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Experimental Investigation On Compressive Strength Of Concrete By Replacement Of Cement Partially With Hypo Sludge

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ABSTRACT

Hypo Sludge is a waste produced in the paper manufacturing industry. Paper mills generate more than 4 million tons of sludge each year for disposal. Hypo Sludge is known to contain useful fibers and chemicals, as my project to get good results by adding of ferrous oxide to the hypo sludge to the fly ash improve the strength, durability, and life span of concrete structures exposed to weather. Paper making generally produces a large amount of solid waste. Paper fibers can be recycled only a limited number of times before they become too short or weak to make high quality paper. It means that the broken, low-quality paper fibers are separated out to become waste sludge. All the inks, dyes, coatings, pigments, staples and "stickiest" (tape, plastic films, etc.) are also washed off the recycled fibers to join the waste solids. The shiny finish on glossy magazine-type paper is produced using a fine kaolin clay coating, which also becomes solid waste during recycling. This paper mill sludge consumes a large percentage of local landfill space for each and every year. Worse yet, some of the wastes are land spread on cropland as a disposal technique, raising concerns about trace contaminants building up in soil or running off into area lakes and streams.

This research work describes the feasibility of using the Hypo Sludge in concrete production as replacement of cement by weight. The use of Hypo Sludge in concrete formulations as a supplementary cementations material was tested as an alternative to conventional concrete. The mix has been replaced by Hypo Sludge accordingly in the range of 0% (without Hypo Sludge), 10%, 20%, 30% and 40% by weight of cement for M-40 mix.

This experimental investigation on strength of concrete and optimum percentage of the partial replacement by preparing a mix M40 grade was designed as per Indian Standard method and the same was used to prepare the test samples. The design mix proportion used were Conventional Concrete, 10%, 20%, 30%, 40% replacement of cement by industrial waste like fly ash and hypo sludge. In the test performed, the optimum compressive stress obtained by utilizing paper waste was at 30% replacement. At the place where strength is not of more importance or rather structure is for temporary basis then design mix proportion up to 40% replacement can also be utilized. Test also point towards developing low cost concrete by varying design mix proportion from 10%replacement to 40%replacement. The compared values of cost show gradual decrement in total cost of per cubic meter concrete.

INTRODUCTION

GENERAL

Paper mill sludge is a major economic and environmental problem for the paper and board industry. The material is a by-product of the de-inking and re-pulping of paper. The total quantity of paper mill sludge produced in the world is many million tones. The main recycling and disposal routes for paper sludge are land-spreading as agricultural fertilizer, producing paper sludge ash, or disposal to landfill. In functional terms, paper sludge consists of cellulose fibers, fillers such as calcium carbonate and china clay and residual chemicals bound up with water. The moisture content is typically up to 40%. In this paper presents making hypo sludge from paper waste, which is use as a construction material.

Paper making generally produces a large amount of solid waste. Paper fibers can be recycled only a limited number of times before they become too short or weak to make high quality paper. Different percentage of hypo sludge replacement. The testing is just carried out after 56 days of casting. The resting specimen was 150mm diameter and 300 mm height cylinder, 150mmX150mmX150mm cube and 600X150X150mm beam. There were total of five batches of concrete mixes, consists of every 10% increment of hypo sludge, fly ash, ferrous oxide replacement from 0%, 10%, 20%, 30% and 40% by its weight. The new technology will offer the pulp and paper industry a practical and economical solution for waste disposal. It will also provide the concrete industry with a low-cost source of fibers to produce a better product for its customers. Government purchases of concrete could potentially decrease by one-third, equal to 20 million cubic yards of concrete annually. By avoiding that amount of concrete production, the industry's annual energy use and carbon dioxide emissions will be significantly reduced, which, along with keeping the mill sludge out of landfills, will be of significant benefit to the environment.

Fly ash is one of the types of coal combustion by-products .The use of these by-products offers environmental advantages divert the material from the waste stream, reduce the energy used in processing virgin materials, use of virgin materials, and decreases pollution. India is a resourceful country for fly ash generation with an annual output of over 110 million tones, but utilization is still below 20 % in spite of quantum jump in last three to four years. Fly ash is a waste by-product from thermal power plants, which use coal as fuel. It is estimated that about 125 million tones of fly ash is being produced from different thermal power plants in India. It consumes thousands of hectares of agriculture land for its disposal. It causes serious health and environmental problems. In spite of continuous efforts made and incentives offered by the government, hardly very few percentage of the produced ash is being used for gainful purposes like brick making, cement manufacture, soil stabilization and fill material. In order to utilize fly ash in bulk quantities, ways and means are being explored all over the world to use it for the construction of embankments and roads. Paper mill sludge is a major economic and environmental problem for the paper and board industry.

HYPO SLUDGE

Hypo Sludge Properties

Where, this hypo sludge contains, low calcium and maximum calcium chloride and minimum amount of silica. Hypo

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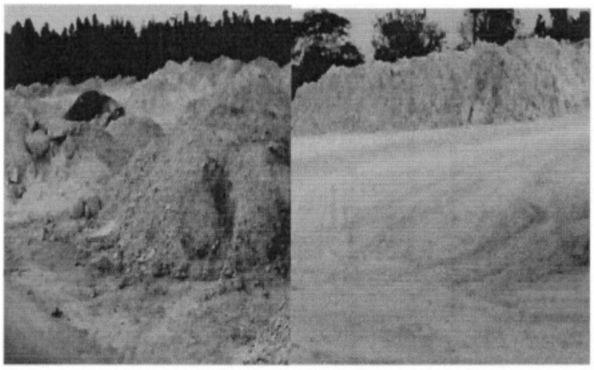
sludge behaves like cement because of silica and magnesium properties. This silica and magnesium improve the setting of the concrete. While producing paper the various wastes are comes out from the various processes in paper industries. Due to the cement production green house gases are emitted in the atmosphere. For producing 4 million tonnes of cement, 1 million green house gases are emitted. Also, to reduce the environmental degradation, this sludge has been avoided in mass level disposal in land. To eliminate the ozone layer depletion, production of cement becomes reduced. For this, the hypo sludge is used as partial replacement in the concrete as high performance concrete. By utilizing this waste the strength will be increased and also cost reduction in the concrete is achieved



OBJECTIVES OF THE STUDY

To investigate the utilization of fly ash, ferrous oxide as Supplementary Cementitious Materials (SCM) and influence of these hypo sludge on the Strength on concretes made with different Cement replacement levels.

