MECHANICAL PROPERTIES OF CONCRETE INCORPORATING USED FOUNDRY SAND

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CERTIFICATE

This is to certify that the thesis entitled '**MECHANICAL PROPERTIES OF CONCRETE INCORPORATING USED FOUNDRY SAND'**, submitted by **Ms. Ishatpreet Kaur** in partial fulfillment of requirements, for the award of degree of **Master of engineering in Civil (structures) Engineering** of **Thapar Institute of Engineering and Technology (Deemed University), Patiala,** is a bonafide work carried out by him under my supervision and guidance.

The matter embodied in this thesis has not been submitted for the award of any other degree and he has worked for nearly six months on this topic.

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I will be failing in my duties if I do not acknowledge my sense of gratitude to God Almighty, my Father and Mother, whose blessing have made me reach my destination.

(*Ishatpreet kaur*)

Place: Patiala
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ABSTRACT

Metal foundries use large amounts of the metal casting process. Foundries successfully recycle and reuse the sand many times in a foundry and the remaining sand that is termed as foundry sand is removed from foundry. This study presents the information about the civil engineering applications of foundry sand, which is technically sound and is environmentally safe. Use of foundry sand in various engg. applications can solve the problem of disposal of foundry sand and other purposes.

Foundry sand consists primarily of silica sand, coated with a thin film of burnt carbon, residual binder (bentonite, sea coal, resins) and dust.Foundry sand can be used in concrete to improve its strength and other durability factors. Foundry Sand can be used as a partial replacement of cement or as a partial replacement of fine aggregates or total replacement of fine aggregate and as supplementary addition to achieve different properties of concrete.

In the present study, effect of foundry sand as fine aggregate replacement on the compressive strength, split tensile strength and modulus of elasticity of concrete having mix proportions of 1:1.45:2.20:1.103 was investigated. Fine aggregates were replaced with three percentages of foundry sand. The percentages of replacements were 10, 20 and 30 % by weight of fine aggregate. Tests were performed for compressive strength, split tensile strength and modulus of elasticity for all replacement levels of foundry sand at different curing periods (28-days & 56-days).

Test results showed that there is some increase in compressive strength, split tensile strength and modulus of elasticity after replacing the fine aggregates with certain percentage of foundry sand so foundry sand can be safely used in concrete for durability and strength purposes.

CHAPTER 1
INTRODUCTION

1.1 General

Foundry sand is high quality silica sand with uniform physical characteristics. It is a by-product of ferrous and nonferrous metal casting industries, where sand has been used for centuries as a molding material because of its thermal conductivity. It is a byproduct from the production of both ferrous and nonferrous metal castings.

The physical and chemical characteristics of foundry sand will depend in great part on the type of casting process and the industry sector from which it originates. In modern foundry practice, sand is typically recycled and reused through many production cycles. Industry estimates that approximately 100 million tons of sand are used in production annually of that 6 - 10 million tons are discarded annually and are available to be recycled into other products and in industry. The automotive industries and its parts are the major generators of foundry sand. Foundries purchase high quality size-specific silica sands for use in their molding and casting operations.

The raw sand is normally of a higher quality than the typical bank run or natural sands used in fill construction sites. The sands form the outer shape of the mold cavity. These sands normally rely upon a small amount of bentonite clay to act as the binder material. Chemical binders are also used to create sand “cores”. Depending upon the geometry of the casting, sands cores are inserted into the mold cavity to form internal passages for the molten metal. Once the metal has solidified, the casting is separated from the molding and core sands in the shakeout process. In the casting process, molding sands are recycled and reused multiple times. Eventually, however, the recycled sand degrades to the point that it can no longer be reused in the casting process. At that point, the old sand is displaced from the cycle as byproduct, new sand is introduced, and the cycle begins again. A schematic of the flow of sands through a typical foundry is shown in Fig.1.3.

Although there are other casting methods used, including die casting and permanent mold casting, sand casting is by far most prevalent mold casting technique. Sand is used in two different ways in metal castings as a molding material, which focuses the external shape of the cast part and as cores that form internal void spaces in products such as engine blocks. Since sand grains do not naturally adhere to each other so binders must be introduced to cause the sand to stick together and holds its shape during the introduction of molten metal into mold and cooling of casting.

1.2 Types of Foundry Sands

Two general types of binder systems are used in metal casting depending upon which the foundry sands are classified as: clay bonded systems (Green sand) and chemically-bonded systems. Both types of sands are suitable for beneficial use but they have different physical and environmental characteristics

- Green sand molds are used to produce about 90% of casting volume in the U.S. Green sand is composed of naturally occurring materials which are blended together; high quality silica sand (85-95%), bentonite clay (4-10%) as a binder, a carbonaceous additive (2-10%) to improve the casting surface finish and water (2-5%). Green sand is the most commonly used recycled foundry sand for beneficial reuse. It is black in color, due to carbon content, has a clay content that results in percentage of material that passes a 200 sieve and adheres together due to clay and water.
- Chemically bonded sands are used both in core making where high strengths are necessary to withstand the heat of molten metal, and in mold making. Most chemical binder systems consist of an organic binder that is activated by a catalyst although some systems use inorganic binders. Chemically bonded sands are generally light in color and in texture than clay bonded sands.

