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DURABILITY TEST (SULPHATE ATTACK) 0N LIGHT WEIGHT CONCRETE BY PARTIAL REPLACEMENT OF VERMICULITE FOR FINE AGGREGATE AND SILICA FUME FOR CEMENT

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ABSTRACT

Concrete is the most widely used building material. Due to large-scale construction being taken up a steady sand mining is taking place at an alarming rate. To overcome the problem Vermiculite aggregate is partially used as a replacement for fine aggregate.

The present study focuses on the preparation of M30 grade concrete by replacing fine aggregate with 0%,5%,10%,15%,20%,25% of vermiculite and cement with 0% and 10% of constant silica fume to improve the performance of concrete. In the present study, an attempt is made to study the effect on acid exposure on strength and weight of concrete through experimentation.

Concrete cubes of different mixes(12no.'s) will be prepared and exposed to Sulphuric acid of (pH=3). Cubes of size 100mm x 100mm x 100mm are cast with M30 grade of concrete, following which the cubes are immersed (cured) in water for 28 days. Next, the cubes are immersed in and sprayed with 4% concentrated Sulphuric acid for 7 days. The cured cubes are then tested under compressive testing machine to determine their compressive strength.

Also, this project investigates the effects of FOSROC CONPLAST SP430, a water reducing superplasticizer on compressive strength and weight of concrete.

CHAPTER I

INTRODUCTION

1.1introduction of light weight concrete

Over the past few decades, the increased use of lightweight concrete for the structural elements of tall or long-span buildings has become a more and more important aspect in the modern construction industry. Lightweight aggregate concrete (LWAC) is not a new material. For many years, traditional aggregates (sand, gravel, etc.) have been replaced in concrete mixes with lightweight natural or human-made materials, or by-products . However, despite many advantages, practical application of such concrete in real structures is limited due to its lower mechanical properties and increased brittleness compared to normal weight concrete (NWC) . On the other hand, a hardened mixture of the appropriate mechanical strength needs to be additionally tested to assess durability properties (freeze–thaw resistance , water absorption , etc.) in order to ensure the sufficient service life of structural members produced from this mixture . The strength of the concrete mixture depends on the properties of the applied aggregate and cement mortar matrix. The application of the small diameter LWA (0.5–4 mm) in lightweight concrete allows the improvement of the homogeneity Materials

Materials of concrete microstructures and the reduction of the possibility of segregation of the mixture . Fine LWA is generally preferred to the coarse LWA due to a smaller distance between the aggregates. As a result, the internal curing water is provided to a greater volume of the mortar matrix Mechanical properties of the mortar matrix are affected by the water-to-cement(w/c) ratio, the amount of cement used, and mortar porosity . The porosity of the matrix is usually reduced by adjusting the granulomere composition of the mixture and by introducing micro fillers. The most commonly used and most effective micro filler is silica fume, which can increase the compressive strength of concrete up to more than 140 MPa. Other micro flora , such as fly ash, limestone, siliceous microflora ,micronized phonolite ,met kaolin, glass powder, etc., may also be used for mixtures. The results achieved after many years of research in this field have shown that expanded clay is one of the most useful aggregates for the structural concrete Densityandcompressivestrengthsuchconcreteafter28daysofhardeningisusuallyinthe rangeof1290–2044kg/m3 and23–60MPa respectively. Recently, as an alternative, expanded glass made from recycled glass waste has been used for the production of concrete. Utilization of this type of aggregate in concrete as a main construction material is of primary importance for the sustainable development of the construction industry. However, it should be emphasized that the application of the expanded glass aggregate (EGA) in concrete is only at its initial stage. Initial studies in this field have shown that the density and compressive strength of concrete after 28 days of hardening can be in the range of 1280–1490 kg/m3 and23.3–30.2MPa, respectively. The great advantage of expanded glass aggregates the possibility to produce them in a much more varied fraction while maintaining a regular spherical shape. In the research reported by Yu et al up to five different fractions of EGA have been used in concrete mixtures. Four of them were up to 2 mm in size (a minimum fraction is 0.1–0.3 mm). Such a variety of particle sizes allows the selection of the optimal proportions of fine lightweight aggregate and ensures the homogenous microstructure of hardened concrete.

1.2 Introduction to vermiculite:

vermiculite

Vermiculite concrete is a low density non-structural construction product. It is insulating (both thermally and acoustically) and intrinsically fire resistant. It is normally made simply by mixing exfoliated vermiculite as the aggregate, with cement and water, plus additives such as plasticisers if required. The ratio of exfoliated vermiculite aggregate to cement and the vermiculite grade can be varied to the properties such as strength and insulation as required for the concrete. The applications for vermiculite concrete are however, all non-structural. Vermiculite concretes can also be produced containing other lightweight aggregates, such as expanded perlite, to give differing physical properties. Normally the type of cement used in these mixes is

Ordinary Portland Cement (O.P.C), although a higher initial strength may be obtained using Rapid Hardening Portland Cement (R.H.P.C). For high temperature refractory applications, high alumina (laminate in the USA) cements may be used with great success to manufacture lightweight in-situ cast insulation mixes and back up insulation products. However, these applications are beyond the scope of this specific application note.

1.3Silica fume in cement:

Sufficient quantity of silica helps for the formation of di-calcium and tri-calcium silicates which impart strength to the cement. Excess silica in cement will increase the strength of cement but at the same time setting time of cement also increases.

Silica fume, also known as micro silica, is an amorphous (non-crystalline) polymorph of silicon dioxide, silica. It is an ultrafine powder collected as a by-product of the silicon and ferrosilicon alloy production and consists of spherical particles with an average particle diameter of 150 nm. The main field of application is as pozzolanic material for high performance concrete.

It is sometimes confused with fumed silica (also known as pyrogenic silica, CAS number 112945-52-5). However, the production process, particle characteristics and fields of application of fumed silica are all different from those of silica fume.

The first testing of silica fume in Portland-cement-based concrete was carried out in 1952. The biggest drawback to exploring the properties of silica fume was a lack of material with which to experiment. Early research used an expensive additive called fumed silica, an amorphous form of silica made by combustion of silicon tetrachloride in a hydrogen-oxygen flame. Silica fume on the other hand, is a very fine pozzolanic, amorphous material, a by-product of the production of elemental silicon or ferrosilicon alloys in electric arc furnaces. Before the late 1960s in Europe and the mid-1970s in the United States, silica fumes were simply vented into the atmosphere.

With the implementation of tougher environmental laws during the mid-1970s, silicon smelters began to collect the silica fume and search for its applications. The early work done in Norway received most of the attention, since it had shown that Portland cement-based-concretes containing silica fumes had very high strengths and low porosities. Since then the research and development of silica fume made it one of the world's most valuable and versatile admixtures for concrete and cementations products.

Components of Cement: Comparison of Chemical and Physical Characteristic

Property		**Portland cement**	**Silicious fly ash**	**Calcareous fly ash**	**Slag cement**	**Silica fume**
Content (%)	**SiO_2**	21.9	52	35	35	85–97
	Al_2O_3	6.9	23	18	12	—
	Fe_2O_3	3	11	6	1	—
	CaO	63	5	21	40	< 1
	MgO	2.5	—	—	—	—
	SO_3	1.7	—	—	—	—
Specific surface[d] (m^2/kg)		370	420	420	400	15,000–30,000
Specific gravity		3.15	2.38	2.65	2.94	2.22
General use in concrete		Primary binder	Cement replacement	Cement replacement	Cement replacement	Property enhancer

Table 1.1

1.4 APLICATIONS:

Because of its extreme fineness and high silica content, silica fume is a very effective pozzolanic material. Standard specifications for silica fume used in cementations mixtures are ASTM C1240 EN 13263.

Silica fume is added to Portland cement concrete to improve its properties, in particular its compressive strength, bond strength, and abrasion resistance. These improvements stem from both the mechanical improvements resulting from addition of a very fine powder to the cement paste mix as well as from the pozzolanic reactions between the silica fume and free calcium hydroxide in the paste.

Addition of silica fume also reduces the permeability of concrete to chloride ions, which protects the reinforcing steel of concrete from corrosion, especially in chloride-rich environments such as coastal regions and those of humid continental roadways and runways (because of the use of de-icing salts) and saltwater bridges.

Prior to the mid-1970s, nearly all silica fume was discharged into the atmosphere. After environmental concerns necessitated the collection and landfilling of silica fume, it became economically viable to use silica fume in various applications, in particular high-performance concrete. Effects of silica fume on different properties of fresh and hardened concrete include:

- Workability: With the addition of silica fume, the slump loss with time is directly proportional to increase in the silica fume content due to the introduction of large surface area in the concrete mix by its addition. Although the slump decreases, the mix remains highly cohesive.
- Segregation and bleeding: Silica fume reduces bleeding significantly because the free water is consumed in wetting of the large surface area of the silica fume and hence the free water left in the mix for bleeding also decreases. Silica fume also blocks the pores in the fresh concrete so water within the concrete is not allowed to come to the surface

1.5 Sulphate attack in concrete

Cement is composed mainly of two minerals tri-calcium silicates (C3S) and di-calcium silicates (C2S). Upon hydration, the main reaction products are calcium silicate gels (C-S-H) and calcium hydroxide Ca(OH)2 or CH in cement chemistry. Moisture makes this reaction happen and can cause serious structural damage to both wall slabs and walls in buildings.

Sulphate attacks happen to ground floor slabs, this issue generally affects properties from the 1950s and 1960s but can affect earlier structures where a concrete floor slab has been installed They occur when the infill material beneath the slab contains sulphates and these are taken up into solution by ground moisture which then migrates into the concrete which forms the floor slab.

The attacks can come from MgSO4 salts NaSO4 salts and other salts containing SO3- ions. The interaction of Ca2+ ions with SO4 present in the solution will produce CaSO4 or gypsum. The effect of gypsum on C-S-H gel , which is the principal component of hardened cement yet a debatable topic. Other components present in cement such as tricalcium aluminate also interact with sulphate ions. Although this reaction is property established in literature.

External attack

This is the more common type and typically occurs where water containing dissolved sulphate penetrates the concrete. Sulphate ions that penetrate the concrete react with CH to form gypsum

$\hat{S}H+CH \rightarrow CSH_2$ (Cement chemist notation)

$C_3A + 3C\hat{S}H_2 + 26H \rightarrow C_3A.3C\hat{S}.H_{32}$

tricalcium aluminate + gypsum → stringier

when concentration of sulphate ions decrease the stringier breaks down into mono sulphates

$2C_3A + C_3A.3C\hat{S}.H_{32} \rightarrow 3C_3A.3C\hat{S}.H_{12}$

When it reacts with concrete, it causes the slab to expand, lifting, distorting and cracking as well as applying pressure to surrounding walls which can mean structural movement, significantly weakening the concrete.

The main infill materials to a solid floor which result in a sulphate attack:

- Red Ash (Shale)
- Black Ash
- Slag

- Grey Fly Ash
- Other industrial materials and building rubble could be used and present a potential problem

These materials originated were used extensively in the North West of England as they were widely available and virtually free from sources such as Coal Mines, Steelworks, Foundries and Power Stations.

Internal attack

This form occurs when the source of sulphates is excess gypsum . The gypsum present in the concrete it reacts with mono sulphates to form stringier

$$C_3A.3C\hat{S}.H_{12} + 2CSH_2 + 16H \rightarrow C_3A.3C\hat{S}.H_{32}$$

A fairly well-defined reaction front can often be seen in polished sections; ahead of the front the concrete is normal, or near normal. Behind the reaction front, the composition and microstructure of the concrete will have changed. These changes may vary in type or severity but commonly include:

- Extensive cracking
- Expansion
- Loss of bond between the cement paste and aggregate
- Alteration of paste composition, with consulate phase converting to stringier and, in later stages, gypsum formation. The necessary additional calcium is provided by the calcium hydroxide and calcium silicate hydrate in the cement paste

The effect of these changes is an overall loss of concrete strength.

Sulphate attacks are identified through a remedial survey but they can often be overlooked when undertaking a damp survey as they can be considered as a structural rather than a dampness issue but moisture is what causes the reaction.

Initially a visual and levelling inspection to the property will be sufficient to recognise there is a sulphate issue. To establish the type and depth of infill, trial holes will need to be used.

If water is present in the subfloor structure, a structural engineer may need to be instructed, subject to the level of damage or movement to the walls.

CHAPTER-II
LITERATURE REVIEW

2.1 OVERVIEW OF VERMICULITE FOR FINE AGGREGATE AND SILICA FUME FOR CEMENT

Mordovia (2016) has studied M30 grade concrete using vermiculite as partial replacement with 40%, 50% and 60% to the total weight of fine aggregate. The aim of their project is to study the strength parameters such as compressive strength, split tensile & flexural strength of concrete. Their study result shows the optimum strength in comparing the strengths for different vermiculite percentages was observed to be 50%.

S Syed Abdul Rahman and Gijon K Babe (2016) In their study, structural lightweight aggregate concrete was designed with the use of natural vermiculite aggregate that will provide an advantage of reducing dead weight of structure and to obtain a more reasonable structural lightweight concrete by the use of vermiculite power as a partial replacement of fine aggregate. Three mixes were created

with a cement content of 479kg/m3 in M30 grade and water cement ratio is 0.40. The proportion of 0%, 5% and 10%, as vermiculite replacement to fine aggregate. And lastly they concluded that the 10% replacement of vermiculite to fine aggregate well compared to control mix.

Sharia and Liaoyang (2016) Have studied replacement of the fine aggregate with the material called vermiculite. It belongs to the family of lightweight aggregates. The exfoliated vermiculite is used as a replacement of fine aggregate. This project is mostly related in places where the ecological temperature is very high. The Replacements were done in 5, 10 and 15% of fine aggregate. And finally conclude that the Vermiculite replaced concrete shows insignificant decrease in density up to 15% when compared to normal concrete. In spit tensile test no much variation in split tensile strength when compared to normal concrete.

B. Krishna Kumara Bai, M. Antara (2015) Have their study of high performance concrete with mineral admixtures, low water cement ratio and super plasticizers are used. Fly ash (FA) is replaced with cement by different percentages i.e., 5%, 10%, 15%, 20%, 25% and silica fume (SF) as addition of 10% by total weight of cement. It has been observed that the workability and required strengths are achieved at optimum percentage i.e. 10% silica fume is addition and 15% fly ash is replacement by weight of cement. Water cement ratio is 0.32. They concluded that the compressive strength is increased by 11% for replacement of cement by 15% fly ash and silica fume 10% was addition of cement. The flexural strength test value for 28 days was found to be 8.5 N/mm2. The split tensile strength test value for 28 days was found to be 4.2N/mm2.