- ➢ To find compressive strength of the concrete cube, beam and cylinder.
- ➢ To compare the results of concretes like hypo sludge concrete with concrete.
- ➢ To compare the results of compressive strength of each mixes of concretes.

1.3 SCOPE OF THE STUDY

a) To provide a most economical concrete.
b) It should be easily adopted in field.
c) Using the wastes in useful manner.
d) To reduce the cost of the construction.
e) To promote the low cost housing to the E.W.S. group people.
f) To find the optimum strength of the partial replacement of concrete.
g) Minimize the maximum demand for cement.
h) Minimize the maximum degradation in environment due to cement and safeguard the ozone layer from green house gases.
i) To study the crack development in hardened concrete.

METHODOLOGY

a) Tested the material properties as per Indian standards code (IS 383 – 1996) procedures.
b) Mix design for concrete proportion has been developed as per IS 10262 – 1982.
c) Casted and cured the concrete specimens as per Indian standards procedures.
d) The characteristic strength of hardened concrete specimen was tested as per IS 456 – 2000.
e) Finding the optimum strength of optimum replacement of hypo sludge as cement.
f) Compare the results of conventional concrete and partial replacement concrete.

STUDY OF MATERIALS

3.1 HISTORY:

Hypo sludge produced in a large amount as by product of paper industry and is usually used in concrete production as partial replacement of cement. It contains low calcium and minimum amount of silica and its due to presence of silica and magnesium properties, that it behaves like cement.

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Figure-2

The chemical composition of paper will depends on the type or grade of paper. Typically most grades of paper consist of organic and inorganic material. Organic portion consisting of cellulose, hemi-cellulose, lignin and or various compound of lignin (Na-lignite etc.) may be 70 to 100%. Inorganic portion consisting of mainly filling and loading material such as calcium carbonate, clay, titanium oxide etc., may be 0 - 30% of paper.

Table-1

Type/Grade of Paper	Organic	Inorganic
1. Newsprint	>95%	<5%
2. Corrugated (Media & Liner)	>95%	<5%
3. Writing, printing, copying & book paper	70-100%	0-30%
4. Hygiene Tissue	>98%	<2%

The basis weight, substance or gram mage is obviously most fundamental property of paper board. The Basis weight of paper is the weight per unit area. This can be expressed as the weight in grams per square meter (GSM or g/m^2), pounds per 1000 sq. ft. or weight in Kg s or pounds per ream (500 sheets) of a specific size. Paper is sold by weight but the buyer is interested in area of paper. The basis weight is what determines, how much area the buyer gets for a given weight. e.g., if basis weight is 50 g/m^2, for every 1 kg weight, the buyer gets 20 m^2.

When the basis weight is expressed as ream weight, it tells the buyers how many reams he/she getting for a given weight. For papermaker basis weight is important from point of view of production rate. For a given machine deckle and machine speed, the production rate

per day in MT will be = Machine Deckle(m) * Machine Speed (m/min) * Basis Weight (g/m^2) * 1440/1000000.

Bulk is another very important parameter of paper particularly for printers. Bulk is a term used to indicate volume or thickness in relation to weight. It is the reciprocal of density (weight per unit volume). It is calculated from caliper and basis weight. Bulk (cubic centimeter/g) = Thickness (mm)* 1000/ Basis Weight (g/m^2). Sheet bulk relates to many other sheet properties. Decrease in bulk or in other words increase in density makes the sheet smoother, glossier, less opaque, darker, lower in strength etc.

High bulk is desirable in absorbent papers while lower bulk is preferred for printing papers particularly bible paper, dictionary paper etc. Book Bulk: It is defined as the overall thickness in mm of a given number of paper sheets.The bulking number is defined as number. Cellulose fibers (main constituent of paper) swell in diameter from 15 to 20% from dry condition to saturation point.

Since most of the fiber in paper sheet are aligned in the machine run direction, absorption and de-absorption of moisture by paper causes the change in CD dimension. Such changes in dimension may seriously affect register in printing processes and interfere with the use of such items as tabulating cards. Dimensional changes in paper originate in the swelling and contraction of the individual fibers Change that occurs in the dimensions of paper with variation in the moisture content is an important consideration in the use of paper.

Formation is an indicator of how uniformly the fibers and fillers are distributed in the sheet. Formation plays an important role as most of the paper properties depend on it. A paper is as strong as its weakest point. A poorly formed sheet will have more weak and thin or thick spots. These will affect properties like strength, coating capabilities and printing characteristics of the paper, etc. There is no standard method or unit to express formation.

Almost all grade of paper has some percentage of moisture. Moisture in paper varies from 2 - 12% depending on relative humidity, type of pulp used, degree of refining and chemical used. Most physical properties of paper undergo change as a result of variations in moisture content. Water has the effect of plasticizing the cellulose fiber and of relaxing and weakening the inter-fiber bonding. The absorption and reflectance of certain bands of infrared and microwave radiation by paper are affected by its moisture content. The amount of water present in a sheet of paper is usually expressed as a percent. The amount of water plays an important role in calendaring, printing and converting process. Moisture control is also significant to the economic aspect of paper making. Water comes free. Poor moisture control can adversely affect many paper properties. The absolute moisture content is expressed as a % of the paper/paperboard weight. The sample is generally not conditioned while doing this test.

It is most important parameter for printer. Smoothness is concerned with the surface contour of paper. It is the flatness of the surface under testing conditions which considers roughness, levelness, and compressibility. In most of the uses of paper, the character of the surface is of great importance. It is common to say that paper has a "smooth" or a "rough"texture. The terms "finish" and "pattern" are frequently used in describing the contour or appearance of paper surfaces.

Smoothness is important for writing, where it affects the ease of travel of the pen over the paper surface. Finish is important in bag paper as it is related to the tendency of the bag to slide when stacked. Smoothness of the paper will often determine whether or not it can be successfully printed. Smoothness also gives eye appeal as a rough paper is unattractive.