Foundries produce Recycled Foundry Sand (RFS) generally in their overall production volume although there are different sand to metal ratios employed in different casting processes and products. Most foundries have two sand systems one feeding the external molding lines and the other feeding the internal core lines. After the metal is poured and the part is cooling, green sand is literally shaken off the castings, recovered and reconditioned for continual reuse. Used cores are also captured during this cooling and shake out process; these break down and are crushed and reintroduced into green sand systems to replace a portion of sand lost in the process. Broken cores are cores, which do not break down, are discarded. Depending on the projected end use, it may be important to segregate sand streams at the foundry as each stream can have different characteristics. Additionally some sand is typically unrecoverable during shake off and finishing processes. These sans may be contaminated with metals or very large chunks of burnt cores and will need to undergo some type of segregation, crushing and screening before recycling.

1.3 Material Properties

1.3.1 Physical Characteristics of Foundry Sand

Foundry sand is typically sub angular to round in shape. After being used in the foundry process, a significant number of sand agglomerations form. When these are broken down, the shape of individual sand grains is apparent.

Fig.-1.1 Unprocessed Foundry Sand

Green sands are typically black, or gray, not green chemically bonded sand is typically a medium tan or off-white color Figs.1.1 & 1.2 shows the unprocessed foundry sand and green sand respectively.

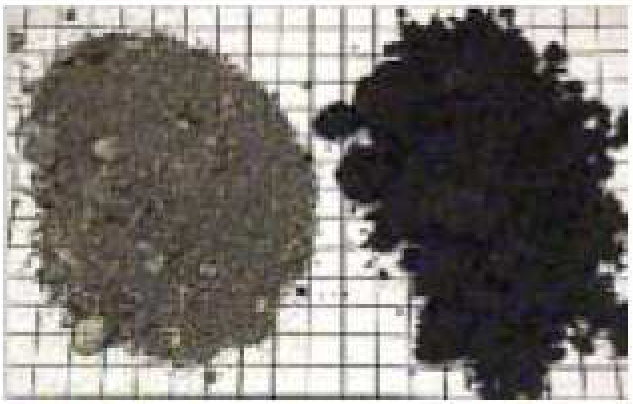

Fig.-1.2 Green Sands from a gray iron Industry

1.3.2 Physical Properties

Typical physical properties of spent foundry sand from green sand systems are given in Table-1.1. The grain size distribution of spent foundry sand is very uniform, with approximately 85 to 95 percent of the material between 0.6 mm and 0.15 mm (No. 30 and No. 100) sieve sizes. Five to 12 percent of foundry sand can be expected to be smaller than 0.075 mm (No. 200 sieve). The particle shape is typically sub angular to round. Waste foundry sand gradations have been found to be too fine to satisfy some specifications for fine aggregate.

Spent foundry sand has low absorption and is nonplastic. Reported values of absorption were found to vary widely, which can also be attributed to the presence of binders and additives. The content of organic impurities (particularly from sea coal binder systems) can vary widely and can be quite high. This may preclude its use in applications where organic impurities could be important (e.g., Portland cement concrete aggregate). The specific gravity of foundry sand has been found to vary from 2.39 to 2.55. This variability has been attributed to the variability in fines and additive contents in different samples .In general, foundry sands are dry, with moisture contents less than 2 percent. A large fraction of clay lumps and friable particles have been reported, which are attributed to the lumps associated with the molded sand, which are easily disintegrated in the test procedure. The variation in permeability, listed in Table-1.1, is a direct result of the fraction of fines in the samples collected.

Table-1.1. Typical physical properties of spent green foundry sand

[American Foundryman's Society, 1991]

Property	Results	Test Method
Specific Gravity	2.39-2.55	ASTM D854
Bulk Relative Density, kg/m^3 (lb/ft^3)	2589(160)	ASTMC48/AASTHO T84
Absorption, %	.45	ASTM C128
Moisture content, %	0.1-10.1	ASTM D2216
Clay Lumps and Friable Particles	1- 44	ASTM C142/AASTHO T112
Coefficient of Permeability (cm/sec)	10^{-3}-10^{-6}	AASTHO T215/ASTM D2434
Plastic Limit/Plastic Index	Nonplastic	AASTHO T90/ASTM D4318

The quality of foundry sand can be quantified by its durability and soundness, chemical composition, and variability. Various aspects of foundry sand production influence these three characteristics. Durability/Soundness of foundry sand is important to ensure the long-term performance of civil engineering applications. Durability of the foundry sand depends on how the sand was used at the foundry. Successive molding can cause the foundry sand to weaken due to temperature shock. At later stages of mold use, this can lead to the accelerated deterioration of the original sand particles. However, in civil engineering uses, the foundry sand will not normally be subjected to such severe conditions. In geotechnical applications, foundry sand often demonstrates high durability.