2.2 OVERVIEW OF LIGHTWEIGHT CONCRETE WITH VERMICULITE

V. V. Sai ram (2017) In this case fine aggregate is partially replacement of vermiculite. Use of vermiculite in concrete will enhance the shrinkage and crack resistance, fire resistance and reduce environmental impact and also reduce the cost. In this present study, an attempt has been made to study the mechanical properties of M35 grade concrete with different percentages at a range of 5%, 10%, 15%, 20%,25% and 30% as partially replacement with vermiculite to the total weight of fine aggregate along with mineral admixtures like Fly ash (FA)is replace with cement by various percentages i.e., 10%, 15% and 20% and silica fume (SF) as adding of 5%, 7.5%, 10% and 12.5% by weight of cement. Water cement ratio is 0.42. Optimum percentage of compressive strength is obtained. NM Wahid (2016) In this paper, an adsorption Heat Storage System

(AdHS-R134a)/heating system utilizing Vermiculite and Calcium Chloride composite adsorbent material was experimentally investigated. The main aim of the experimental investigations is to carry out preliminary tests on a small-scale Adsorption Heat Storage Systems (AdHS-R134a) using a heat pump circuit as the regeneration heat source. The test rig was constructed using Vertical Glass Pipes with a heat pump circuit using a mini compressor for transporting the refrigeration gas as heat source for desorption cycle. The system also incorporates condenser coils, evaporator coils, and an expansion valve. The integration with a heat pump circuit is to analyse the performance of an AdHS-R134a using off-peak power in desorption/charging cycle or utilizing renewable energy sources to minimize conventional energy generated from fossil fuels. Firstly, desorption phase occurs during night hours, when cheap off-peak electricity is available under the 'Economy 7' tariff that is more suitable for households with night storage heaters or if we use lots of electricity at night. Secondly, in the heat pumping phase/adsorption loop which will occur during the day. The useful heat of adsorption in the adsorbent pipe could be used for under floor heating (35°C-40°C), or for domestic hot water production (55°C-60°C) during the day. The maximum temperature lift observed from the adsorption process is 68.67°C (inside adsorption pipe) with the corresponding COP of 0.55-1.39.

2.3 DURABILITY STUDIES OF CONCRETE OVERVIEW

W.C. Pasta, teal., 1988, made their investigation on sulphate durability of concrete under constant sustained load. The aim of this paper is to study of durability of concrete with limestone and granite aggregate under simultaneous long-term compressive stress and sulphate attack. Min-Hong Zhang, Odd E., Gyor., 1991, had made study on "Characteristics of lightweight aggregate for high-strength concrete". Light weight aggregate are produced from a wide variety of raw materials, and the production conditions may also vary. The characteristics of light weight aggregate may vary within wide limits. K.D. Hertz., 1992, had studied on "Davis investigation on silica fume concrete at elevated temperatures". This explains the fire tests in which the increased 10 risk of explosive spelling of concrete densified by silica fume was first discovered. Results were discussed from test to define appropriate limits of SF content and to develop a new concrete for slender column units. Observations were made about circumstances under which super plasticize ring additive in concrete gave rise to development of toxic gases. Xiao Feng Cong, teal. 1992, had noticed that the strengths of concrete using silica fume as partial replacement in cement is higher side when compared to normal concrete, this is due to an addition of silica fume in binding material.

Owens, P.L., 1993, conducted experimental studies on densities of light weight aggregate concrete and normal weight aggregate concrete and stated that the density of lightweight aggregate concrete ranges from 1400 to 2000 kg/m³ compared with that of normal weight aggregate concrete (about 2400 kg/m³). Neville, A.M., 1995, stated that Pumice is a natural light weight material used in concrete as coarse aggregate where it is locally available or easily imported. Moira A.Harding, 1995, had studied on "Structural Lightweight aggregate concrete". Terence, Holland et. al., 1995, had studied on" Use of silica fume in concrete". Both reveal the effects of silica fume on strengths. Jalousie, teal., 1999, studied on light weight concrete by using different unit weight aggregates without using natural fine aggregate (no-fines concrete). They obtained a light weight concrete with 22 MPa cylinder compressive strength and 1520 kg/m³ dry unit weight at 28 days.

Ali R. Kahlo, and Nasik Kim., 1999, conducted tests and studied the effect of different curing periods and different temperatures on concrete. It results that the influence of various curing conditions on the major mechanical strength properties of light weight high strength concrete (LWHSC) is in considerable limits. Prakash Decay, teal., (16,17,18,19,20,21, and 1993, 1993, 1999, 1999, 1999, 2000, and 2000, studied about Mode-II fracture studies using DCN specimen geometry which fails in predominant Mode-II failure, They have also made finite element analysis to arrive at stress intensity factor. Using this DCN 11 geometry lot of experimental investigation using cement paste, mortar, plain concrete have been studied. Details of this geometry are presented

CHAPTER-III

MATERIAL SURVEY

3.1 CEMENT

Fig:3.1

3.1.1 INTRODUCTION

Cement is a binder, a substance that sets and hardens and can bind other materials together. The word "cement" traces to the romans, who used the term opus caementicium to describe masonry resembling modern concrete that was made from crushed rock with burnt lime as binder. The volcanic ash and pulverized brick supplements that were added to the burnt lime to obtain a hydraulic binder were later referred to as cementum, cement, and cement.

3.1.2. Ordinary Portland cement(opt):

Cement can be defined as the bonding material having cohesive & adhesive properties which makes it capable to unite the different construction materials &form the compacted assembly. Ordinary Portland cement is the one of mostly used type of Portland cement. The name Portland cement was given by joseph asp din 1824 due to its similarity in colour and its quality when it hardens like Portland stone. Portland stone is white grey limestone in island of Portland, Dorset.

Properties of cement:

- it is an excellent binding material
- it is easily workable
- it gives good strength to masonry
- it offers good resistance to moisture
- it possesses good plasticity
- it can take more loads on hardening
- it attains homogeneity quickly during mixing

contents	%
Cao	60-67
Sio2	17-25
Al2o3	3-8
Fe2o3	0.5-0.6
Mgo	0.5-0.4
Alkalies	0.3-1.2
So3	2.0-3.5

Table 3.1

Testing of cement

Testing can be done under two categories

1) Field tests
2) Laboratory test

Field testings:

a) Open the bag and take a good look at the cement then it should not contain any visible lumps
b) Colour of cement should be greenish grey
c) Should get cool feeling when get trusted
d) When we touch the cement we should get a soft and smooth feeling but not gritty feeling
e) When we throw the cement in a bucket full of water before it sinks the particle should flow in the water
f) When we make a stiff paste of cement and cut it with sharp edges and kept on a glass plate under water there won't be any disturbance to the shape and should get strength after 24 hours

If a sample of cement satisfies the above field tests it may be concluded that the cement is not bad. The above tests do not really indicate that the cement is really good for important works

LABORATORY TESTS:

For using cement in important and major works it is incumbent on the part of the user to test the cement in laboratory to confirm the requirements of the Indian standard specifications with respect to its physical and chemical properties

the following are the laboratory tests for cement

1. Standard consistency of cement
2. Compressive strength of cement
3. Setting times of cement
4. Specific gravity of cement
5. fitness of cement.

3.2AGGREGATES:

Aggregates are coarse particulate rock-like material consisting of a collection of particles ranging in size from < 0.1 mm to > 50 mm. It includes gravel, crushed rock, sand, recycled concrete, slag, and synthetic aggregate.

Aggregate is a granular material, such as sand, gravel, crushed stone, crushed hydraulic-cement concrete, or iron blast-furnace slag, used with a hydraulic cementing medium to produce either concrete or mortar. Types of aggregates include Coarse aggregate and fine aggregate. The aggregate of each type is further subdivided into many types and classification based on its size. The technique of Sieve Analysis is used for gradation of aggregate for use in concrete and for other applications.

Aggregate is called bound material when it is mixed with cement or binding materials and referred to as unbound material when used without cement or binding materials.

Classification of aggregates based on: Grain Size
If you separate aggregates by size, there are two overriding categories:

- Fine
- Coarse

The size of **fine aggregates** is defined as 4.75mm or smaller. That is, aggregates which can be passed through a number 4 sieve, with a mesh size of 4.75mm. Fine aggregates include things such as sand, silt and clay. Crushed stone and crushed gravel might also fall under this category.
Typically, fine aggregates are used to improve workability of a concrete mix.
Coarse aggregates measure above the 4.75mm limit. These are more likely to be natural stone or gravel that has not been crushed or processed. These aggregates will reduce the amount of water needed for a concrete mix, which may also reduce workability but improve its innate strength.
Classification of aggregates based on: Density
There are three weight-based variations of aggregates:

- Lightweight
- Standard
- High density

Different density aggregates will have much different applications. Lightweight and ultra lightweight aggregates are more porous than their heavier counterparts, so they can be put to great use in green roof construction, for example. They are also used in mixes for concrete blocks and pavements, as well as insulation and fireproofing.
High density aggregates are used to form heavyweight concrete. They are used for when high strength, durable concrete structures are required – building foundations or pipework ballasting, for example

.

Classification of aggregates based on: Geographical Origin
Another way to classify aggregates is by their origin. You can do this with two groups:

- **Natural** – Aggregates taken from natural sources, such as riverbeds, quarries and mines. Sand, gravel, stone and rock are the most common, and these can be fine or coarse.
- **Processed** – Also called 'artificial aggregates', or 'by-product' aggregates, they are commonly taken from industrial or engineering waste, then treated to form construction aggregates for high quality concrete. Common processed aggregates include industrial slag, as well as burnt clay. Processed aggregates are used for both lightweight and high-density concrete mixes.

Classification of aggregates based on: Shape

Shape is one of the most effective ways of differentiating aggregates. The shape of your chosen aggregates will have a significant effect on the workability of your concrete. Aggregates purchased in batches from a reputable supplier can be consistent in shape, if required, but you can also mix aggregate shapes if you need to.

The different shapes of aggregates are:

- **Rounded –** Natural aggregates smoothed by weathering, erosion and attrition. Rocks, stone, sand and gravel found in riverbeds are your most common rounded aggregates. Rounded aggregates are the main factor behind workability.
- **Irregular –** These are also shaped by attrition, but are not fully rounded. These consist of small stones and gravel, and offer reduced workability to rounded aggregates.
- Angular – Used for higher strength concrete, angular aggregates come in the form of crushed rock and stone. Workability is low, but this can be offset by filling voids with rounded or smaller aggregates.
- Flaky – Defined as aggregates that are thin in comparison to length and width. Increases surface area in a concrete mix.
- Elongated – Also adds more surface area to a mix – meaning more cement paste is needed. Elongated aggregates are longer than they are thick or wide.
- Flaky and elongated – A mix of the previous two – and the least efficient form of aggregate with regards to workability.

Knowing the various aggregate classifications is a good starting point when planning a concrete construction project. If you're in need of specific advice for the kind of aggregates required for your needs, it helps to talk to the pros. A reliable aggregates supplier will be able to provide the perfect selection of aggregates for your project, ensuring they meet the quality requirements to form an integral part of your concrete mix.

Aggregates are commonly obtained by crushing naturally occurring rock. The properties of aggregates depend on the parent rock which can be igneous, sedimentary, or metamorphic. Aggregates are evaluated through tests to determine their suitability for various applications. Mineralogy, grain size and texture, and petrographic description of rock samples are also used to evaluate suitability.

Properties of Aggregates also have an effect on resulting concrete. e.g. variation in size, grading, texture, shape and strength of aggregates means variation in the properties of resulting concrete.

Purpose & Uses of Aggregates

In concrete, an aggregate is used for its economy factor, to reduce any cracks and most importantly to provide strength to the structure.

1. Aggregates are used as the base, subcase, and/or surface of roads in several forms
2. In roads and railway ballast, it is used to help distribute the load and assist in ground water running off the road.
3. Increases the volume of concrete, thus reduces the cost. Aggregates account for 60-75% of the volume of concrete and 79-85% weight of PCC
4. Provide dimensional stability
5. Influence hardness, abrasion resistance, elastic modulus and other properties of concrete to make it more durable, strong and cheaper.

6. Other uses include fills, backfills, and drainage and filtration applications.

Types of Aggregates

Coarse Aggregate

Coarse-grained aggregates will not pass through a sieve with 4.75 mm openings (No. 4).

Those particles that are predominantly retained on the 4.75 mm (No. 4) sieve and will pass through 3-inch screen, are called **coarse aggregate.** The coarser the aggregate, the more economical the mix. Larger pieces offer less surface area of the particles than an equivalent volume of small pieces. Use of the largest permissible maximum size of coarse aggregate permits a reduction in cement and water requirements. Using aggregates larger than the maximum size of coarse aggregates permitted can result in interlock and form arches or obstructions within a concrete form. That allows the area below to become a void, or at best, to become filled with finer particles of sand and cement only and results in a weakened area.

For Coarse Aggregates in Roads following properties are desirable:

1. Strength
2. Hardness.
3. Toughness
4. Durability
5. Shape of aggregates
6. Adhesion with bitumen

Fig 3.2

TESTS ON COARSE AGGREGATE:

1. Sieve analysis of coarse aggregate
2. Specific gravity and water absorption of coarse aggregate
3. Bulk density of coarse aggregate

Fine Aggregate

The other type of aggregates are those particles passing the 9.5 mm (3/8 in.) sieve, almost entirely passing the 4.75 mm (No. 4) sieve, and predominantly retained on the 75 µm (No. 200) sieve are called fine aggregate. For increased workability and for economy as reflected by use of less cement, the fine aggregate should have a rounded shape. The purpose of the fine aggregate is to fill the voids in the coarse aggregate and to act as a workability agent.

fig.3.3

Properties of Aggregates also have an effect on resulting concrete. e.g. variation in size, grading, texture, shape and strength of aggregates means variation in the properties of resulting concrete.

Tests on fine aggregate:

1. Sieve analysis of fine aggregate
2. Specific gravity and water absorption of fine aggregate
3. Bulk density of fine aggregate

3.3WATER

Generally, the quality of water for construction works is the same as drinking water. This is to ensure that the water is reasonably free from such impurities as suspended solids, organic matter and dissolved salts, which may adversely affect the properties of the concrete, especially the setting, hardening, strength, durability, pit value, etc.

The water shall be clean and shall not contain sugar, molasses or Gur or their derivatives, or sewage, oils, organic substances.