As explained above it is important to control the moisture content of paper and keep it stable during converting operation. To keep moisture content constant, it is important that paper is conditioned. Conditioning of paper is also of important in many printing and converting operations. The tendency for paper to develop static becomes greater with increasing dryness. Cellulose fibers are hygroscopic i.e. they are capable of absorbing water from the surrounding atmosphere. The amount of absorbed water depends on the humidity and the temperature of the air in contact with the paper. Hence, changes in temperature and humidity, even slight changes, can often affect the test results. So, it is necessary to maintain standard conditions of humidity and temperature for conditioning.

The waste paper (newspaper, card boards etc) is collected from the MSW, and cut into small pieces either manually or mechanically, and cut pieces of paper are as shown in the below fig 3.1. the cut paper soaked in water for 24 hrs. This sample is made into slurry (pulp) for getting uniform size of particles with the help of heavy duty stirrers. After that water is removed from the slurry by squeezing.

Once the paper has been "pulped", the cement is added. Depending on what the papercrete will be used for, more or less cement is added – more for harder surface such as floors; less for walls.

At that point, the papercrete is a thick, grey paste and can do used exactly like concrete. After that the papercrete is simply poured into mould, and then kept in the open air to dry. Once dry, the bricks or cubes can be used like traditional bricks – using more papercrete as the mortar to hold the bricks together. Because the paper is absorbent, there must be some type of coating on structure made with papercrete. Any water resistant paint or coating may be used. Lime wash made with lime, water, salt, and Nepal cactus, stays cool even in direct sunlight and adds to the insulating ability of the papercrete.

Table-2

SL.NO	Constituent	Present In Hypo Sludge
1	MOISTURE	56.8
2	MAGNESIUM OXIDE(MgO)	3.3
3	CALCIUM OXIDE(CaO)	46.2
4	LOSS ON IGNESENT	27.00
5	ACID INSOLUBLE	11.1
6	SILLICA(SiO2)	9.0
7	R2O3	3.6

FLY ASH:

Fly ash is defined in Cement and Concrete Terminology (ACI Committee 116) as "the finely divided residue resulting from the combustion of ground or powdered coal, which is transported from the firebox through the boiler by flue gases." Fly ash is a by-product of coal-fired electric generating plants.

Two classifications of fly ash are produced, according to the type of coal used. Anthracite and bituminous coal produces fly ash classified as Class F. Class C fly ash is produced by burning lignite or subbituminous coal. Class C fly ash is preferable for the applications presented in the Green Building Guide and is the main type offered for residential applications from ready-mix suppliers.

3.3.1 CONSIDERATIONS:

Fly ash is one of three general types of coal combustion byproducts (CCBP's). The use of these byproducts offers environmental advantages by diverting the material from the waste stream, reducing the energy investment in processing virgin materials, conserving virgin materials, and allaying pollution.

Thirteen million tons of coal ash is produced in Texas each year. Eleven percent of this ash is used which is below the national average of 30%. About 60 – 70% of central Texas suppliers offer fly ash in ready-mix products. They will substitute fly ash for 20 – 35% of the Portland cement used to make their products.

Although fly ash offers environmental advantages, it also improves the performance and quality of concrete. Fly ash affects the plastic properties of concrete by improving workability, reducing water demand, reducing segregation and bleeding, and lowering heat of hydration. Fly ash reaches its maximum strength more slowly than concrete made with only portland cement. Some wall-form materials are made from EPS (expanded polystyrene) which is a lightweight non-CFC foam material. There are also fiber-cement wall-form products that can contain wood waste. The EPS/concrete systems offer high insulating qualities and easy installation. The fiber-cement blocks offer insulating qualities as well. Some EPS products also have recycled content.

CHEMICAL COMPOSITION AND CLASSIFICATION

Fly ash material solidifies while suspended in the exhaust gases and is collected by electrostatic precipitators or filter bags. Since the particles solidify rapidly while suspended in the exhaust gases, fly ash particles are generally spherical in shape and range in size from 0.5 µm to 300 µm. The major consequence of the rapid cooling is that only few minerals will have time to crystallize and that mainly amorphous, quenched glass remains. Nevertheless, some refractory phases in the pulverized coal will not melt (entirely) and remain crystalline. In consequence, fly ash is a heterogeneous material. SiO_2, Al_2O_3, Fe_2O_3 and occasionally CaO are the main chemical components present in fly ashes. The mineralogy of fly ashes is very diverse. The main phases encountered are a glass phase, together with quartz, mullite and the iron oxides hematite, magnetite. The concentrations of other trace elements vary as well according to the kind of coal combusted to form it. In fact, in the case of bituminous coal, with the notable exception of boron, trace element concentrations are generally similar to trace element concentrations in unpolluted soils.

Two classes of fly ash are defined by ASTM C618: Class F fly ash and Class C fly ash. The chief difference between these classes is the amount of calcium, silica, alumina, and iron content in the ash. The chemical properties of the fly ash are largely influenced by the chemical content of the coal burned (i.e., anthracite, bituminous, and lignite).

75% of the ash must have a fineness of 45 µm or less, and have a carbon content, measured by the loss on ignition (LOI), of less than 4%. In the U.S., LOI needs to be under 6%. The particle size distribution of raw fly ash is very often fluctuating constantly, due to changing performance of the coal mills and the boiler performance.

This makes it necessary that, if fly ash is used in an optimal way to replace cement in concrete production, it needs to be processed using beneficiation methods like mechanical air classification. But if fly ash is used also as a filler to replace sand in concrete production, unbeneficiated fly ash with higher LOI can be also used. Especially important is the ongoing quality verification. This is mainly expressed by quality control seals like the Bureau of Indian Standards mark or the DCL mark of the Dubai Municipality.

