add the coarse aggregate and mix with cement until it is uniformly distributed throughout the batch.
3. Add iron & steel bars of 30mm length and 1mm in diameter and mix it thoroughly.
3. Add water and mix it until the concrete appears to be homogeneous and of desired consistency.
4. Fill the concrete in mould in layers and compact each layer by using a tamping rod.
5. Specimen was stored in moist air for 24 hrs. after which it was stored in clear fresh water.
6. Curing was done for 14 days.
7. Compressive strength of concrete blocks having steel & iron bars with 5% reinforcement for normal M20 at 14 days curing is **19 N/ mm<sup>2</sup>**.

**Compressive strength of concrete block having steel reinforcement (3%) dated 20 march using M20 concrete.**

- 1 .Mix the cement and fine aggregate thoroughly.
2. Add the coarse aggregate and mix with cement until it is uniformly distributed throughout the batch.
3. Add steel bars of 30mm length and 1mm in diameter and mix it thoroughly.
3. Add water and mix it until the concrete appears to be homogeneous and of desired consistency.
4. Fill the concrete in mould in layers and compact each layer by using a tamping rod.
5. Specimen was stored in moist air for 24 hrs. after which it was stored in clear fresh water.
6. Curing was done for 14 days.
7. Compressive strength of concrete blocks having steel bars with 3% reinforcement for normal M20 at 14 days curing is **17.4 N/ mm<sup>2</sup>**.

**Compressive strength of concrete block having iron reinforcement (3%) dated 23 march using M20 concrete.**

- 1 .Mix the cement and fine aggregate thoroughly.
2. Add the coarse aggregate and mix with cement until it is uniformly distributed throughout the batch.
3. Add steel bars of 30mm length and 1mm in diameter and mix it thoroughly.
3. Add water and mix it until the concrete appears to be homogeneous and of desired consistency.
4. Fill the concrete in mould in layers and compact each layer by using a tamping rod.
5. Specimen was stored in moist air for 24 hrs. after which it was stored in clear fresh water.
6. Curing was done for 14 days.
7. Compressive strength of concrete blocks having iron bars with 3% reinforcement for normal M20 at 14 days curing is **17 N/ mm<sup>2</sup>**.

**Compressive strength of concrete block having both iron & steel reinforcement (3%) dated 23 march using M20 concrete.**

- 1 .Mix the cement and fine aggregate thoroughly.
2. Add the coarse aggregate and mix with cement until it is uniformly distributed throughout the batch.
3. Add iron & steel bars of 30mm length and 1mm in diameter and mix it thoroughly.
3. Add water and mix it until the concrete appears to be homogeneous and of desired consistency.
4. Fill the concrete in mould in layers and compact each layer by using a tamping rod.
5. Specimen was stored in moist air for 24 hrs. after which it was stored in clear fresh water.
6. Curing was done for 14 days.

7. Compressive strength of concrete blocks having steel & iron bars with 3% reinforcement for normal M20 at 14 days curing is **18.2 N/ mm<sup>2</sup>**.



**Iron and steel wires**



**Mixing of aggregate with steel bars.**



Preparation of mould





Checking of compressive strength concrete moulds having steel & iron reinforcement.

## Summary

**Reinforced concrete** is concrete in which the undesirably low tensile strength and elasticity of the concrete component are averted by including reinforcing structures of high tensile strength in the mass of the concrete. Such structures usually, though not necessarily, are reinforcing bars of steel (rebar) and also usually, though also not necessarily, are embedded passively in the concrete before it sets. Such reinforcing structures are designed to take up working stresses that otherwise would have placed the concrete mass under unacceptable tension. Modern concrete reinforcing structures however, may contain non-steel materials with high tensile strength, and also may be permanently stressed before or after the mass sets, so as to improve the behaviour of the final structure under working loads.

For Estimation of concrete strength in concrete structures becomes necessary when inspecting the compressive strength and retrofitting the existing structures. This study aims to provide a basic information necessary for estimating the concrete strength in reinforced concrete structures is more than 10788 cores were sampled from 1130 existing buildings and subjected to statistical analysis to estimate compressive strength of the existing structures. Effect of the design strength and the date of completion upon the compressive strength are also studied.

### **The major findings are as follows:-**

- (1) Average compressive strength increased and exhibited less chance to become low strength when the date of completion became younger.
- (2) Coefficient of variation of the compressive strengths was tabulated with the design strengths and the date of completion.
- (3) Significant number of existing buildings had very low concrete strength.



## References

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