Alternatively, the water shall be tested in an approved Laboratory for its use in preparing concrete / mortar.

fig.3.4

The water quality for construction shall be tested or monitored regularly, as it affects the overall strength of concrete. For plain and reinforced cement concrete permissible limits for solids shall be as follows

Type of Solid in water	**Permissible Limits for Construction**
Organic matter	200 mg/l
Inorganic matter	3000 mg/l
Sulphates (SO4)	500 mg/l

Chlorides (Cl)	a) 1000 mg/l for RCC work and, b) 2000 mg/l for PCC work
Suspended matter	2000 mg/l

Table 3.2

The function of water in concrete:

- it acts as a lubricant
- it acts as a chemically with cement to form the binding paste for coarse aggregate and reinforcement
- it enables the concrete mix to flow into formwork

3.4vermiculite:

Vermiculite is a hydrous phyllo silicate mineral which undergoes significant expansion when heated. Exfoliation occurs when the mineral is heated sufficiently, and commercial furnaces can routinely produce this effect. Vermiculite forms by the weathering or hydrothermal alteration of biotite or phonolite. Large commercial vermiculite mines currently exist in Russia, South Africa, China, and Brazil.

Structure of vermiculite: -

Vermiculite is a 2:1 clay, meaning it has two tetrahedral sheets for every one octahedral sheet. It is a limited-expansion clay with a medium shrink–swell capacity. Vermiculite has a high cation-exchange capacity (CEC) at 100–150 me/100 g. Vermiculite clays are weathered micas in which the potassium ions between the molecular sheets are replaced by magnesium and iron ions.

3.5Silica Fumes:

Silica fume is a by-product of producing silicon metal or ferrosilicon alloys. One of the most beneficial uses for silica fume is in concrete. Because of its chemical and physical properties, it is a very reactive pozzolanic. Concrete containing silica fume can have very high strength and can be very durable. Silica fume is available from suppliers of concrete admixtures and, when specified, is simply added during concrete production. Placing, finishing, and curing silica-fume concrete require special attention on the part of the concrete contractor.

Silicon metal and alloys are produced in electric furnaces as shown in this photo. The raw materials are quartz, coal, and woodchips. The smoke that results from furnace operation is collected and sold as silica fume, rather than being landfilled. Perhaps the most important use of this material is as a mineral admixture in concrete.

Silica fume consists primarily of amorphous (non-crystalline) silicon dioxide (SiO_2). The individual particles are extremely small, approximately 1/100th the size of an average cement particle. Because of its fine particles, large surface area, and the high SiO_2 content, silica fume is a very reactive pozzolanic when used in concrete. The quality of silica fume is specified by ASTM C 1240 and AASHTO M 307.

High-strength concrete is a very economical material for carrying vertical loads in high-rise structures. Until a few years ago, 6,000 psi concrete was considered to be high strength. Today, using silica fume, concrete with compressive strength in excess of 15,000 psi can be readily produced. The structure shown at the above right used silica-fume concrete with a specified compressive strength of 12,000 psi in columns reaching from the ground through the 57th story.

The greatest cause of concrete deterioration in the US today is corrosion induced by de-icing or marine salts. Silica-fume concrete with a low water content is highly resistant to penetration by chloride ions. More and more transportation agencies are using silica fume in their concrete for construction of new bridges or rehabilitation of existing structures.

Silica-fume concrete does not just happen. A specified must make a conscious decision to include it in concrete to achieve desired concrete properties. Assistance in specifying silica-fume concrete for high strength or increased durability can be obtained from the SFA or from major admixture suppliers

Silica fume for use in concrete is available in wet or dry forms. It is usually added during concrete production at a concrete plant as shown in the photo. Silica fume-concrete has been successfully produced in both central-mix and dry-batch plants. Assistance is readily available on all aspects of handling silica fume and using it to produce consistent, high-quality concrete.

Silica-fume concrete should be transported, placed, finished, and cured following the good concreting practices outlined by the American Concrete Institute. Flatwork containing silica fume concrete generally requires less finishing effort than conventional concrete. The photo shows the "one-pass" finishing process in which the silica-fume concrete is placed, consolidated, and textured with little or no waiting time between operations. To gain the most benefits from using silica fume, the concrete must be cured effectively. The SFA or your concrete supplier can provide any necessary assistance concerning construction operations

3.5. SUPER PLASTISIZER (FOSROC)

Compact SP430 is a chloride free, super plasticizing admixture based on selected sulphonated naphthalene polymers. It is supplied as a brown solution which instantly disperses in water.

Advantages

- Major increases in strength at early ages without increased cement contents are of particular benefit in precast concrete, allowing earlier stripping times.
- Makes possible major reductions in water: cement ratio which allow the production of high strength concrete without excessive cement contents.
- Use in production of flowing concrete permits easier construction with quicker placing and compaction and reduced labour costs without increasing water content.
- Increased workability levels are maintained for longer than with ordinary sulphonated melamine admixtures.
- Improved cohesion and particle dispersion minimise segregation and bleeding and improves pumpability.
- Chloride free, safe for use in pre-stressed and reinforced concrete.
- In screed material, the lower water content leads to quicker drying times

FOSROC CONPLAST SP340. Fig 3.5

CHAPTER-IV

EXPERIMENTAL INVESTIGATIONS AND MIX DESIGN

4.1 study of materials

The materials which are used in study of durability test using vermiculite as a partial replacement for fine aggregate and silica fume for cement are given below

1. cement
2. fine aggregate
3. coarse aggregate
4. vermiculite
5. silica fume
6. water
7. Super plasticizer sp340

Cement

ordinary Portland cement has been used. The physical properties of the cement

is obtained on conducting appropriate tests

Fine aggregate

In this present investigation fine aggregate is of natural sand obtained locally the physical properties of fine aggregate like specific gravity, bulk density finest modulus are tested

Coarse aggregate

The crushed coarse aggregate of 20mm maximum sizes are obtained. The physical properties of coarse aggregates such as specific gravity, bulk density, flakiness and elongation index, finest modulus are tested.

Water

Clean potable water is used for casting and curing operation for the work. The water supply in the campus is of portable standard of ph.=7.50.

4.2. STUDY OF FRESH CONCRETE:

Fresh concrete is freshly mixed materials which can be moulded into any shape relative quantities of cement, aggregate water mixed together, control the properties of concrete in wet state as well as in the hardened state.

4.2.1 workability

Workability is defined as "the property of concrete which determines the amount of useful internal work necessary to produce full compaction". Another definition which envelopes a wider meaning is that ,it is defined as that "ease with which concrete can be compacted 100% having regard to mode of compaction and place of deposition".

In the present investigation's workability is measured by slump and compacting factor tests.

4.2.2. Slump test

The concrete slump test is an empirical test that measures the workability of fresh concrete.

More specifically, it measures the consistency of the concrete in that specific batch. This test is performed to check the consistency of freshly made concrete.

Consistency is a term very closely related to workability. It is a term which describes the state of fresh concrete flows. It is used to indicate degree of wetness. Workability of concrete is mainly affected by consistency i.e. Wetter mixes will be more workable than drier but, concrete of same consistency may vary in workability

Principle:

The slump test result is a slump of behaviour of compacted inverted cone of a concrete under action of gravity. It measures consistency of concrete

Apparatus:

1. weights and weighing device
2. tools & containers for mixing or concrete mixer
3. tamper (16mm die & 600mm length)
4. ruler
5. slump cone has the shape of frustum of a cone with the following dimensions

- base diameter -20 cm
- top diameter-10cm
- height-30 cm
- material thickness-1.6 mm

Procedure for Concrete Slump Cone Test:

1. Clean the internal surface of the mould and apply oil.
2. Place the mould on a smooth horizontal non- porous base plate.
3. Fill the mould with the prepared concrete mix in 4 approximately equal layers.
4. Tamp each layer with 25 strokes of the rounded end of the tamping rod in a uniform manner over the cross section of the mould. For the subsequent layers, the tamping should penetrate into the underlying layer.
5. Remove the excess concrete and level the surface with a trowel.

6. Clean away the mortar or water leaked out between the mould and the base plate.
7. Raise the mould from the concrete immediately and slowly in a vertical direction.
8. Measure the slump as the difference between the height of the mould and that of height point of the specimen being tested.

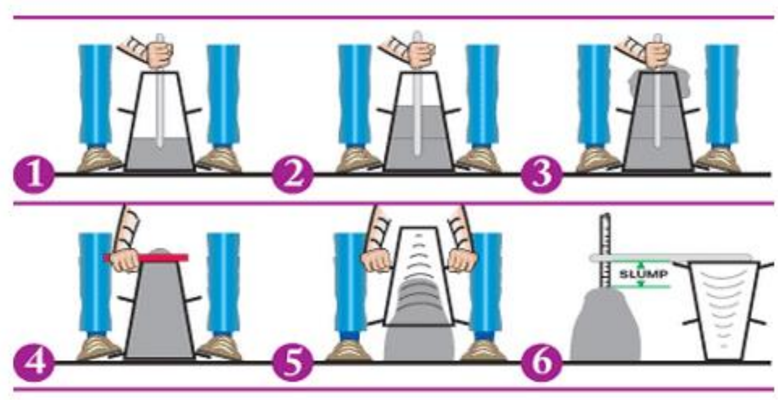


fig.4.2.1 slump

When the slump test is carried out, following are the shape of the concrete slump that can be observed:

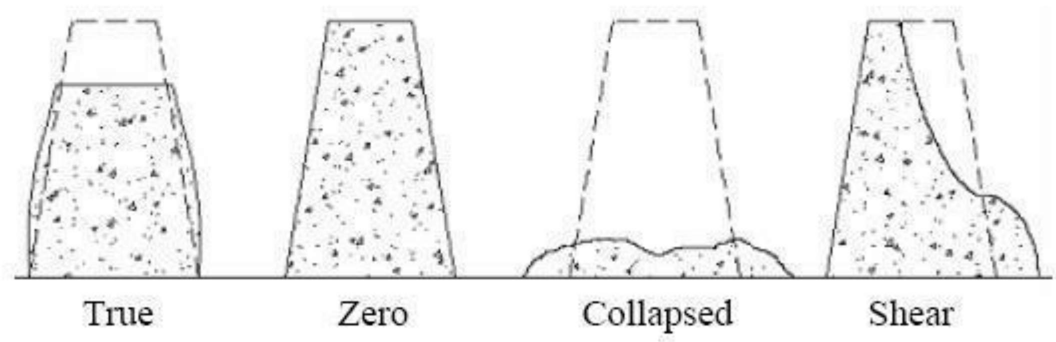


Figure-4.2.2: Types of Concrete Slump Test Results

- **True Slump --** – True slump is the only slump that can be measured in the test. The measurement is taken between the top of the cone and the top of the concrete after the cone has been removed as shown in figure-1.
- **Zero Slump** – Zero slump is the indication of very low water-cement ratio, which results in dry mixes. This type of concrete is generally used for road construction.
- **Collapsed Slump** – This is an indication that the water-cement ratio is too high, i.e. concrete mix is too wet or it is a high workability mix, for which a slump test is not appropriate.
- **Shear Slump** – The shear slump indicates that the result is incomplete, and concrete to be retested.

Slump for the given sample= _____mm

When the slump test is carried out, following are the shape of the concrete slump that can be observed:

Concrete Slump Test Results – True slumps

Samples	1	2	3	4	5	6	7	8	9	10	11	12
Slump Values(in mm)	32	30	28	26	25	24	34	32	30	28	26	25

Table 4.1

4.2.3 Compaction factor test:

Aim: to determine the compaction factor test

Specifications:

1.compaction factor apparatus
2.tray
3. balance
4.tampering rod
5.weights

Procedure for compaction factor test:

1. Place the concrete sample gently in the upper hopper to its brim using the hand scoop and level it.
2. Cover the cylinder.
3. Open the trapdoor at the bottom of the upper hopper so that concrete falls into the lower hopper. Push the concrete sticking on its sides gently with the road.
4. Open the trapdoor of the lower hopper and allow the concrete to fall into the cylinder below.
5. Cut off the excess of concrete above the top level of the cylinder using trowels and level it.
6. Clean the outside of the cylinder.
7. Weight the cylinder with concrete to the nearest 10 g. This weight is known as the weight of partially compacted concrete (**W1**).
8. Empty the cylinder and then refill it with the same concrete mix in layers approximately 5 cm deep, each layer being heavily rammed to obtain full compaction.
9. Level the top surface.

10.Weigh the cylinder with fully compacted. This weight is known as the weight of fully compacted concrete (**W2**).

11.Find the weight of an empty cylinder (**W**).

The test is sufficiently sensitive to enable difference in workability arising from the initial process in the hydration of cement to be measured.

Each test, therefore should be carried out at a constant time interval after the mixing is completed, if strictly comparable results are to be obtained. Convenient time for releasing the concrete from the upper hopper has been found to be two minutes after the completion of mixing.

Calculation of Compaction Factor Value:

The compaction factor is defined as the ratio of the weight of partially compacted concrete to the weight of fully compacted concrete. It shall normally be stated to the nearest second decimal place.

Compaction Factor Value= (W1-W) / (W2-W)

Result of Compaction Factor

Compaction Factor Value= (W1-W) / (W2-W)

The Compaction factor values ranges from 0.7 to 0.95.

Samples	1	2	3	4	5	6	7	8	9	10	11	12
Compaction factor values	0.83	0.81	0.79	0.77	0.75	0.74	0.85	0.83	0.80	0.78	0.75	0.74

Table 4.2

4.3 CASTING OF TEST SPECIMEN

THE present experimental study includes casting and testing of cubes specimen to know the compressive strength of concrete

4.4 MIXING OF CONCRETE

Proper mixing of concrete ingredients is of utmost importance in order to produce good quality fresh concrete. During the process of mixing the surface of all the aggregate particles is coated with cement paste. Well mixed concrete is required for the desired workability and performance of concrete in both the fresh as well as the hardened state. If the concrete is not well mixed, then it tends to segregation and bleeding.

When it comes to mixing concrete, following three mixing methods are used for the production of effective and good quality concrete.

01. Hand Mixing of Concrete (Mixing concrete manually without a mixer machine)

02. Machine Mixing of Concrete (Mixing concrete with a mixer machine)

03. Ready Mix Concrete (Mixing in automatic or semi-automatic batching plant)

In this present investigation machine mixing was employed. In the case of vermiculite was mixed along with fine aggregate.

4.5 COMPACTION OF CONCRETE

To make your structure strong and long lasting for its designed life, it is very important that your structure is nonporous or impermeable. Porous concrete can lead to various problems like leakages, corrosion etc. These can happen if proper compaction is not done during the placing of concrete.

Poor compaction results into following problems:

- Poor strength of concrete, which may lower the service life of the house or building.
- High porosity in concrete, which may lead to leakage in the house or building.
- Honeycombing in concrete, which may also lead to leakage in the house or building.
- Lower the durability of concrete, which may increase the chances of repair and maintenance of house or building.

Theoretically, compaction of concrete is the process adopted for expelling the entrapped air as far as possible from the fresh concrete to achieve the highest possible density of the compacted mass. It simply means that there shouldn't be any void present in concrete.

The main purpose of compaction of concrete is to get a dense mass without voids, to get the concrete to surround all reinforcement and to fill all corners.