Table-3

Chemical Requirements for Fly Ash Classification

Properties	Fly Ash Class	
	Class F	Class C
Silicon dioxide (SiO_2) plus aluminum oxide (Al_2O_3) plus iron oxide (Fe_2O_3), min, %	70.0	50.0
Sulfur trioxide (SO_3), max, %	5.0	5.0
Moisture Content, max, %	3.0	3.0
Loss on ignition, max, %	6.0	6.0

EXPERIMENTAL INVESTIGATIONS

4.1 SIZE OF SPECIMEN

Plain Concrete cube, plain concrete beam and cylinder

1. The size of the cube:150 x 150 x150 mm
2. The size of the cylinder:150 x300 mm

MATERIALS

Materials used in the experimental work

- Cement
- Hypo sludge
- Ferrous oxide
- Fine Aggregate

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➢ Coarse Aggregate

AGGREGATE

➢ Aggregates are the important constituents in concrete. They give body to the concrete, reduce shrinkage and effect economy. One of the most important factors for producing workable concrete is good gradation of aggregates. Minimum paste will mean less quantity of cement and less water, which will further mean increased economy, higher strength, lower shrinkage and greater durability.

➢ Aggregate comprises about 55% of the volume of mortar and about 85% volume of mass concrete. Mortar contains a size of 4.75 mm and concrete contains aggregate up to a maximum size of 150 mm. Aggregate occupies most of the volume of the concrete show they are the important constituents of concrete.

COARSE AGGREGATE

➢ The fractions from 80 mm to 4.75 mm are termed as coarse aggregate. The fractions from 80 mm to 4.75 mm are termed as coarse aggregate. The Coarse Aggregates from crushed Basalt rock, conforming to IS: 383 is be use. The Flakiness and Elongation Index were maintained well below 15%.

Figure-3 Coarse Aggregate

➢ Those fractions from 4.75 mm to 150 micron are termed as fine aggregate.

➢ Those fractions from 4.75 mm to 150 micron are termed as fine aggregate. The river sand and crushed sand is to be used in combination as fine aggregate conforming to the requirements of IS: 383. The river sand is wash and screen, to eliminate deleterious materials and over size particles.

Figure-4 Fine Aggregate

WATER

➢ Water is an important ingredient of concrete as it actually participates in the chemical reaction with cement. Since it helps to from the strength giving cement gel, the quantity and quality of water is required to be looked into very carefully.

HYPO SLUDGE

Figure shows the hypo sludge used in this project.

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PAPER

CHEMICAL COMPOSITION OF PAPER

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MIX DESIGN

The process of selecting suitable ingredients of concrete and determining their relative amounts with the objective of producing a concrete of the required, strength, durability, and workability as economically as possible, is termed the concrete mix design. The proportioning of ingredient of concrete is governed by the required performance of concrete in 2 states, namely the plastic and the hardened states. If the plastic concrete is not workable, it cannot be properly placed and compacted. The property of workability, therefore, becomes of vital importance. The compressive strength of hardened concrete which is generally considered to be an index of its other properties, depends upon many factors, e.g. quality and quantity of cement, water and aggregates; batching and mixing; placing, compaction and curing. The cost of concrete is made up of the cost of materials, plant and labour. The variations in the cost of materials arise from the fact that the cement is several times costly than the aggregate, thus the aim is to produce as lean a mix as possible. From technical point of view the rich mixes may lead to high shrinkage and cracking in the structural concrete, and to evolution of high heat of hydration in mass concrete which may cause cracking.

The actual cost of concrete is related to the cost of materials required for producing a minimum mean strength called characteristic strength that is specified by the designer of the structure. This depends on the quality control measures, but there is no doubt that the quality control adds to the cost of concrete. The cost of labour depends on the workability of mix, e.g., a concrete mix of inadequate workability may result in a high cost of labor to obtain a degree of compaction with available equipment.

Requirements of concrete mix design

The requirements which form the basis of selection and proportioning of mix ingredients are :

a) The minimum compressive strength required from structural consideration

b) The adequate workability necessary for full compaction with the compacting equipment available.

c) Maximum water-cement ratio and/or maximum cement content to give adequate durability for the particular site conditions

d) Maximum cement content to avoid shrinkage cracking due to temperature cycle in mass concrete.

TYPES OF MIXES

NOMINAL MIXES

In the past the specifications for concrete prescribed the proportions of cement, fine and coarse aggregates. These mixes of fixed cement-aggregate ratio which ensures adequate strength are termed nominal mixes. These offer simplicity and under normal Circumstances, have a margin of strength above that specified. However, due to the variability of mix ingredients the nominal concrete for a given workability varies widely in strength.

4.4.1 STANDARD MIXES

The nominal mixes of fixed cement-aggregate ratio (by volume) vary widely in strength and may result in under- or over-rich mixes. For this reason, the minimum compressive strength has been included in many specifications. These mixes are termed standard mixes. IS 456-2000 has designated the concrete mixes into a number of grades as M10, M15, M20, M25, M30, M35 and M40. In this designation the letter M refers to the mix and the number to the specified 28 day cube strength of mix in N/mm^2. correspond approximately to the mix proportions (1:3:6), (1:2:4), (1:1.5:3) and (1:1:2) respectively.

DESIGNED MIXES

In these mixes the performance of the concrete is specified by the designer but the mix proportions are determined by the producer of concrete, except that the minimum cement content can be laid down. This is most rational approach to the selection of mix proportions with specific materials in mind possessing more or less unique characteristics. For the concrete with undemanding performance nominal or standard mixes (prescribed in the codes by quantities of dry ingredients per cubic meter and by slump) may be used only for very small jobs, when the 28-day strength of concrete does not exceed 30 N/mm^2. No control testing is necessary reliance being placed on the masses of the ingredients.

FACTORS AFFECTING THE CHOICE OF MIX PROPORTIONS

The various factors affecting the mix design are:

COMPRESSIVE STRENGTH

It is one of the most important properties of concrete and influences many other describable properties of the hardened concrete. The mean compressive strength required at a specific age, usually 28 days, determines the nominal water-cement ratio of the mix. The other factor affecting the strength of concrete at a given age and cured at a prescribed temperature is the degree of compaction. According to Abraham's law the strength of fully compacted concrete is inversely proportional to the water-cement ratio.

WORKABILITY

The degree of workability required depends on three factors. These are the size of the section to be concreted, the amount of reinforcement, and the method of compaction to be used. For the narrow and complicated section with numerous corners or inaccessible parts, the concrete must have a high workability so that full compaction can be achieved with a reasonable amount of effort. This also applies to the embedded steel sections. The desired workability depends on the compacting equipment available at the site.