DIFFERENT TYPES OF COMPACTION OF CONCRETE

1. **Manual Compaction (Hand Compaction):**

- Rodding
- Ramming
- Tamping

02. Mechanical Compaction by Vibration:

- Internal vibrator (Needle vibrator)
- Formwork vibrator (External vibrator)
- Table vibrator
- Platform vibrator
- Surface vibrator (screed vibrator)
- Vibratory roller

03. Compaction by Pressure and Jolting

04. Compaction by Spinning

4.6 CURING OF CONCRETE:

Curing of Concrete is a method by which the concrete is protected against loss of moisture required for hydration and kept within the recommended temperature range. Curing will increase the strength and decrease the permeability of hardened concrete. Curing also helps in mitigating thermal and plastic cracks, which can severely impact durability of structures.

METHODS:

Concrete curing methods may be divided broadly into four categories

1.water curing

2.membrane curing

3.application curing

4.miscelllaneous

In the present study curing is done by immersion which is one of the methods of water curing

4.7 STUDY OF HARDENED CONCRETE

The properties of concrete which are of practical importance are those concerning this strength ,stress, strain characteristics ,shrinkage and creep deformations,permeability,durability,modulus of elasticity, abrasion resistance .of those properties strength of concrete assumes a greater significance because it is related to the structure of hardened concrete assumes a greater significance because it is related to the structure of hardened cement paste and gives an overall picture of quality of concrete

4.7.1 COMPRESSIVE STRENGTH OF CONCRETE

The compressive strength of the concrete cube test provides an idea about all the characteristics of concrete. By this single test one judges whether Concreting has been done properly or not. Concrete compressive strength for general construction varies from 15 MPa (2200 psi) to 30 MPa (4400 psi) and higher in commercial and industrial structures.
Compressive strength of concrete depends on many factors such as water-cement ratio, cement strength, quality of concrete material, quality control during the production of concrete, etc.

Test for compressive strength is carried out either on a cube or cylinder. Various standard codes recommend a concrete cylinder or concrete cube as the standard specimen for the test. American Society for Testing Materials ASTM C39/C39M provides Standard Test Method.
Compressive Strength Definition
Compressive strength is the ability of material or structure to carry the loads on its surface without any crack or deflection. A material under compression tends to reduce the size, while in tension, size elongates.

Compressive Strength Formula:
Compressive strength formula for any material is the load applied at the point of failure to the cross-section area of the face on which load was applied.

Compressive Strength = Load / Cross-sectional Area
Procedure for Compressive Strength Test of Concrete :
For cube test specimens cubes of 10cm X 10cm x 10cm depending upon the size of aggregate are used. For most of the works cubical melds of size 10cm x 10cm x 10cm are commonly used.

This concrete is poured in the meld and appropriately tempered so as not to have any voids. After 24 hours, melds are removed, and test specimens are put in water for curing. The top surface of these specimens should be made even and smooth. This is done by placing cement paste and spreading smoothly on the whole area of the specimen.

These specimens are tested by a compression testing machine after seven days curing or 28 days curing. Load should be applied gradually at the rate of 140 kg/cm2 per minute till the Specimens fails. Load at the failure divided by area of specimen gives the compressive strength of concrete.

Apparatus for Concrete Cube Test
Compression testing machine

Preparation of Concrete Cube Specimen
The proportion and material for making these test specimens are from the same concrete used in the field.

Specimen
2 CUBES OF SIZE 10CM*10CM*10CM* ARE USED

Sampling of Cubes for Test:

1. Clean the mounds and apply oil.
2. Fill the concrete in the melds in layers approximately 5 cm thick.
3. 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).
4. Level the top surface and smoothen it with a trowel.

Testing of cube specimen:

For acid attack test concrete cube of size 100 ´100 ´ 100 mm are prepared for various percentages of silica fume addition. The specimen are cast and cured in mold for 24 hours, after 24 hours, all the specimen are demolded and kept in curing tank for 28-days.After 28-days all specimens are kept in atmosphere for 2-days for constant weight, subsequently, the specimens are weighed and immersed in 4% Sulphuri acid (HH2SO4) solution for 28-days.

The pH value of the acidic media was at 5. The pH value was periodically checked and maintained at 3. After 28-days of immersing in acid solution, the specimens are taken out and were washed in running water and kept in atmosphere for 2-day for constant weight.

Subsequently the specimens are weighed and loss in weight and hence the percentage loss of weight was calculated.

Curing of Cubes

Normal water curing

Water unsuitable for drinking is generally considered unsuitable for curing concrete as well. The water used for normal water curing of concrete samples was taken from concrete technology laboratory. The concrete samples were tested after 7 days,14 days and 28 days of proper 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 freshwater until taken out prior to the test.

Acidic curing

Concrete is not fully resistant to acids and most acids disintegrate the cement slowly or rapidly depending upon the type of pH value of acidic water. The solution used for acidic curing of concrete samples was prepared using concentrated H2SO4, which was diluted to obtain a pH of 3. The concrete samples were tested after 7 days of proper acidic curing.

ACID RESISTANCE TEST

Acid resistance test is done by the concrete cube specimens were immersed in Sulphur acid solution. The specimens were immersed in acid solution for a period of 7 days in room temperature. After the specified duration, the specimens were taken out, wiped off and left to dry in room temperature for away. Then all the specimens were weighed again and the weight losses were noted and plotted. After that, the weighed specimens were tested for their compressive strength under CTM as per IS 516-1959. Substituting the values of applied load and cross-sectional area in the Equation, the values of compressive strength were obtained. The mean values of strength were recorded and plotted as graph to compare their performances. The mean compressive strength of conventional and CCW cube specimens at normal exposures were 31.50 and 37.5 N/mm2 respectively.

Precautions for Tests:

The water for curing should be tested every 7 days and the temperature of the water must be at 27+-2oC.

Procedure for Concrete Cube Test:

1. Remove the specimen from the water after specified curing time and wipe out excess water from the surface.
2. Take the dimension of the specimen to the nearest 0.2m
3. Clean the bearing surface of the testing machine
4. Place the specimen in the machine in such a manner that the load shall be applied to the opposite sides of the cube cast.
5. Align the specimen centrally on the base plate of the machine.
6. Rotate the movable portion gently by hand so that it touches the top surface of the specimen.
7. Apply the load gradually without shock and continuously at the rate of 140 kg/cm^2/minute till the specimen fails
8. Record the maximum load and note any unusual features in the type of failure.

4.8 CONCEPT OF MIX DESIGN

Definition: Mix design can be defined as the process of selecting suitable ingredients of concrete and determining their relative proportions with the object of producing concrete of certain minimum strength and durability as economically as possible. One of the ultimate aims of studying the various properties of the materials of concrete, plastic concrete and hardened concrete is to enable a concrete technologist to design a concrete mix for a particular strength and durability.

The design of concrete mix is not a simple task on account of the widely varying properties of the constituent materials, the conditions that prevail at the site of work, in particular the exposure condition, and the conditions that are demanded for a particular work for which the mix is designed. Design of concrete mix requires complete knowledge of the various properties of these constituent materials, these make the task of mix design more complex and difficult.

Design of concrete mix needs not only the knowledge of material properties and properties of concrete in plastic condition; it also needs wider knowledge and experience of concrete. Even then the proportion of the materials of concrete found out at the laboratory requires modification and re adjustments to suit the field conditions. With better understanding of the properties, the concrete is becoming more and more an exact material than in the past. The structural designer specifies certain minimum strength; and the concrete technologist designs the concrete mix with the knowledge of the materials, site exposure conditions and standard of supervision available at the site of work to achieve this minimum strength and durability. Further, the site engineer is required to make the concrete at site, closely following the parameters suggested by the mix designer to achieve the minimum strength specified by the structural engineer.

In some cases the site engineer may be required to slightly modify the mix proportions given by the mix designer. He also makes cubes or cylinders sufficient in numbers and tests them to confirm the achievements with respect to the minimum specified strength. Mix designers, earlier, may have made trial cubes with representative materials to arrive at the value of standard deviation or coefficient of variation to be used in the mix design. American Concrete Institute Method of Mix Design 11.3 (ACI Concrete Mix Design) This method of proportioning was first published in 1944 by ACI committee 613. In 1954 the method was revised to include, among other modifications, the use of entrained air. In 1970, the method of ACI mix design became the responsibility of ACI committee 211. We shall now deal with the latest ACI Committee 211.1 method. It has the advantages of simplicity in that it: 1. Applies equally well 2. With more or less identical procedure to rounded or angular aggregate 3. To regular or light weight aggregates 4. To air entrained or non-air-entrained concrete. Production of concrete requires meticulous care at every stage The ingredients of good and bad concrete are same but good rules are not Observed it may become bad

4.9REQUIREMENTS OF CONCRETE MIX DESIGN

1. Characteristic strength of concrete required: Characteristic strength is the strength of concrete below which not more than 5% of test results of samples are expected to fall. This can also be called as the grade of concrete required for mix design. For example, for M30 grade concrete, the required concrete compressive strength is 30 N/mm^2 and characteristic strength is also same

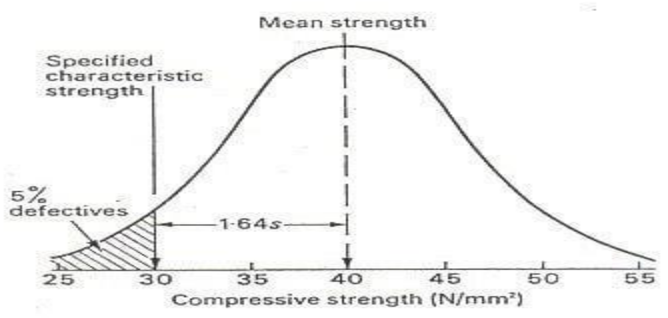


Fig 4.9: Characteristic Strength of Concrete

2. Workability requirement of concrete: The workability of concrete is commonly measured by slump test. The slump value or workability requirement of concrete is based on the type of concrete construction.

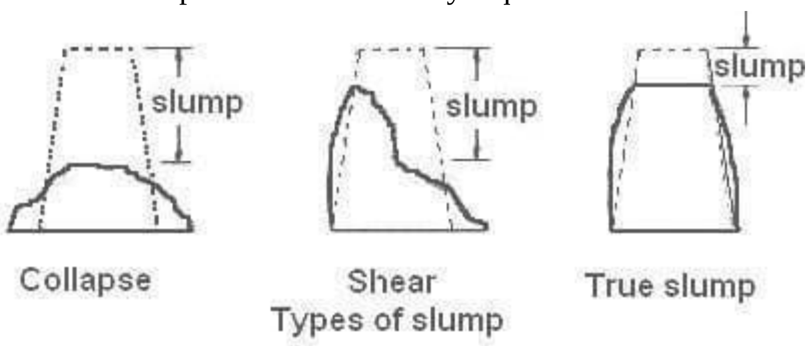


Fig:4.9.1 Workability of Concrete – Slump Test

3. Quality control at site: The strength and durability of concrete depends on the degree of quality control during construction operation at site. Nominal mixes of concrete assumes the worst quality control at site based on past experiences.

4. Weather conditions: Weather impacts the setting time of concrete. In hot climates, the concrete tends to set early due to loss in moisture, and in this case, the concrete needs to have a higher water cement ratio or special admixtures to delay initial setting of concrete. Recommendations for concrete cooling agents also required to be mentioned in the mix design for very hot weather conditions.

In cold climates, the initial setting time of concrete increases as the moisture loss rate is very low. Due to this, water cement ratio is considered appropriately. Admixtures should also be recommended to prevent freezing of concrete in case of very cold climate.

5. Exposure conditions of concrete: Exposure conditions play an important role in the mix design of concrete. The exposure conditions such as chemical actions, coastal areas etc. needs to be considered for the given site. Generally exposure conditions as per code of practices are mild, moderate, severe, very severe and extreme exposure conditions for concrete constructions.
The grade of concrete and durability requirements of concrete changes with exposure conditions. For extreme exposure conditions some standard codes mention the minimum strength of concrete as M35.

6. Batching and mixing methods: There are two types of batching methods, i.e. volumetric batching and batching by weight. These two conditions should be known for concrete mix design calculations.
Mixing methods include manual mixing, machine mixing, ready mix concrete etc. The quality control of concrete varies with each type of mixing method.

7. Quality of materials: Each construction material should have been tested in the laboratory before it is considered for mix design calculations. The type of material, their moisture content, suitability for construction, and their chemical and physical properties affects the mix design of concrete. Type of cement to be used for construction, coarse and fine aggregate sources, their size and shape should be considered.
8. Special Requirements of concrete: Special requirement of concrete such as setting times, early strength, flexural strength

4.10FACTORS TO BE CONSIDERED FOR CONCRETE MIX DESIGN
1. Compressive strength of concrete

- Concrete compressive strength is considered as the most important concrete property. It influences many other describable properties of the hardened concrete.
- The mean compressive strength (fem.) required at a specific age, usually 28 days, determines the nominal water-cement ratio of the mix.
- ISO 456-200, British Standard, and Euro code utilize the term mean compressive strength which is slightly greater than characteristic compressive strength. However, ACI Code does not use such terms.
- Other factors which influence the concrete compressive strength at a given time and are cured at a specified temperature is compaction degree.
- Finally, it is demonstrated that concrete compressive strength of fully compacted concrete is inversely proportional to the water-cement ratio.

2. Workability of concrete

- Concrete workability for satisfactory placement and compaction depends on the size and shape of the section to be concreted, the amount and spacing of reinforcement, and concrete transportation; placement; and compaction technique.
- Additionally, use high workability concrete for the narrow and complicated section with numerous corners or inaccessible parts. This will ensure the achievement of full compaction with a reasonable amount of effort.
- Frequently, slump test values used to evaluate concrete workability.
- Lastly, ACI 211.1 provides slump test values for various reinforced concrete sections which ranges from 25 mm to 175 mm.

3. Durability of concrete

- The ability of concrete to withstand harmful environment conditions termed as concrete durability.
- High strength concrete is generally more durable than low strength concrete.
- In the situations when the high strength is not necessary but the conditions of exposure are such that high durability is vital, the durability requirement will determine the utilized water-cement ratio.
- Concrete durability decreases with the increase of w/c ratio.

4. Maximum nominal size of aggregate

- Reinforcement spacing controls maximum aggregate size.
- Aggregate size is inversely proportional to cement requirement for water-cement ratio. This is because workability is directly proportional to size of aggregate
- However, the compressive strength tends to increase with the decrease in size of aggregate. a smaller aggregate size offers greater surface area for bonding with mortar mix that gives higher strength.