DURABILITY

The durability of concrete is its resistance to the aggressive environmental conditions. 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 water-cement ratio to be used.

SIZE OF AGGREGATE:

In general, larger the maximum size of aggregate, smaller is the cement requirement for a particular water-cement ratio, because the workability of concrete increases with increase in maximum size of the aggregate. However, the compressive strength tends to increase with the decrease in size of aggregate.

IS 456:2000 and IS 1343:1980 recommend that the nominal size of the aggregate should be as large as possible.

GRADING AND TYPE OF AGGREGATE:

The grading of aggregate influences the mix proportions for a specified workability and water cement ratio. Coarser the grading leaner will be mix which can be used. Very lean mix is not desirable since it does not contain enough finer material to make the concrete cohesive. The type of aggregate influences strongly the aggregate-cement ratio for the desired workability and stipulated water cement ratio. An important feature of a satisfactory aggregate is the uniformity of the grading which can be achieved by mixing different size fractions.

QUALITY CONTROL:

The degree of control can be estimated statistically by the variations in test results. The variation in strength results from the variations in the properties of the mix ingredients and lack of control of accuracy in batching, mixing, placing, curing and testing. 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.

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MIX PROPORTION DESIGNATIONS:

The common method of expressing the proportions of ingredients of a concrete mix is in the terms of parts or ratios of cement, fine and coarse aggregates. For e.g., a concrete mix of proportions 1:2:4 means that cement, fine and coarse aggregate are in the ratio 1:2:4 or the mix contains one part of cement, two parts of fine aggregate and four parts of coarse aggregate. The proportions are either by volume or by mass. The water-cement ratio is usually expressed in mass.

FACTORS TO BE CONSIDERED FOR MIX DESIGN

- The grade designation giving the characteristic strength requirement of concrete.
- The type of cement influences the rate of development of compressive strength of concrete.
- Maximum nominal size of aggregates to be used in concrete may be as large as possible within the limits prescribed by IS 456:2000.

  The workability of concrete for satisfactory placing and compaction is related to the size and shape of section, quantity and spacing of reinforcement and technique used for transportation, placing and compaction.

WORKABILITY OF FRESH CONCRETE BY SLUMP TEST

Slump test is used to determine the workability of fresh concrete. Slump test as per IS: 1199 – 1959 is followed. The apparatus used for doing slump test

The behavior of green or fresh concrete from mixing up to compaction depends mainly on the property called "workability of concrete". Workability of concrete is a term which consists of the following four partial properties of concrete namely, Mixability, Transportability, Mouldability and Compactibility. In general terms, workability represents the amount of work which is to be done to compact the compact the concrete in a given mould. The desired workability for a particular mix depends upon the type of compaction adopted and the complicated nature of reinforcement used in reinforced concrete. A workable mix should not segregate. The partial properties of workability are discussed below:

a. MIXABILITY:

It is the ability of the mix to produce a homogeneous green concrete from the constituent materials of the batch, under the action of the mixing forces. A less mixable concrete mix requires more time of mixing to produce a homogeneous and uniform mix.

b. TRANSPORTABILITY:

Transportability is the capacity of the concrete mix to keep the homogeneous concrete mix to keep the homogeneous concrete mix from segregating during a limited time period of transportation of concrete, when forces due to handling operations of limited nature act. Any segregation that is caused during the remaining operations that follows. In most of the countries, general recommendations for practice exist for transporting the concrete, which fact highlights the importance of this property.

c. MOULDABILITY:

It is the ability of the fresh concrete mix to fill completely the forms or moulds without losing continuity or homogeneity under the available techniques of placing the concrete at a particular job/ this property is complex, since the behavior of concrete is to be considered under dynamic conditions.

d. COMPACTIBILITY:

Compactibility is the ability of concrete mix to be compacted into a dense, compact concrete, with minimum voids, under the existing means of compaction at the site. The best mix from the point of view of compactibility should close the voids to an extent of 99% of the original voids present, when the concrete was placed in the moulds.

FACTORS AFFECTING WORKABILITY:

Workable concrete is the one which exhibits very little internal friction between particle and particle or which overcomes the frictional resistance offered by the formwork surface or reinforcement contained in the concrete with just the amount of compacting efforts forthcoming. The factors helping concrete to have more lubricating effect to reduce internal friction for helping easy compaction are given below:

a. Water content
b. Size of aggregates
c. Surface texture of aggregate
d. Use of admixtures
e. Mix proportions
f. Shape of aggregates
g. Grading of aggregates

WATER CONTENT:

Water content in a given volume of concrete, will have significant influences on the workability. The higher the water content per cubic meter of concrete, the higher will be the fluidity of concrete, which is one of the important factors affecting workability. At the work site, supervisors who are not well versed with the practice of making good concrete resort to adding more water for increasing workability. It should be noted that from the desirability point of view, increase of water content is the last recourse to be taken for improving the workability even in the case of uncontrolled concrete. For controlled concrete one cannot arbitrarily increase the water content.

a. MIX PROPORTIONS:

Aggregate/ cement ratio is an important factor influencing workability. The higher the aggregate/cement ratio, the leaner is the concrete. In lean concrete, less quantity of paste is available for providing lubrication, per unit surface area of aggregate and hence the mobility of aggregate is restrained. On the other hand, in case of rich concrete with lower aggregate/cement ratio, more paste is available to make the mix cohesive and fatty to give better workability.

b. SIZE OF AGGREGATE:

The bigger the size of the aggregate, the less the surface area and hence less amount of water is required for wetting the surface and less matrix or paste is required for lubricating the surface to reduce internal friction. For a given quantity of water and paste, bigger size of aggregates will give higher workability. The above of course will be true within certain limits.

c. SHAPE OF AGGREGATES:

The shape of the aggregate influences the workability in good measure. Angular, elongated or flaky aggregate makes the concrete very harsh when compared to rounded aggregates or cubical shaped aggregates. Contribution to better workability to rounded aggregate will come from the fact that for the given volume or weight it will have less surface area and less voids than angular or flaky aggregate. Not only that, being round in shape, the frictional resistance is also greatly reduced.

This explains the reason why river sand and gravel provide greater workability to concrete than crushed sand and aggregate. The importance of shape of the aggregate will be of great significance in the case of present day high strength and high performance concrete when we use very low w/c in the order of about 0.25. We have already talked about that in years to come natural sand will be exhausted or costly.

Problem;

1.**DESIGN STIPULATIONS FOR PROPORTIONING**

Grade designation : M40
Type of mix : mix powder (hypo sludge)
Maximum nominal size of aggregates: 20 mm
Minimum mix powder:360 kg/m3
Maximum water mix ratio: 0.40
Workability : 23 mm (slump)
Exposure condition: Mild
Degree of supervision : Good
Type of aggregate: Crushed angular aggregate
Maximum mix powder content: 450 kg/m3
Chemical admixture :Not recommended

2. TEST DATA FOR MATERIALS

i) Mix used : nil
ii) Specific gravity of mix : nil
iii) Specific gravity of Coarse aggregate : 2.68
Fine aggregate : 2.65
iv) Water absorption
Coarse aggregate : 0.6 percent
Fine aggregate : 1.0 percent
v) Free (surface) moisture
Coarse aggregate : Nil (absorbed moisture full)
Fine aggregate : Nil
vi) Sieve analysis
Coarse aggregate : Conforming to Table 2 of IS: 383 Fine aggregate : Conforming to Zone I of IS: 383

3. TARGET STRENGTH FOR MIX PROPORTIONING

f'ck = fck + 1.65 s Where

f'ck = Target average compressive strength at 28 days, fck = Characteristic compressive strength at 28 days,

s = Standard deviation

From Table 1 standard deviation, s = 5 N/mm2

Therefore target strength = 40 + 1.65 x 5 = 45.25 N/mm2

4. SELECTION OF WATER CEMENT RATIO

From Table 5 of IS: 456-2000, maximum water cement ratio = 0.38 (Mild exposure)

5. SELECTION OF WATER CONTENT

Required water content = 163.4 liters

6. CALCULATION OF CEMENT CONTENT

Water mix ratio = 0.38

mix content = 163.4/0.38 = 430 kg/m3 >360 kg/m3(given)

From Table 5 of IS: 456, minimum mix content for mild exposure condition = 360 kg/m3 Hence OK.

7. MIX CALCULATIONS

a) Volume of coarse aggregates = e x Volume of CA x specific gravity of CA = 1118.02 kg/m3

b) Volume of fine aggregates = e x Volume of FA x specific gravity of FA = 516.02 kg/m3. Aggregates are assumed to be in SSD. Otherwise corrections are to be applied while calculating the water content. Necessary corrections are also required to be made in mass of aggregates.

8. MIX PROPORTIONS FOR TRIAL NUMBER 1

Mix = 430 kg/m3

Water = 163.4 kg/m3 Fine aggregate = 516.02 kg/m3 Coarse aggregates = 1118.02 kg/m3

9. The slump shall be measured and the water content and dosages of admixture shall be adjusted for achieving the required slump based on trials, if required. The mix proportions shall be reworked for the actual water content and checked for durability requirements.

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11. Two more trials having variation of ± 10 percent of water cement ratio in A-10 shall be carried out keeping water content constant, and a graph between three water cement ratios and their corresponding strengths shall be plotted to work out the mix proportions for the given target strength for field trials. However, durability requirements shall be met.

A mix M40 grade was designed as per Indian Standard method and the same was used to prepare the test samples. The design mix proportion is done in Table

Table-5

DESIGN MIX PROPORTION

Kg/m^3	Water	Cement	Fine Aggregate	Coarse Aggregate
BY WEIGHT(KG)	163.4	430	516.02	1118.02

SPLIT TENSILE STRENGTH OF A CONCRETE CYLINDER

The tensile strength of concrete is one of the basic and important properties. Splitting tensile strength test on concrete cylinder is a method to determine the tensile strength of concrete. The concrete is very weak in tension due to its brittle nature and is not expected to resist the direct tension. The concrete develops cracks when subjected to tensile forces. Thus, it is necessary to determine the tensile strength of concrete to determine the load at which the concrete members may crack.

Sampling of Concrete Cylinders:

The cylinder mould shall is of metal ,3mm thick. Each mould is capable of being opened longitudinally to facilitate the removal of the specimen and is provided with a means of keeping it closed while in use. The mean internal diameter of the mould is 15 cm ± 0.2 mm and the height is 30 +/- 0.1 cm. Each mould is provided with a metal base plate mould and base plate should be coated with a thin film of mould oil before use, in order to prevent adhesion of concrete.

Tamping Bar:

The tamping bar is a steel bar of 16 mm diameter , 60 cm long and bullet pointed at the lower end.

Compacting of Concrete

The test specimen should be made as soon as practicable after the concrete is filled into the mould in layers approximately 5 cm deep. Each layer is compacted either by hand or by vibration.

Compacting by Hand

When compacting by hand, the standard tamping bar is used and the stroke of the bar should be distributed in a uniform manner. The number of strokes for each layer should not less than. After top layer has been compacted,the surface of the concrete should be finished level with the top of the mould,using a trowel and covered with a glass or metal plate to prevent evaporation.

Curing of Specimen:

The test specimen should be stored in a place at a temperature of 27° +/- 2°C for 24 +/- 0.5 hrs. from the time addition of water to the dry ingredients. The water or solution in witch the specimen s are kept should be renewed every seven days and should be maintained at a temperature of 27° +/- 2°c.Concrete cylinder 15 cm diameter & 30cm long.

Procedure of Splitting Tensile Test:

1. Take the wet specimen from water after 7 days of curing
2. Wipe out water from the surface of specimen
3. Draw diametrical lines on the two ends of the specimen to ensure that they are on the same axial place.