5. Grading and type of aggregate

- Aggregate grading influences the mix proportions for a specified workability and water-cement ratio.
- The relative proportions between coarse and fine aggregate in concrete mix influence concrete strength.
- Well graded fine and coarse aggregate produce a dense concrete because of the achievement of ultimate packing density.
- If available aggregate, which is obtained from a natural source, does not conform to the specified grading, the proportioning of two or more aggregates becomes essential.
- Additionally, for specific workability and water to cement ratio, type of aggregate affects aggregate to cement ratio.
- Lastly, An important feature of a satisfactory aggregate is the uniformity of the grading that is achieved by mixing different size fractions.

6. Quality Control at site

- The degree of control could be evaluated by the variations in test results.
- The variation in strength results from the variations in the properties of the mix ingredients, in addition to lack of control of accuracy in batching, mixing, placing, curing and testing.
- Finally, the lower the difference between the mean and minimum strengths of the mix lower will be the cement-content required. The factor controlling this difference is termed as quality control.

4.11 MIX DESIGN ACCORDING TO IS 10262-2009

Design of specifications

Step-1

- Grade designation
- Type of cement be used
- Maximum nominal size of aggregate
- Minimum and maximum cement content
- Maximum water cement ratio
- Workability

- Exposure conditions
- Maximum temperature of concrete
- Method of transporting and placing
- Early age strength
- Type of aggregate
- Type of admixture to be used

Step-2 table 4.3 testing of materials

Concrete ingredients		Tests to be done		
cement	Specific gravity	-	-	-
Coarse aggregate	Specific gravity	Water absorption	Free surface moisture	Sieve analysis
Fine aggregate	Specific gravity	Water absorption	Free surface moisture	Sieve analysis
		-	-	-

Step-3 target strength calculation:

Calculate the target strength of concrete using the formulae given below

fck' = fck + 1.65s.

where,

fck'= target compressive strength at 28 days in N/ mm^2

fck=characteristic compressive strength at 28 days in N/mm^2

s= standard deviation

the value of standard deviation is given below, can be taken for initial calculation

table 4.4

S.NO	grade of concrete	characteristic compressive strength N/mm^2	assumed standard deviation
1	M10	10	3.5
2	M15	15	3.5
3	M20	20	4.0
4	M25	25	4.0

5	M30	30	6.0
6	M35	35	6.0
7	M40	40	6.0
8	M45	45	6.0
9	M50	50	6.0
10	M55	55	6.0

Step-4 selection of water content

table4.5

Exposure Conditions	**Plain Concrete**			**Reinforced Concrete**		
	Minimum cement content kg/cum	Maximum free water-cement ratio	Minimum grade of concrete	Minimum cement content kg/cum	Maximum free water-cement ratio	Minimum grade of concrete
Mild	220	0.60	–	300	0.55	M 20
Moderate	240	0.60	M 15	300	0.50	M 25
Severe	250	0.50	M 20	320	0.45	M 30
Very Severe	260	0.45	M 20	340	0.45	M 35
Extreme	280	0.40	M 25	360	0.40	M 40

Table 4.6 type of environment depending up on different exposure conditions to concrete

Sl. No.	Environment	Exposure Conditions
I	Mild	Concrete surfaces protected against weather or aggressive conditions, except those situated in coastal areas
ii	Moderate	Concrete surface sheltered from severe rain or freezing whilst wet; concrete exposed to condensation and rain, concrete continuously under water; concrete in contact or buried under non-aggressive soil/ground water; concrete surfaces sheltered from saturated salt air in coastal area
iii	Severe	Concrete surfaces exposed to severe rain, alternate wetting and drying or occasional freezing whilst wet or severe condensation; concrete completely immersed in sea water; concrete exposed to coastal environment
iv	Very Severe	Concrete surfaces exposed to sea water spray, corrosive fumes or severe freezing conditions whilst wet; concrete in contact with or buried under aggressive sub-soil/ground water
v	Extreme	Surfaces of members in tidal zone; members in direct contact with liquid/solid aggressive chemicals

Step 5: selection of water content:

Selection of water content depends upon a number of factors such as

- Aggregate size, shape and texture
- Water cement ratio
- Type of cement
- Environmental conditions

Factors that can increase water demand as follows:

- Increased temperature at site
- Increase cement content
- Increased slump
- Increased water cement ratio
- Increased aggregate angularity

Factors that decrease water demand as follows:

- Increased aggregate size
- Reducing water cement ratio
- Using rounded aggregate

Table 4.7 maximum water content per unit volume of concrete

SI No.	Nominal Maximum Size of Aggregate (mm kg)	Maximum water content
1	10	208

2	20	186
3	40	165

Step 6: calculating cementations material content

From the water cement ratio and the quantity of water per unit volume of cement, calculate the amount of cementations material. After calculating the quantity of cementations material, compare it with the values given in the table shown in step 4.the greater of the two values is then adopted.

Step 7: finding out volume proportion for coarse aggregate and fine aggregate

Table 4.8 volume of coarse aggregate corresponding to unit volume of total aggregate for different zones of fine aggregate.

S.NO	Nominal maximum size of aggregate	Volume of coarse aggregate per unit volume of total aggregate for different zones of fine aggregate			
		Zone IV	zoneIII	zoneII	Zone **I**
1	10	0.50	0.48	0.46	0.44
2	20	0.66	0.64	0.62	0.60
3	30	0.75	0.73	0.71	0.69

Step 8:trial mix:

TEST DATA FOR MATERIALS:
Data required for mix design
(i) Concrete Mix Design Stipulation

a) Characteristic compressive strength required in the field at 28 days grade designation — M30
b) Nominal maximum size of aggregate — 10 mm
c) Shape of CA — Angular
d) Degree of workability required at site — 50-75 mm (slump)
e) Degree of quality control available at site — As per IS:456
f) Type of exposure the structure will be subjected to (as defined in IS: 456) — Mild
g) Type of cement: PSC conforming IS:455
h) Method of concrete placing: pump able concrete.
i) Specific gravity of fine aggregate-2.63
j) Specific gravity of coarse aggregate-2.61
k) Specific gravity of cement-3.14

l) Degree of quality control very good

m) Degree of workability for M30 Grade concrete-0.8 compaction factor.

n) Slump = 20mm

Target mean strength

Fck = fck +t.s

=30+1.6555×5
=38.25N/mm2

Selection W/C ratio
for M30 grade W/C ratio=0.39=0.4
Air content
Nominal size of aggregate-10mm
For 10mm entrapped air -3%

Water content and fine aggregate ratio
W/C ratio-0.6
Workability-0.8CF

Size of coarse aggregate	Water content	sand
10mm	208	40

Adjustments

M30	Water content	%sand
For decrease in w/c ratio by (0.6-0.39) =0.21 No correction since compacting factor is 0.8	0	-4.2%

Final water content &find to total aggregate ratio
Water content = (208+0) =208kg/m^3
Fine to total aggregate ratio=40-(40/100*4.2) =38.32

Determination of cement content
w/c ratio-0.39
water content-208kg/m^3
cement content =208/0.39=533.33kg/m^3

Determination of fine aggregate content

$$V = \left[W + \frac{C}{S_c} + \frac{1}{p}\frac{f_a}{S_{fa}}\right] \times \frac{1}{1000}$$

1-0.03 = (208 + 533.33/3.14 + fa/ (0.3832*2.63)) *1/1000
fa = 596.78

Determination of coarse aggregate content

$$V = \left[W + \frac{C}{S_c} + \frac{1}{1-p}\frac{C_a}{S_{ca}}\right] \times \frac{1}{1000}$$

0.98 = (208 + 520/3.15 + (1/ (1-0.46)) *Ca/2.66) *1/1000
Ca = 871.78 kg/m^3

Final mix proportions

1:1.40:1.68
w/c ratio -0.4
water content -208 kg/m^3

Adjustment for field conditions

The proportions are required to be adjusted for the field conditions fine aggregate has surface moisture of 2%

weight of F. A=728.67+0.002*728.67
=743.24 kg/m^3

Coarse aggregate absorbs 1% water

Weight of C. A=871.78-0.001*871.78
=863.06 kg/m^3

1:1.42:1.66

Twelve cubes quantity:
12*0.1*0.1*0.1=0.0312m^3
Extra for wastage=1.2*0.02=0.0144m^3
M30 proportion-1:1.42:1.66=4.08=0.0144*2400=34.56kgs
Cement content=(34.56/4.08)*1.42=8.47kgs
Fine aggregate=(34.56/08)*1.42=12.02kgs
Coarse aggregate=(34.56/4.08)*1.66=14.06kgs

Cement is replaced with silica fume as 0%,10%
Fine aggregate is replaced with vermiculate as 0%,5%,10%,15%,20%,25%

4.9 Batching proportions for M30 grade concrete

samples	cement	Silica Fume (%)	Fine aggregate	vermiculite (%)	Coarse aggregate	w/c ratio
1	8.4705	0	12.02	0	14.06	0.4
2	8.4705	0	11.43	0.6	14.06	0.4
3	8.4705	0	10.83	1.2	14.06	0.4
4	8.4705	0	1022	1.8	14.06	0.4
5	8.4705	0	9.62	2.4	14.06	0.4
6	8.4705	0	9.02	3	14.06	0.4
7	7.6234	0.847	12.02	0	14.06	0.4
8	7.6234	0.847	11.43	0.6	14.06	0.4
9	7.6234	0.847	10.83	1.2	14.06	0.4
10	7.6234	0.847	10.22	1.8	14.06	0.4
11	7.6234	0.847	9.62	2.4	1.06	0.4
12	7.6234	0.847	9.02/	3	14.06	0.4

Total quantity:

Cement =(8.47*6)+(7.62*6)=96.56kgs
Silica fume=5.06kgs
Fine aggregate= 126.29 kgs
Vermiculite=18.03 kgs
Coarse aggregate=168.72 kgs

4.12 DURABILITY TEST PROCEDURE:

- After curing of cube, the cubes surface are to be dried in a shaded area for 24 hours .take the weights of cubes before placing in to the sulphuric acid solution (4% concentrated) of pH 3.
- Cubes are placed in a drum which contains sulphuric acid with constant Ph of 5 .
- After placing, cubes are to kept in acid solution for 7 days.
- After 7 days of acid curing cubes are to be removed from the acid solution and to be kept in running water for sometime and then allow the cube surface to be dry.
- After that again take the weights of cubes and do the compressive strength test
- Note the difference in values of strengths of cubes after placing in with acid and without acid.

CHAPTER-V

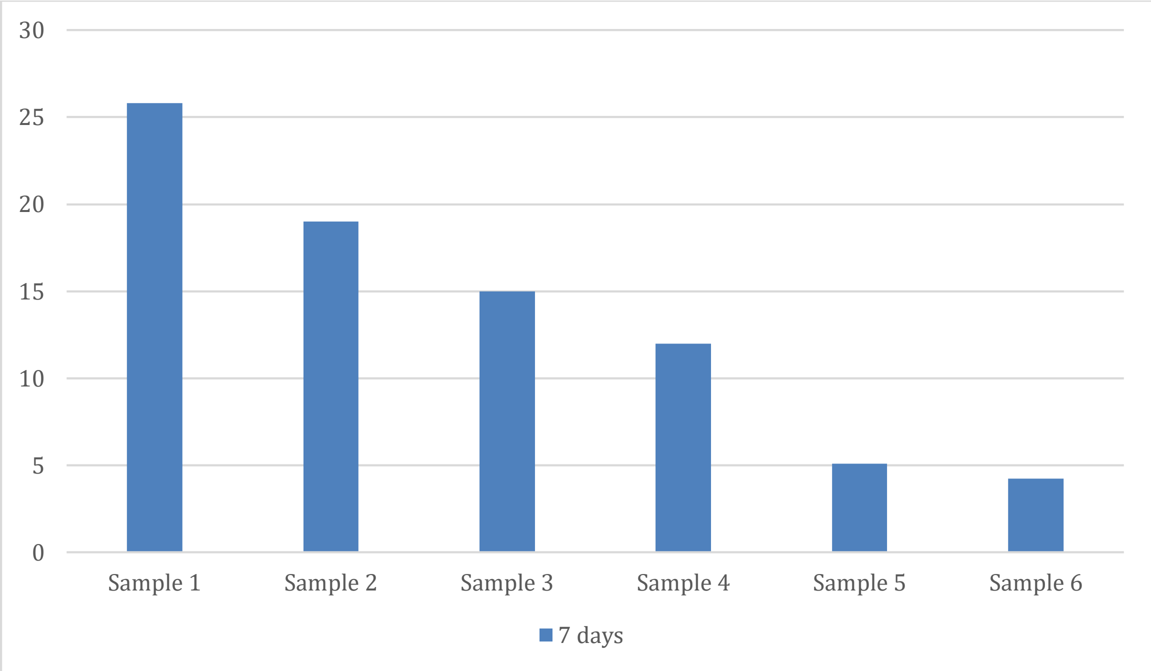
RESULTS AND DISCUSSION

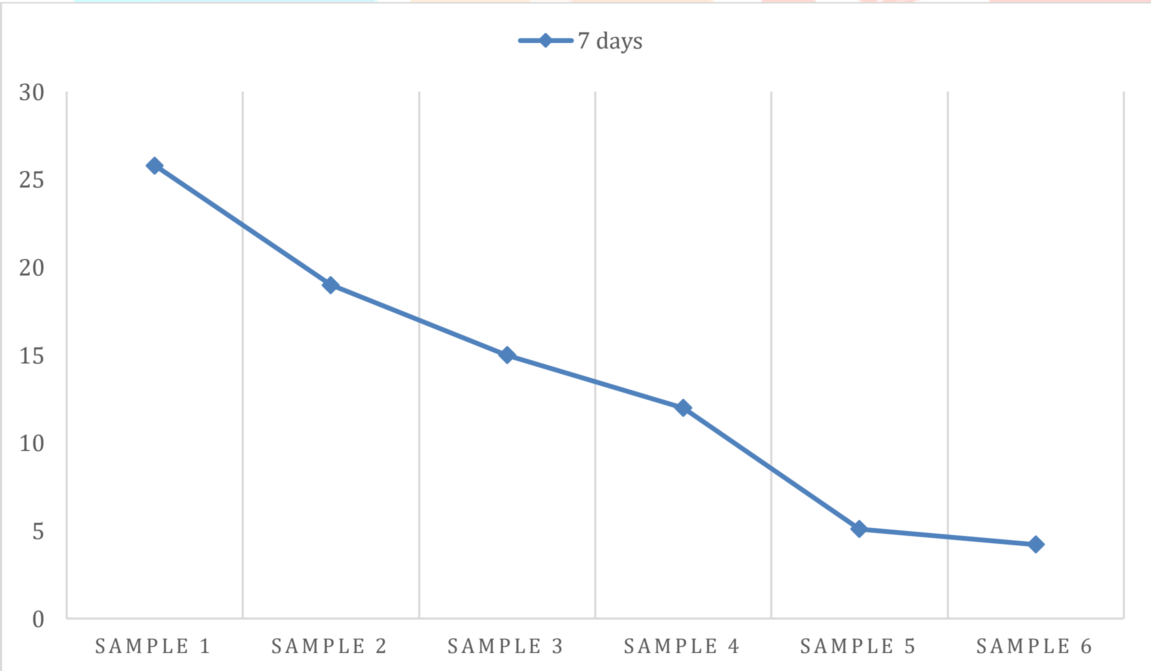
Compressive strength of M30 grade concrete for 7 days Table 5.1