4. Note the weight and dimension of the specimen.
5. Set the compression testing machine for the required range.
6. Keep are plywood strip on the lower plate and place the specimen.
7. Align the specimen so that the lines marked on the ends are vertical and centered over the bottomplate.
8. Place the other plywood strip above the specimen.
9. Bring down the upper plate to touch the plywood strip.
10. Apply the load continuously without shock at a rate of approximately 14-21kg/cm2/minute (Which corresponds to a total load of 9900kg/minute to 14850kg/minute)
11. Note down the breaking load(P)

CALCULATIONS:

Range Calculation

The splitting tensile strength is calculated using the formula

Tsp = 2P/pi DL

Where P = applied load

D = diameter of the specimen L = length of the specimen Therefore P = Tsp x pi DL/2

Expected load = P x f.s

SPLIT TENSILE STRENGTH

T = 2P/pi DL

Splitting tensile strength of given concrete = 4.68 N/mm²

Figure 9

COMPRESSIVE STRENGTH TEST

150 mm × 150 x 150 mm concrete cubes were casting using M20 grade concrete. Specimens with mixing of hypo sludge, fly ash and adding of mix with ferrous oxide at 10%, 20%, 30%, and 40% levels were cast. During casting the cubes were mechanically vibrated by using a table

vibrator. After 24 h the specimens were removed from the mould and subjected to water curing for 3,7,28 and 56 days. After curing, the specimens were tested for compressive strength using a calibrated compression testing machine of 60 kN capacity.

MIX -CONTENT:

For a given water-mix ratio if the mix content is required to increase the workability of the concrete mix, the compressive strength increases with the increases in the richness. However, for a particular water-mix ratio there would always be optimum cement content resulting in 28-days compressive strength being the highest. Increasing the mix beyond the optimum values may not increase the strength of the concrete.

It has been noticed that greater the 7-days strength of mix, the greater the compressive strength of concrete at 28 days.

AGE OF TESTING :

Although the hypo sludge, fly ash hypo sludge fly ash and iron oxide of different types result in different rate of gain of initial strength, the strengths at later age tend to become similar. Therefore, a mix which results in comparatively lower strength at 28 days would have proportionately greater increase in strength at the later ages and vice-versa. The mix proportions themselves influence the rate of gain of strength, e.g., a concrete with lower water-cement ratio tend to attain high early strength.

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Therefore the further gain in strength at later ages is approximately smaller.

COMPACTION AND CURING

A through compaction is the basic necessity to successful concrete manufacture. The compaction eliminates most of the air pockets on the surface of concrete. The presence of even 5 percent voids in the hardened concrete due to incomplete compaction may result in a decrease in compressive strength by about 35 percent. The concrete starts attaining strength immediately after setting is completed and the strength continues to increase with time.

Moist curing for first 7 to 14 days may result in compressive strength being about 90 percent of that of 28 days moist curing IS:456-1978 stipulates a minimum of 7-days moist curing, while IS:7861(part-I)- 1975 stipulates a minimum of 10 days curing under hot weather conditions.

DEFINITION:

The term mortar is used to indicate a paste prepared by adding required quantity of water to a mixture of binding material like hypo sludge, fly ash or lime and fine aggregate like sand. The above two components of mortar, namely, the binding material and fine aggregate are sometimes referred to as matrix and adulterant respectively. The matrix binds the particles of the adulterant and as such, the durability, quality and strength of mortar will mainly on the quantity and quality of the matrix.

PROPERTIES OF GOOD MORTAR:

Following are the properties of a good mortar:

(1) It should be capable of developing good adhesion with the building units such as bricks, stones, etc

(2) It should be capable of developing the designed stresses.

(3) It should be capable of resisting penetration of rain water.

(4) It should be cheap and durable.

(6) It should be easily workability.

Leading manufacturers use an industrial standard known as "Pulverized fuel ash for lime-Pozzolana mixture" using over 75% post-industrial recycled waste, and a compression process. American civil engineer Henry Liu announced the invention of a new type of hypo sludge brick in 2007. Liu's brick is compressed at 4,000 psi and cured for 24 hours in a 150°F (66 °C) steam bath, then toughened with an air entrainment agent, so that it lasts for more than 100 freeze-thaw cycles. Workability reduces at with cement and vice versa it increase with higher replacement of hypo sludge. Compressive strength of the concrete measured after 7 days decreases when the percentage of replacement of increases and 10 % hypo sludge compressive strength increases after 7 days. Compressive strength of the concrete measured after 28 days increases when the percentage of replacement of increases up to 30% and if replacements of 20% hypo sludge compressive strength increases after 28 days.A better measure by a New Construction Material's formed.

RESULTS AND DISCUSSIONS

Table-6

COMPRESSIVE STRENGTH @ 0% OF HYPO SLUDGE:

Sample no.	Age in days	Comp strength (Mpa)	Avg. comp strength (Mpa)
1	3	16.09	21.05
2	3	21.02	
3	3	26.06	
4	7	24.16	29.12
5	7	34.62	
6	7	28.59	
7	28	46.18	46.83
8	28	49.68	
9	28	44.63	

In the above table the compressive test values are shown for 0% Hypo Sludge The

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3 days compressive test average value is 21.05 N/mm^2. The 7 days compressive test average value is 29.12 N/mm^2. The 28 days compressive test average value is 46.83 N/mm^2.

Table-7

COMPRESSIVE STRENGTH @10% OF HYPO SLUDGE:

Sample no.	Age in days	Comp strength (Mpa)	Avg. comp strength (Mpa)
1	3	25.14	24.80
2	3	23.13	
3	3	26.15	
4	7	30.17	30.17
5	7	27.16	
6	7	33.19	
7	28	52.31	48.28
8	28	45.26	
9	28	47.28	

In the above table the compressive test values are shown for 10% Hypo Sludge The 3 days compressive test average value is 24.80 N/mm^2. The 7 days compressive test average value is 30.17 N/mm^2 The 28 days compressive test average value is 48.28 N/mm^2

Table-8

COMPRESSIVE STRENGTH @ 20% OF HYPO SLUDGE:

Sample no	Age in days	Comp strength (Mpa)	Avg. comp strength (Mpa)
1	3	19.11	21.12
2	3	21.12	
3	3	23.13	
4	7	26.15	27.82
5	7	32.19	
6	7	25.14	
7	28	48.28	45.93
8	28	39.23	
9	28	40.23	

In the above table the compressive test values are shown for 20% Hypo Sludge The 3 days compressive test average value is 12.12 N/mm^2. The 7 days compressive test average value is 27.82 N/mm^2. The 28 days compressive test average value is 45.93 N/mm^2.