Without replacement of silica fumes

Sample	Weight (Kg)	Avg Weight (Kg)	Force (KN)	Area(mm^2)	Strength(N/mm^2)	Avgas Strength(N/mm^2)
1	2.423	2.421	250	10000	25	25.8
	2.42		260	10000	26	
	2.421		265	10000	26.5	
2	2.418	2.416	180	10000	18	19
	2.416		200	10000	20	
	2.415		190	10000	19	
3	2.30	2.31	140	10000	14	15
	2.31		150	10000	15	
	2.32		160	10000	16	
4	2.29	2.276	120	10000	12	12
	2.26		110	10000	11	
	2.28		130	10000	13	
5	2.2	2.2	50	10000	5	5.11
	2.204		52.5	10000	5.25	
	2.2		51	10000	5.1	
6	2.05	2.01	45	10000	4.5	4.23
	1.99		40	10000	4	
	2		42	10000	4.2	

Graphical representation for 7 days of compressive strength by without using silica fume:

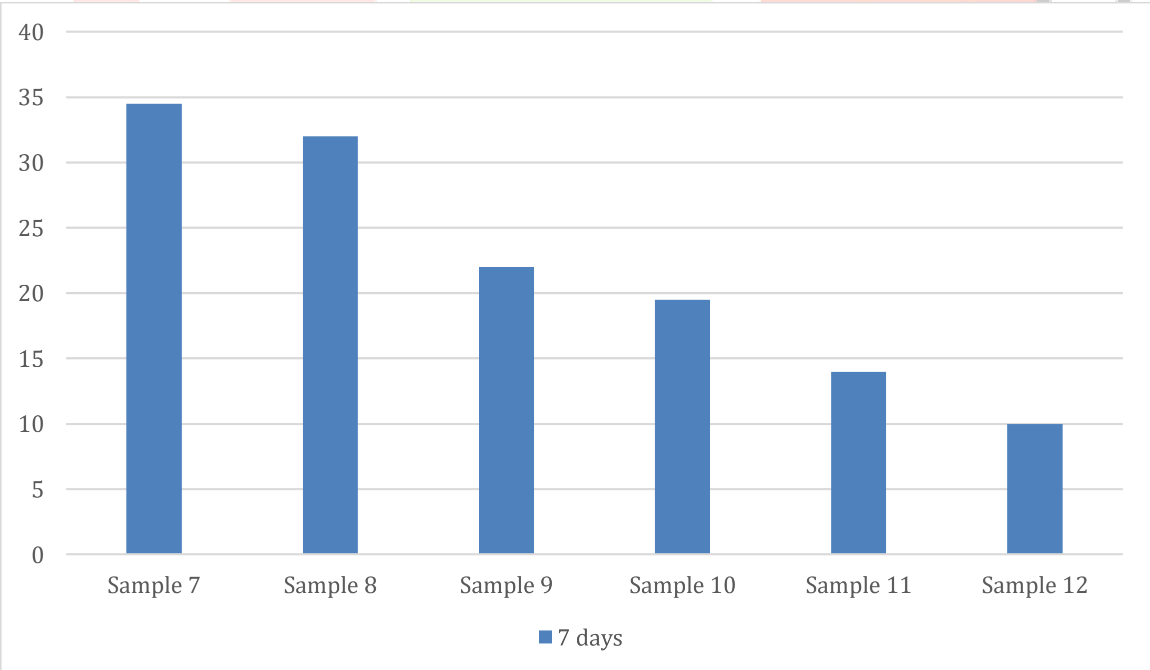


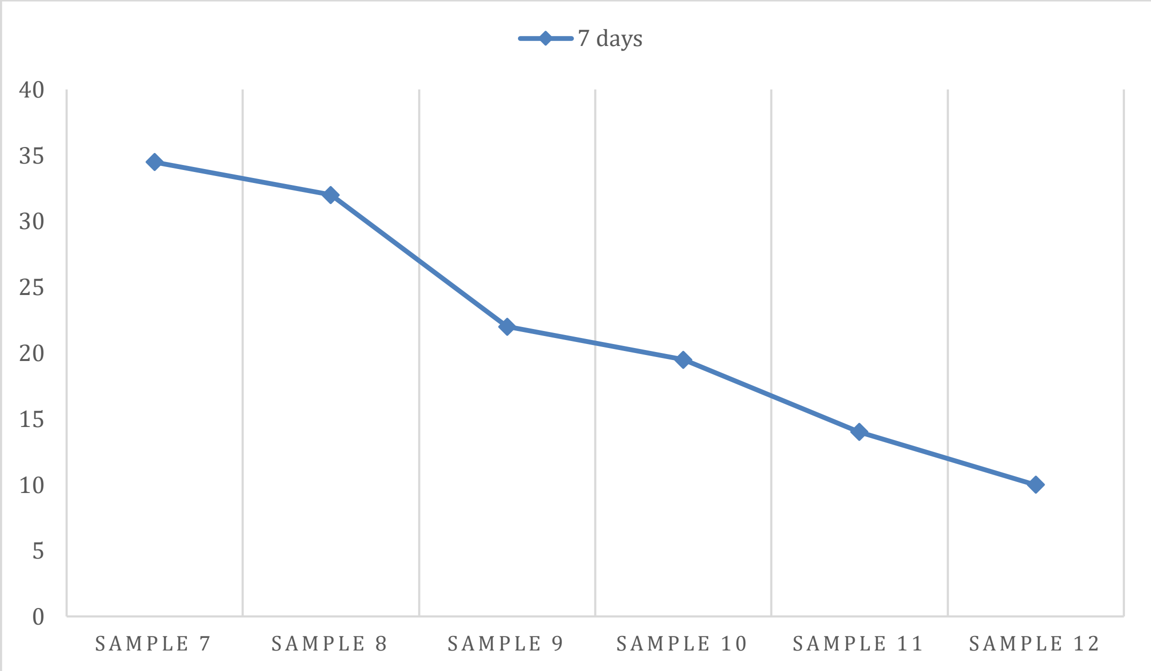


With replacement of silica fume

Sample	Weight (Kg)	Avg Weight (Kg)	Force (KN)	Area(mm^2)	Strength(N/mm^2)	Avg Strength(N/mm^2)
7	2.4	2.4	350	10000	35	34.5
	2.39		340	10000	34	
	2.41		345	10000	34.5	
8	2.35	2.36	327.5	10000	32.75	32
	2.36		302.5	10000	30.25	
	2.38		330	10000	33	
9	2.3	2.28	230	10000	23	22
	2.28		220	10000	22	
	2.27		210	10000	21	
10	2.22	2.21	200	10000	20	19.5
	2.21		190	10000	19	
	2.2		195	10000	19.5	
11	2.18	2.18	150	10000	15	14
	2.19		140	10000	14	
	2.17		130	10000	13	
12	2.15	2.14	100	10000	10	10
	2.13		90	10000	9	
	2.14		110	10000	11	

Graphical representation for 7 days of compressive strength by using silica fume:





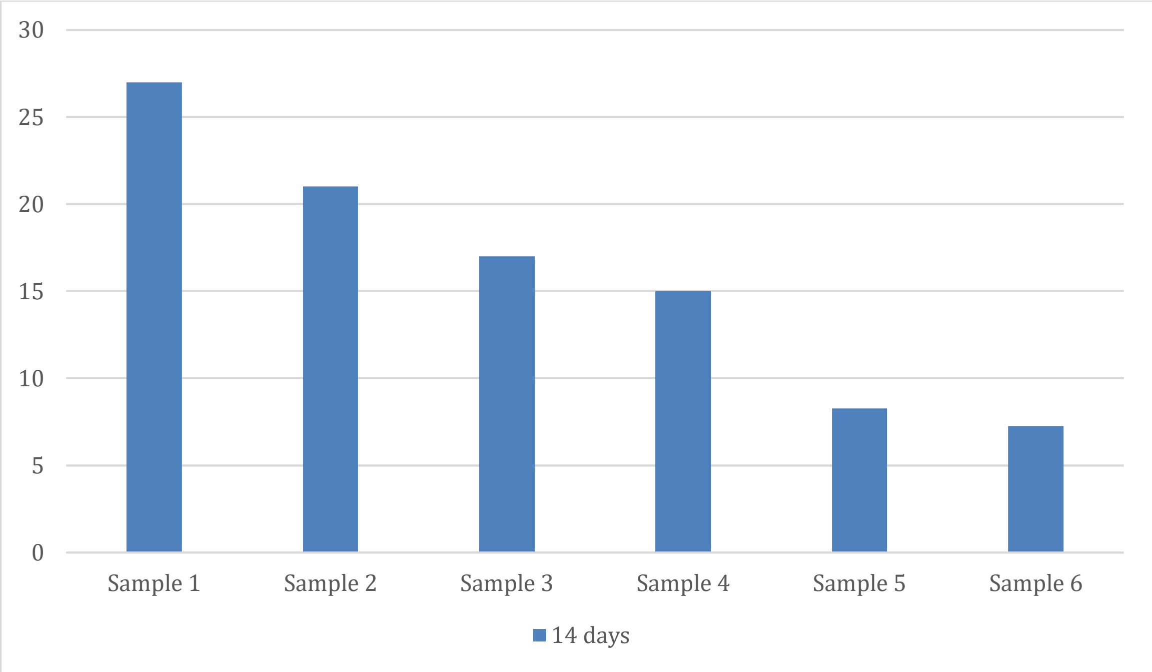
5.1.2 COMPRESSIVE STRENGTH FOR 14 DAYS

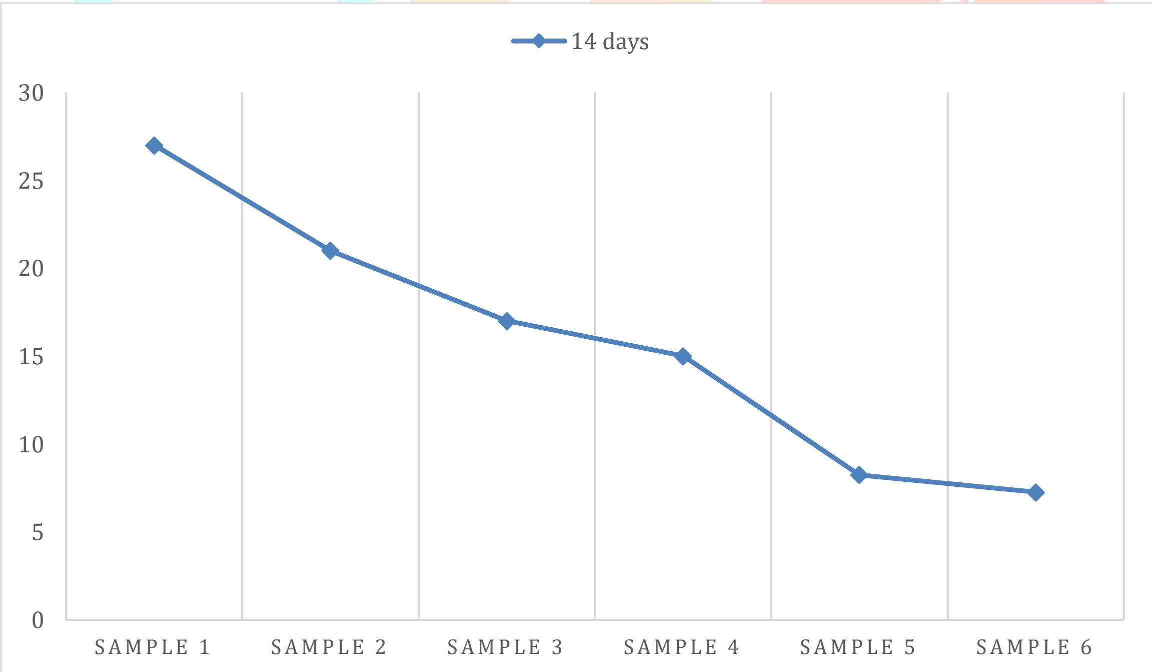
Compressive strength of M30 grade concrete for 14 days Table 5.2

Without replacement of silica fume

Sample	Weight (Kg)	Avg Weight (Kg)	Force (KN)	Area(mm^2)	Strength(N/mm^2)	Avg Strength(N/mm^2)
1	2.42	2.42	270	10000	27	27
	2.421		280	10000	28	
	2.419		260	10000	26	
2	2.415	2.416	200	10000	20	21
	2.417		210	10000	21	
	2.418		220	10000	22	
3	2.31	2.308	160	10000	16	17
	2.3		180	10000	18	
	2.316		170	10000	17	
4	2.28	2.25	150	10000	15	15
	2.25		160	10000	16	
	2.23		140	10000	14	
5	2.18	2.19	60	10000	8	8.25
	2.2		67.5	10000	9.75	
	2.21		70	10000	7	
6	2.1	2.05	75	10000	7.5	7.25
	2.05		72.5	10000	7.25	
	2		70	10000	7	

Graphical representation for 14 days of compressive strength by without using silica fume:

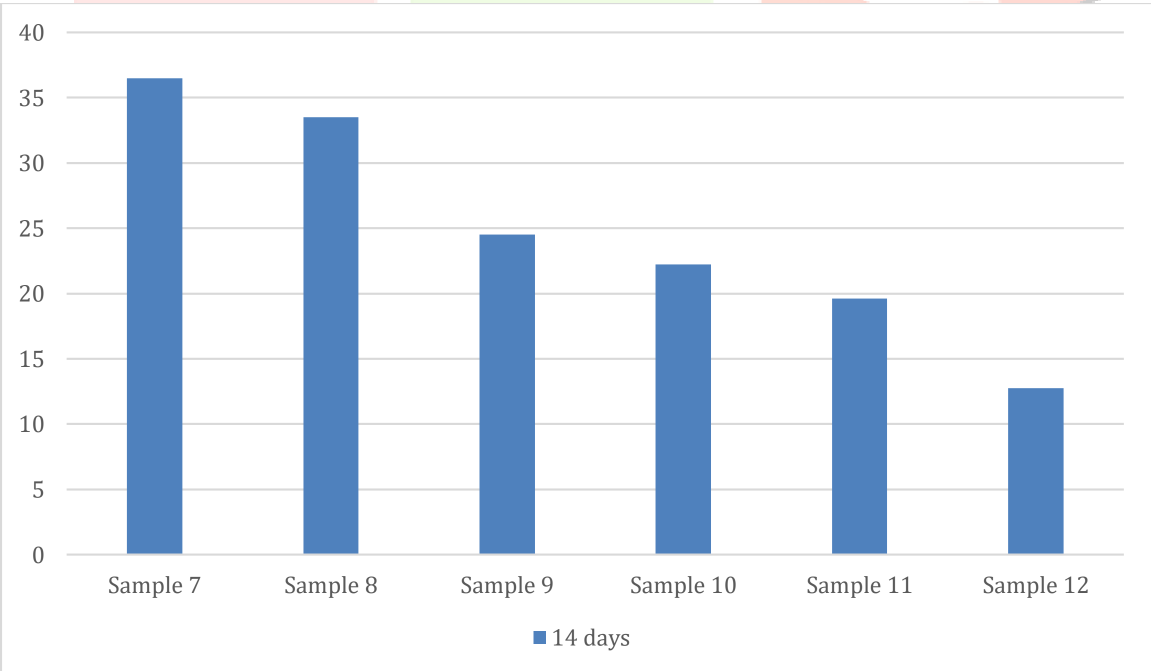


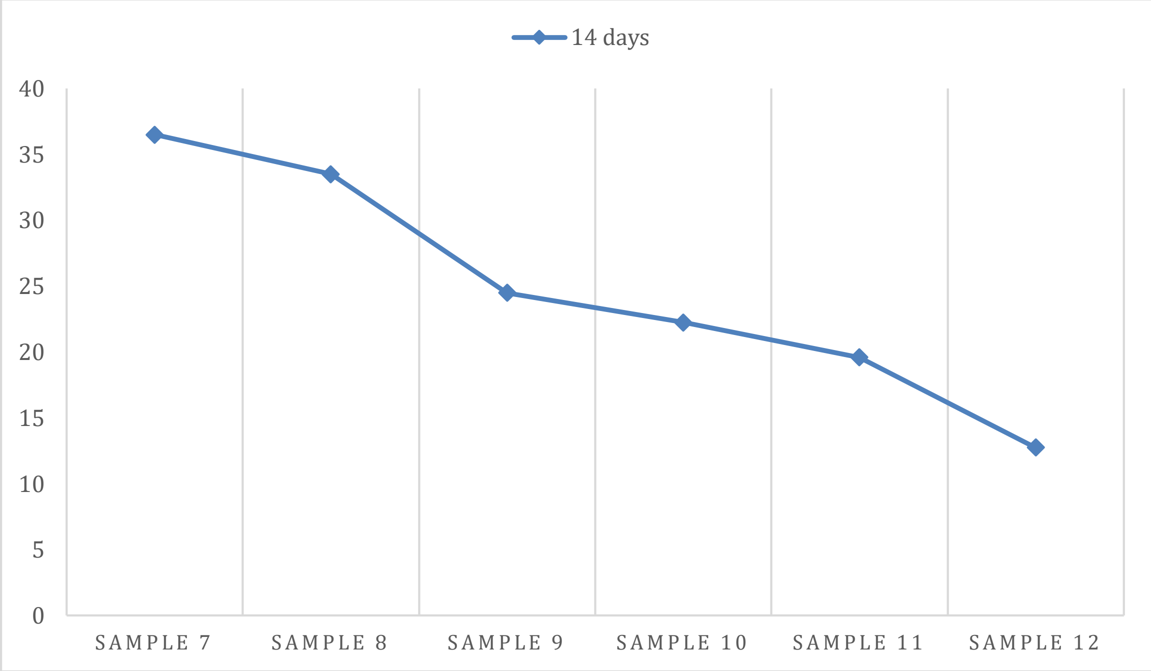


With replacement of silica fume

Sample	Weight (Kg)	Avg Weight (Kg)	Force (KN)	Area(mm^2)	Strength(N/mm^2)	Avg Strength(N/mm^2)
7	2.42	2.40	360	10000	36	36.5
	2.41		362.5	10000	36.25	
	2.39		370	10000	37	
8	2.36	2.37	336	10000	33.6	33.75
	2.38		337.5	10000	33.75	
	2.39		340	10000	34	
9	2.31	2.29	250	10000	25	24.5
	2.29		240	10000	24	
	2.28		245	10000	24.5	
10	2.23	2.23	225	10000	22.5	22.25
	2.22		220	10000	22	
	2.24		222.5	10000	22.25	
11	2.19	2.19	190	10000	19	19.6
	2.2		195.5	10000	19.55	
	2.18		202.5	10000	20.25	
12	2.16	2.15	125	10000	12.5	12.75
	2.14		130	10000	13	
	2.15		127.5	10000	12.75	

Graphical representation for 14 days of compressive strength by using silica fume:




14 days
40
35
30
25
20
15
10
5
0
SAMPLE 7
SAMPLE 8
SAMPLE 9
SAMPLE 10
SAMPLE 11
SAMPLE 12

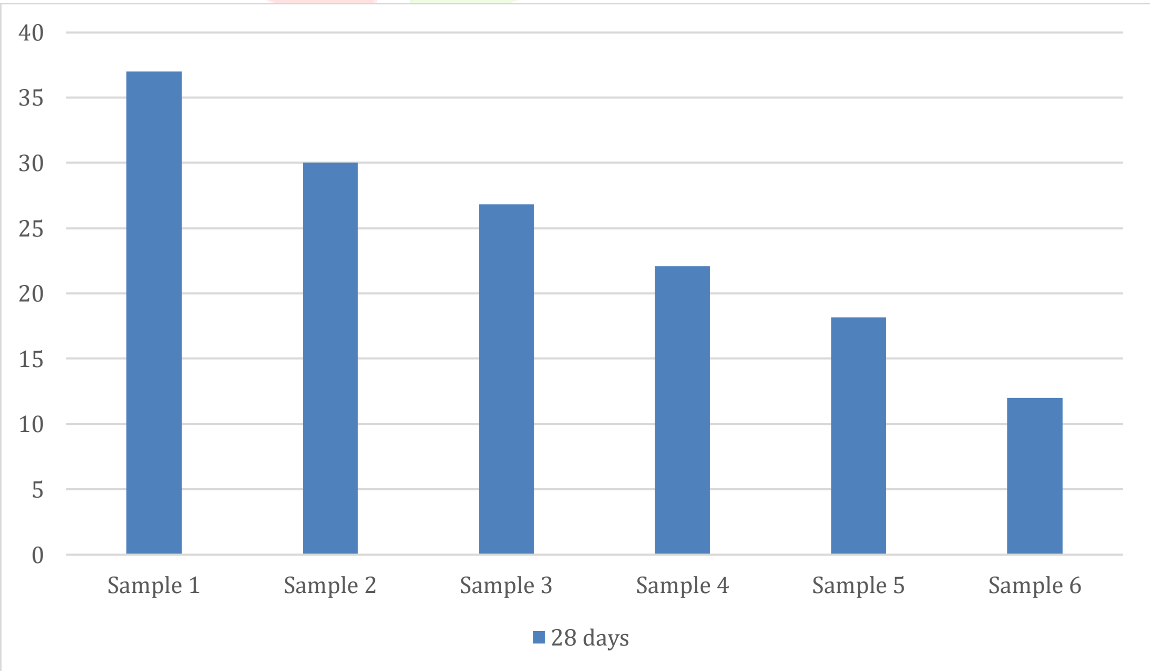
5.1.3 COMPRESSIVE STRENGTH FOR 28 DAYS

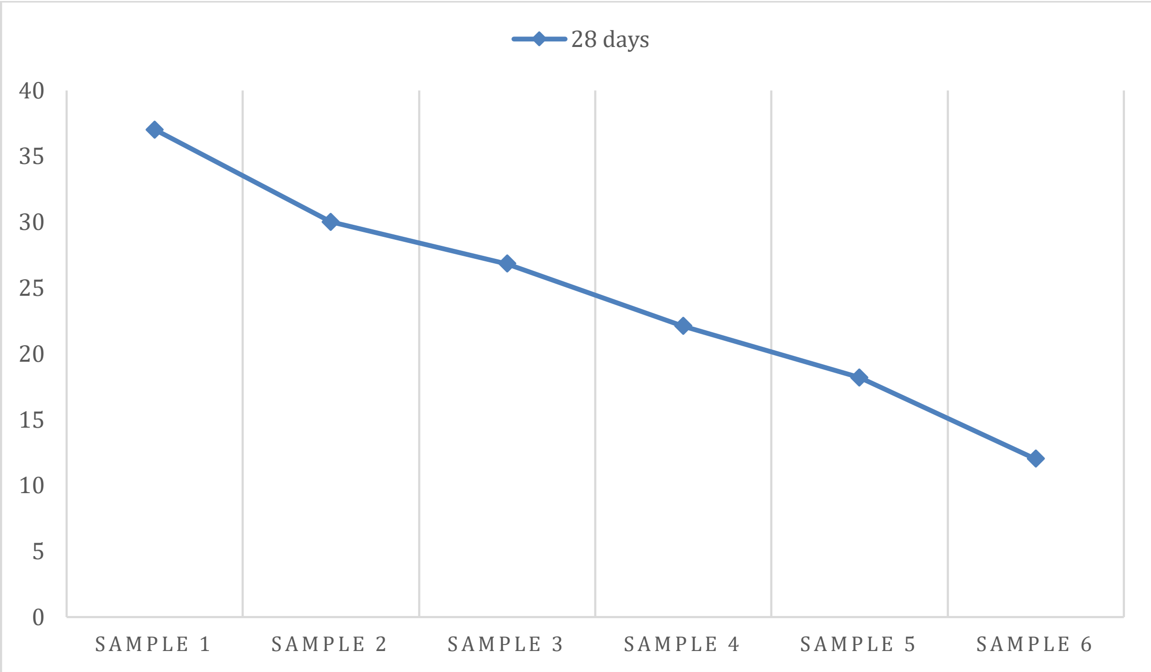
Compressive strength of M30 grade concrete for 28 days Table 5.3

Without replacement of silica fume

Sample	Weight (Kg)	Avg Weight (Kg)	Force (KN)	Area(mm^2)	Strength(N/mm^2)	Avg Strength(N/mm^2)
1	2.45	2.43	300	10000	37	37
	2.42		320	10000	38	
	2.43		320	10000	36	
2	2.39	2.39	300	10000	30	30
	2.4		290	10000	29	
	2.38		310	10000	31	
3	2.32	2.325	270	10000	27	26.83
	2.315		275	10000	27.5	
	2.34		260	10000	26	
4	2.29	2.26	225	10000	22.5	22.08
	2.26		220	10000	22	
	2.24		217.5	10000	21.75	
5	2.19	2.20	190	10000	19	18.18
	2.21		180	10000	18	
	2.22		175.5	10000	17.55	
6	2.12	2.09	130	10000	13	12
	2.1		120	10000	12	
	2.05		110	10000	11	

Graphical representation for 28 days of compressive strength by without using silica fume:

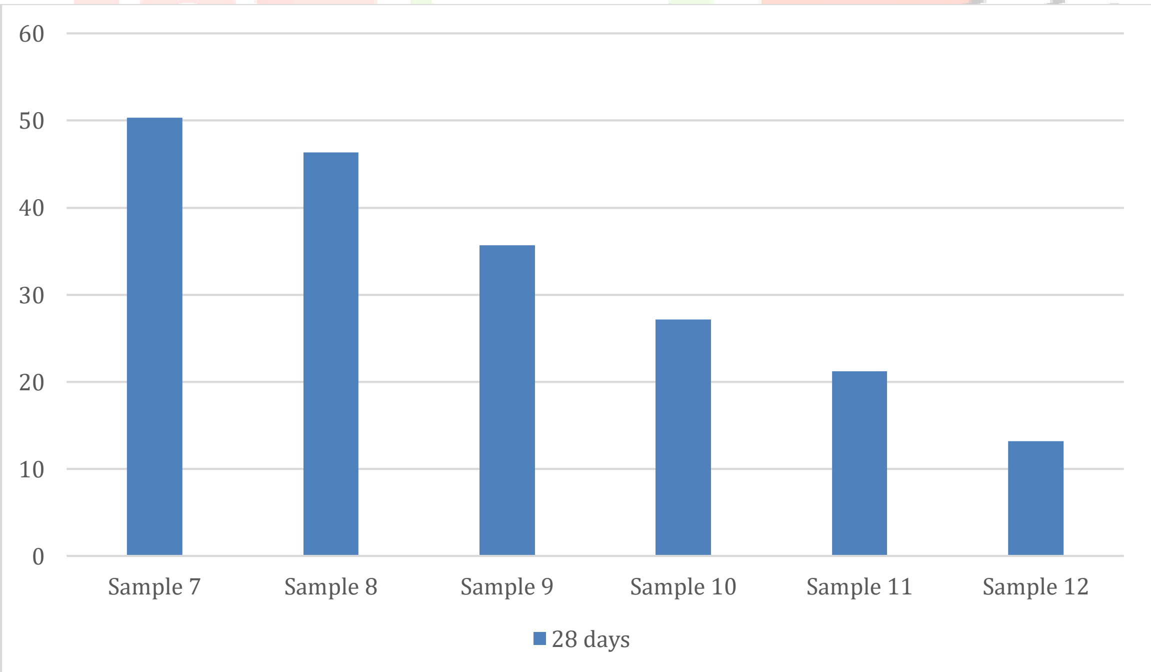


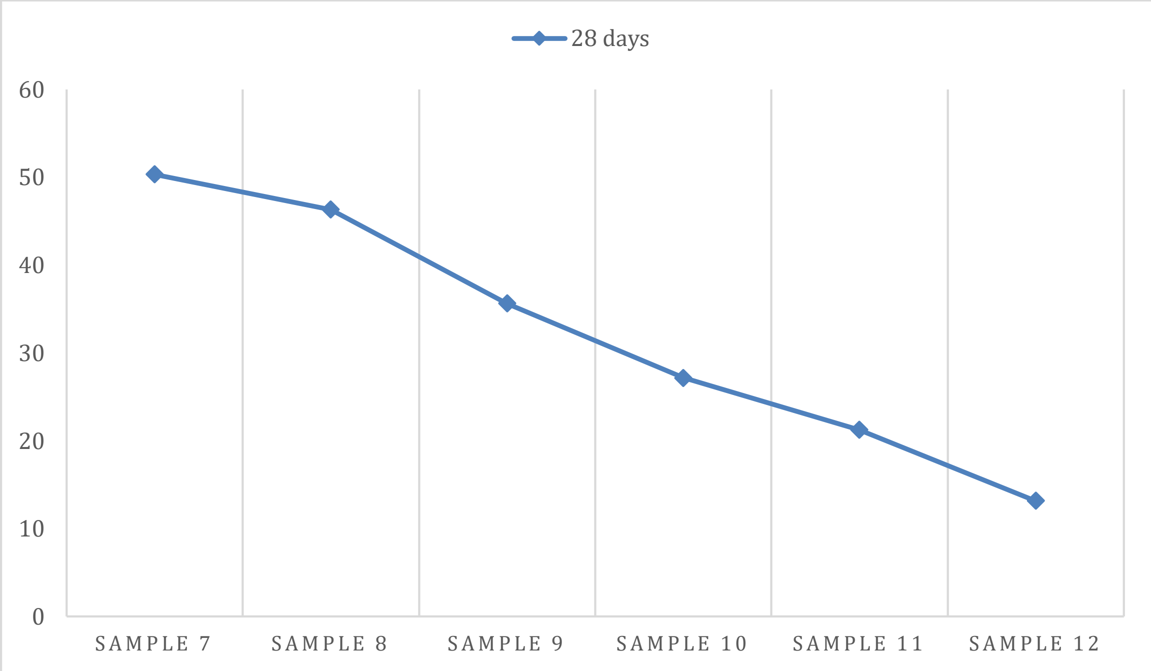

28 days
40
35
30
25
20
15
10
5
0
SAMPLE 1
SAMPLE 2
SAMPLE 3
SAMPLE 4
SAMPLE 5
SAMPLE 6

With replacement of silica fume

Sample	Weight (Kg)	Avg Weight (Kg)	Force (KN)	Area(mm^2)	Strength(N/mm^2)	Avg Strength(N/mm^2)
7	2.28	2.29	480	10000	48	50.33
	2.29		520	10000	52	
	2.31		510	10000	51	
8	2.27	2.26	480	10000	48	46.33
	2.26		440	10000	44	
	2.25		470	10000	47	
9	2.23	2.21	340	10000	34	35.66
	2.22		380	10000	38	
	2.19		350	10000	35	
10	2.18	2.166	260	10000	26	27.18
	2.17		280	10000	28	
	2.15		275.5	10000	27.55	
11	2.14	2.148	220	10000	22	21.25
	2.15		200	10000	20	
	2.155		217.5	10000	21.75	
12	2.13	2.12	130	10000	13	13.18
	2.11		130	10000	13	
	2.12		135.5	10000	13.55	

Graphical representation for 28 days of compressive strength by using silica fume:





Compressive strength for 7,14,28 days:

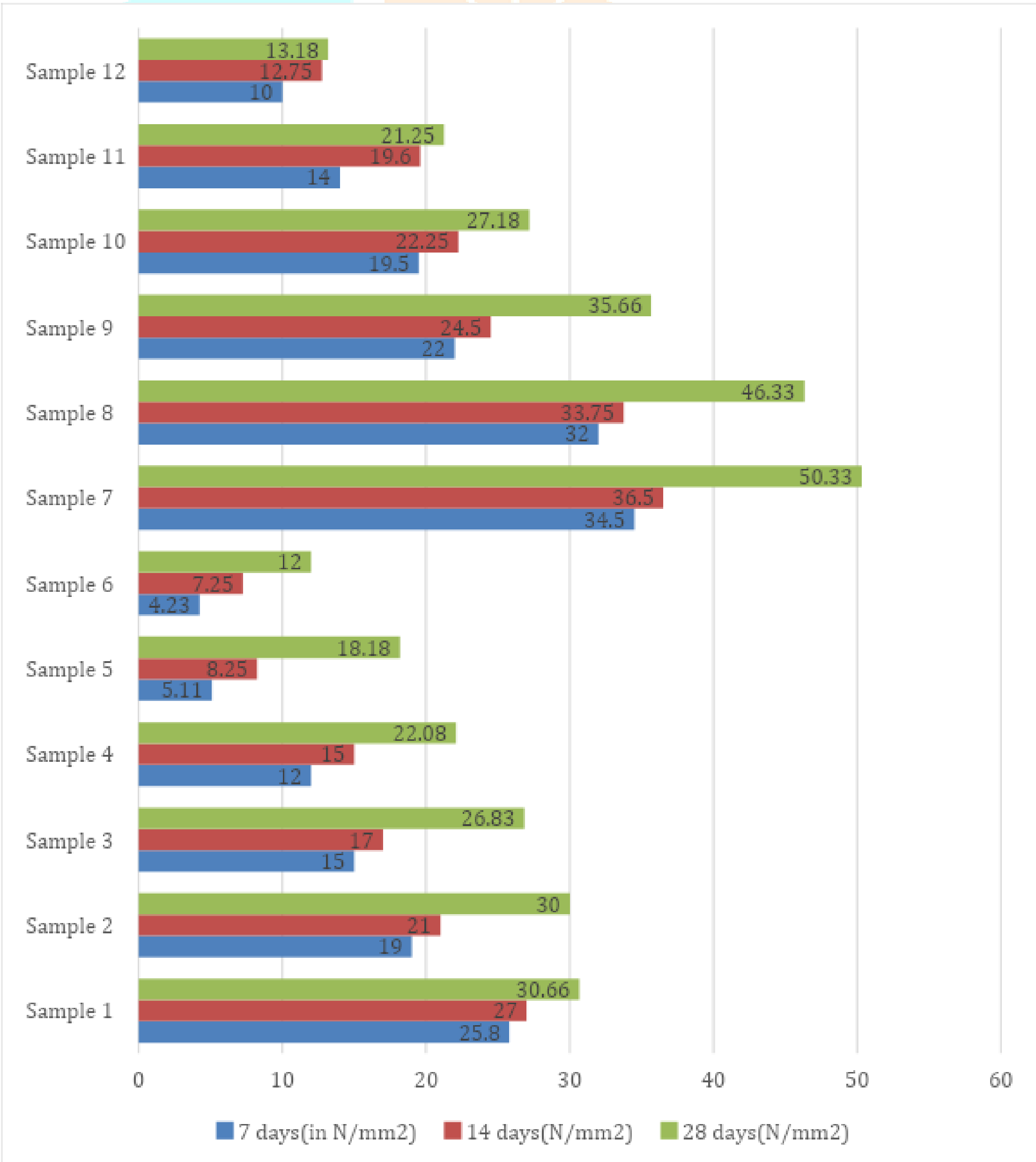


Table 5.4 durability test (sulphuric acid test) for M30 Grade concrete for 7 days:

sample	Weight (kg)	Force (KN)	Area(mm2)	Strength(N/mm2)	average strength(N/mm2)
1	2.25	445	10000	44.5	
	2.4	450	10000	45	33.575
	2.3	448	10000	44.8	
2	2.45	180	10000	18	
	2.45	200	10000	20	19
	2.45	190	10000	19	
3	2.33	230	10000	23	
	2.30	255	10000	25.5	24.23
	2.32	243	10000	24.3	
4	2.29	145	10000	14.5	
	2.31	180	10000	18	16.25
	2.30	162.5	10000	16.25	
5	2.20	55	10000	5.5	
	2.14	85	10000	8.5	7
	2.17	70	10000	7.0	
6	2.30	108	10000	10.8	

	2.30	110	10000	11	10.9
	2.30	109	10000	10.9	
7	2.36	475	10000	47.5	
	2.35	450	10000	45.0	46.25
	2.34	462.5	10000	46.25	
8	2.36	360	10000	36.0	
	2.34	380	10000	38.0	37
	2.35	370	10000	37.0	
9	2.31	255	10000	25.5	
	2.38	280	10000	28.0	26.75
	2.28	267.5	10000	26.75	
10	2.17	175	10000	17.5	
	2.20	272	10000	27.2	22.35
	2.18	223.5	10000	22.35	
11	2.2	205	10000	20.5	
	2.24	207	10000	20.7	20.6
	2.23	206	10000	20.6	
12	2.16	125	10000	12.5	

	2.19	107	10000	10.7	11.5
	2.14	116	10000	11.6	

Comparison Compressive strength for 28days with acid and without acid

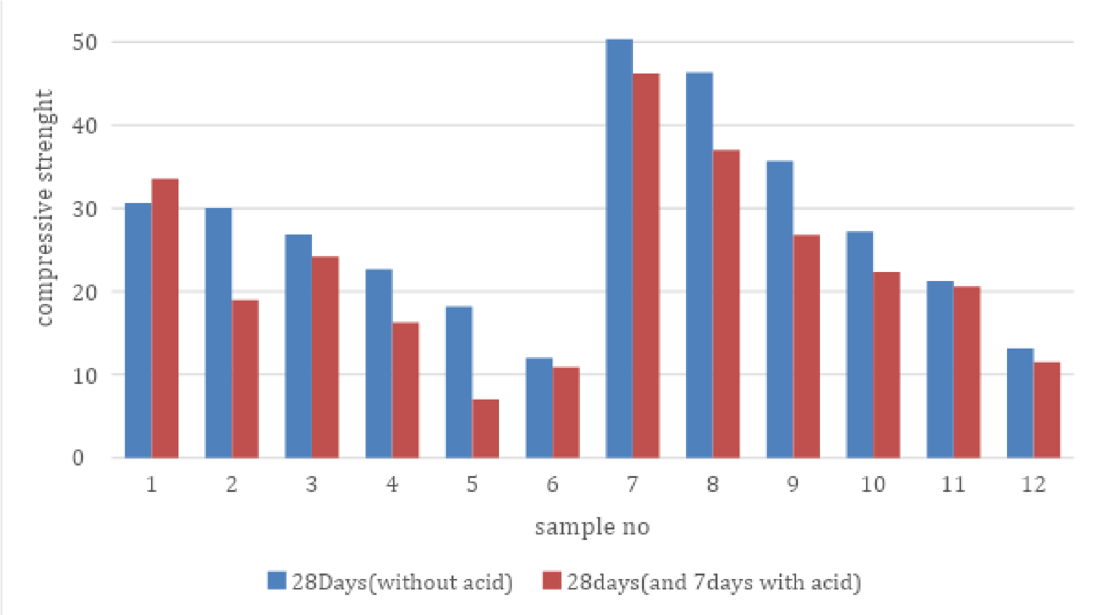


Table 5.5 comparing of %of increase or decrease of compressive strengths with and without acid for 7 days

Sample no	Compressive strength before acid			Strength after acid test			%loss or gain		
	(1)	(2)	(3)	(1)	(2)	(3)	(1)	(2)	(3)
1	30	30	32	44.5	45	44.8	14.5	15	14.8
2	30	29	31	18	20	19	-12	-9	-12
3	27	27.5	26	23	25.5	24.3	-4	-2	-1.7
4	22.5	22	21.5	14.5	18	16.25	-8	-4	-5.5
5	19	18	17.5 5	5.5	8.5	7	-13.5	-9.5	-10.55
6	13	12	11	10.8	11	10.9	-2.2	-1	-0.1
7	48	52	51	47.5	45	46.25	-0.5	-7	-4.75

8	48	44	47	36	38	37	-12	-6	-10
9	34	38	35	25.5	28	26.75	-8.5	-10	-8.25
10	26	28	27.5 5	17.5	27.2	22.35	-8.48	-0.8	-5.2
11	22	20	21,5	20.5	20.7	20.6	-1.5	0.7	-1.15
12	13	13	13.5 5	12.5	10.7	11.6	-0.5	-2.3	-1.95

of compressive strength with acid and without acid

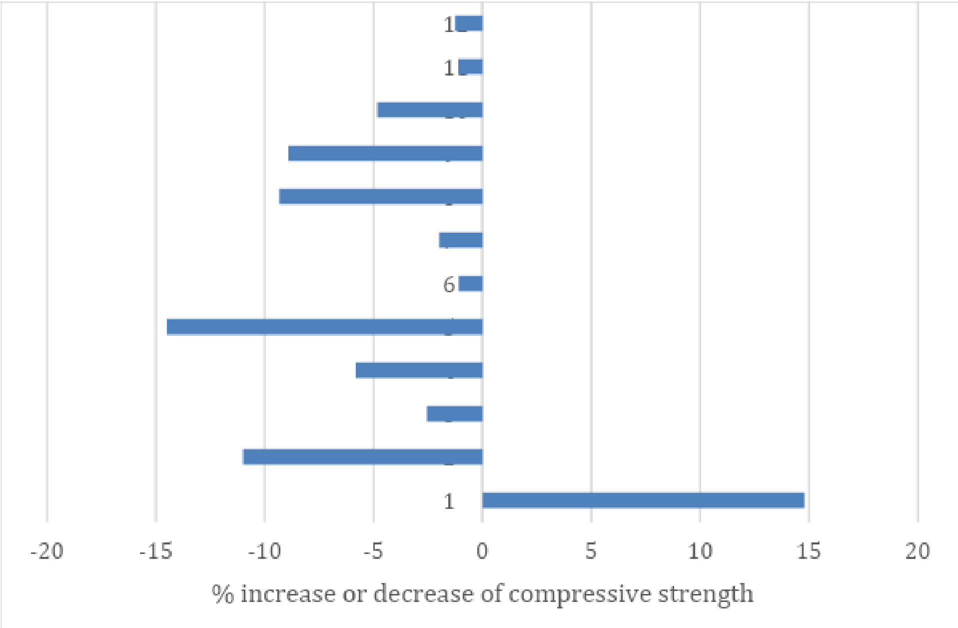


PHOTO GRAPHS:

fig.5

fig.6

fig.7

fig.8

fig.9

CONCLUSION

Based on above experimental results following conclusions were made:

6.1 Conclusion

- Upon analysis of results it was found that compressive strength with 10% replacement of Silica Fume was substantially higher than 0% Silica fume replacement and compressive strength decreased with increase in vermiculite percentage.
- Upon increasing of vermiculite percentage as a partial replacement of fine aggregate with 0% silica fume strength decreased
- Minimum strength obtained without silica fume is 11N/mm^2 and with replacement of silica fume the minimum strength is 13N/mm^2
- The compressive strength at 7,14,28 days for 10% Silica Fume replacement was found to be very high
- The maximum compressive strength was achieved for sample 7 i.e. by replacing cement with 10% of Silica, at 28 days.
- The compressive strength was found to be increased compared to conventional concrete
- On comparison of water and acid curing, it was found that maximum compressive strength in acid curing was substantially more than water curing at 7 days and lesser than 28 days water curing
- The maximum compressive strength at 28 days in water curing was found to be 52 N/mm^2 , while in acid curing it was found to be 47.5N/mm^2
- The maximum compressive strength at 7 days in water curing was obtained at 10% Silica fume replacement while in acid curing it was obtained by replacing cement with 10% Silica fume and fine aggregate with 5% vermiculite.
- Resistance against alkaline attack of silica fume concrete increases as silica fume content increases from 0% to 10%

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