Table-9

COMPRESSIVE STRENGTH @ 30% of Hypo Sludge:

Sample no	Age in days	Comp strength (Mpa)	Avg. comp strength (Mpa)
1	3	17.10	17.43
2	3	16.09	
3	3	19.11	
4	7	25.14	27.82
5	7	27.16	
6	7	31.18	
7	28	35.20	39.22
8	28	45.26	
9	28	37.22	

In the above table the compressive test values are shown for 30% Hypo Sludge The 3 days compressive test average value is 17.43 N/mm^2.

The 7 days compressive test average value is 27.82 N/mm^2.

The 28 days compressive test average value is 39.22 N/mm^2.

Table-10

Compressive Strength @ 40% of Hypo Sludge

Sample no	Age in days	Comp strength (Mpa)	Avg. comp strength (Mpa)
1	3	12.07	13.07
2	3	13.07	
3	3	14.08	
4	7	22.13	19.44
5	7	15.08	
6	7	21.12	
7	28	37.22	35.20
8	28	36.21	
9	28	32.19	

In the above table the compressive test values are shown for 40% Hypo Sludge

The 3 days compressive test average value is 13.07 N/mm^2

The 7 days compressive test average value is 19.44 N/mm^2.

The 28 days compressive test average value is 35.20 N/mm^2.

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Table-11

COMPRESSIVE STRENGTH @ 0, 10, 20, 30 & 40% of Hypo Sludge

Days	Comp. strength 0%	Comp. strength 10%	Comp. strength 20%	Comp. strength 30%	Comp. strength 40%
3	21.05	24.80	21.12	17.43	13.07
7	29.12	30.17	27.82	27.82	19.44
28	46.83	48.28	45.93	39.22	35.20

Table-11

COMPRESSIVE STRENGTH @ 0, 10, 20, 30 & 40% of Hypo Sludge

Days	Comp. strength 0%	Comp. strength 10%	Comp. strength 20%	Comp. strength 30%	Comp. strength 40%
3	21.05	24.80	21.12	17.43	13.07
7	29.12	30.17	27.82	27.82	19.44
28	46.83	48.28	45.93	39.22	35.20

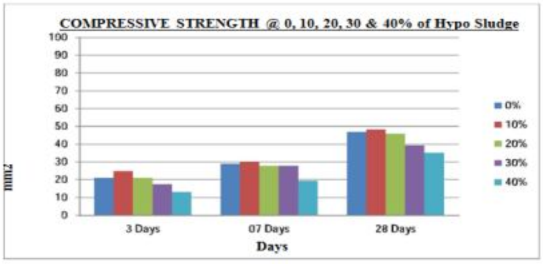


Figure-11

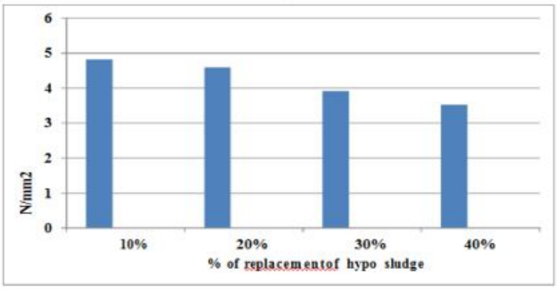
Bar chart of Compressive strength of different percentages by adding Hypo sludge

Table-12

Split Tensile Strength Of Cylinder @ 0, 10, 20, 30 & 40% of Hypo Sludge

% OF REPLACEMENT OF HYPO SLUDGE	TENSILE STRENGTH FOR 28 DAYS
0%	4.68
10%	4.82
20%	4.59
30%	3.92
40%	3.52

Bar chart of Tensile strength



Percentages of replacement of hypo sludge

CONCLUSION

Based on limited experimental investigations concerning the compressive strength and tensile strength of concrete , the following conclusions are drawn:

1. The 0% replacement of cement in M40 grade of concrete gives compressive strength of 46.83 N/mm2 and tensile strength of 4.68 N/mm2for 28 days.
2. The 10% replacement of cement by hypo sludge in M40 grade of concrete gives compressive strength of 48.28 N/mm2 and tensile strength of 4.82 N/mm2for 28 days.
3. The 20% replacement of cement by hypo sludge in M20 grade of concrete gives compressive strength of 45.93 N/mm2 and tensile strength of 4.59 N/mm2 28 days.
4. The 30% replacement of cement by hypo sludge in M20 grade of concrete gives compressive strength of 39.22 N/mm2 and tensile strength of 3.92 N/mm2 28 days.
5. By above results we know that the use of FERROUS HYPO SLUDGE should be in between of 10-15 % will increase the strength of concrete.
6. Use of Hypo Sludge reduces the amount of cement content. Thus, the construction work with Hypo sludge in cement becomes environmentally safe and also economical.
7. In Hypo sludge cement concrete strength is increases up to 20% replacement of cement then when add extra 10% or more then strength of concrete is decreases.

Scope for the future study

This experiment can also be carried out for the strength of the concrete for 56 days. And also can be done investigations for the strength of the concrete other than these percentages of replacements. Likewise the other factory wastes such as metakaolin ,foundry sand etc can be done for the strength of concrete at different percentages of replacement of particular materials.

REFERENCES

1. Concrete technology by- M.S SHETTY
2. IS: 4031(part I) 1996: methods of physical test for hydraulic cement is referred for determination of fineness by dry sieving.
3. IS: 4031(part IV) 1988: methods of physical test for hydraulic cement are referred for determination of consistency of standard cement paste.
4. IS: 4031(part VI) 1988: methods of physical test for hydraulic cement are referred for determination of compressive strength.
5. IS: 12269 – 1987: Indian standard specifications for 53 grade ordinary Portland cement.
6. Bureau of Indian Standards, IS 516-1959, Methods of tests for strength of concrete, BIS Publications.
7. Bureau of Indian Standards, IS 10262-1982, Recommended Guidelines for Concrete Mix design, BIS Publications.
8. Bureau of Indian Standards, IS 10086-1982, specification for moulds for use in tests of cement and concrete, BIS Publications.