1.3.3 Chemical Composition

Chemical Composition of the foundry sand relates directly to the metal molded at the foundry. This determines the binder that was used, as well as the combustible additives. Typically, there is some variation in the foundry sand chemical composition from foundry to foundry. Sands produced by a single foundry, however, will not likely show significant variation over time. Moreover, blended sands produced by consortia of foundries often produce consistent sands. The chemical composition of the foundry sand can impact its performance. Spent foundry sand consists primarily of silica sand, coated with a thin film of burnt carbon, residual binder (bentonite, sea coal, resins) and dust.

Silica sand is hydrophilic and consequently attracts water to its surface. This property could lead to moisture-accelerated damage and associated stripping problems in an asphalt pavement. Antis tripping additives may be required to counteract such problems. Depending on the binder and type of metal cast, the pH of spent foundry sand can vary from approximately 4 to 8 . It has been reported that some spent foundry sands can be corrosive to metals. Because of the presence of phenols in foundry sand, there is some concern that precipitation percolating through stockpiles could mobilize leach able fractions, resulting in phenol discharges into surface or ground water supplies. Foundry sand sources and stockpiles must be monitored to assess the need to establish controls for potential phenol discharges.

1.3.4 Mechanical Properties

Typical mechanical properties of spent foundry sand are listed in Table–1.2. Spent foundry sand has good durability characteristics as measured by low Micro-Deval abrasion and magnesium sulfate soundness loss tests. The Micro-Deval abrasion test is an attrition/abrasion test where a sample of the fine aggregate is placed in a stainless steel jar with water and steel bearings and rotated at 100 rpm for 15 minutes. The percent loss has been determined to correlate very well with magnesium sulfate soundness and other physical properties. Recent studies have reported relatively high soundness loss, which is attributed to samples of bound sand loss and not a breakdown of individual sand particles. The angle of shearing resistance (friction angle) of foundry sand has been reported to be in the range of 33 to 40 degrees, which is comparable to that of conventional sands.

Table-1.2. Typical mechanical properties of spent foundry sand

[American Foundryman's Society, 1991]

Property	***Results***	***Test Method***
Micro-Devil Abrasion Loss,%	<2	_
Magnesium Sulphate Soundness Loss,%	5-15 6-47	ASTM C88
Friction Angle (deg)	33-40	_
California Bearing Ratio,%	4-20	ASTM D1883

1.4 Handling of Foundry Sand

Foundry sand is most often collected and stockpiled outside of the foundries, exposed to the environment. Prior to use in an engineering application, the majority of foundry sand is:

- Collected in closed trucks and transported to a central collection facility;
- Processed, screened, and sometimes crushed to reduce the size of residual core sand pieces. Other objectionable material, such as metals, is removed.

1.5 Foundry Sand Economics

The success of using foundry sand depends upon economics. The bottom line issues are cost, availability of the foundry sand and availability of similar natural aggregates in the region. If these issues can be successfully resolved, the competitiveness of using foundry sand will increase for the foundries and for the end users of the sand. This is true of any recycled material.

1.6 Foundry Sand Engg. Characteristics

Since foundry sand has nearly all the properties of natural or manufactured sands, it can normally be used as a sand replacement. It can be used directly as a fill material in embankments. It can be used as a sand replacement in hot mix asphalt, flowable fills, and

Portland cement concrete. It can also be blended with either coarse or fine aggregates and used as a road base or sub base material.

1.7 Foundry Sand Environmental Characterization

Trace element concentrations present in most clay-bonded iron and aluminum foundry sands are similar to those found in naturally occurring soils. The leachate from these sands may contain trace element concentrations that exceed water quality standards; but the concentrations are no different than those from other construction materials such as native soils or fly ashes. Environmental regulatory agencies will guide both the foundry sand supplier and the user through applicable test procedures and water quality standards. If additional protection from leachate is desired, mechanical methods such as compacting and grading can prevent and further minimize leachate development. In summary, foundry sand suppliers will work with all potential users to ensure that the product meets environmental requirements for the engineering application under consideration. Foundry sand can be used to produce a quality product at a competitive cost under normal circumstances.

1.8 Current Management Options

1.8.1 Recycling

In typical foundry processes, sand from collapsed molds or cores can be reclaimed and reused. Some new sand and binder is typically added to maintain the quality of the casting and to make up for sand lost during normal operations. Five different foundry classes produce foundry sand. The ferrous foundries (gray iron, ductile iron and steel) produce the most sand and the rest is produced by Aluminum, copper, brass and bronze. The 3,000 foundries in the United States generate 6 million to 10 million tons of foundry sand per year. While the sand is typically used multiple times within the foundry before it becomes a byproduct, only 10 percent of the foundry sand was reused elsewhere outside of the foundry industry in 2001. The sands from the brass, bronze and copper foundries are generally not reused. While exact numbers are not available, the best estimate is that approximately 10 million tons of foundry sand can beneficially be used annually. Fig.1.3 shows how the sand is reused and becomes foundry sand.

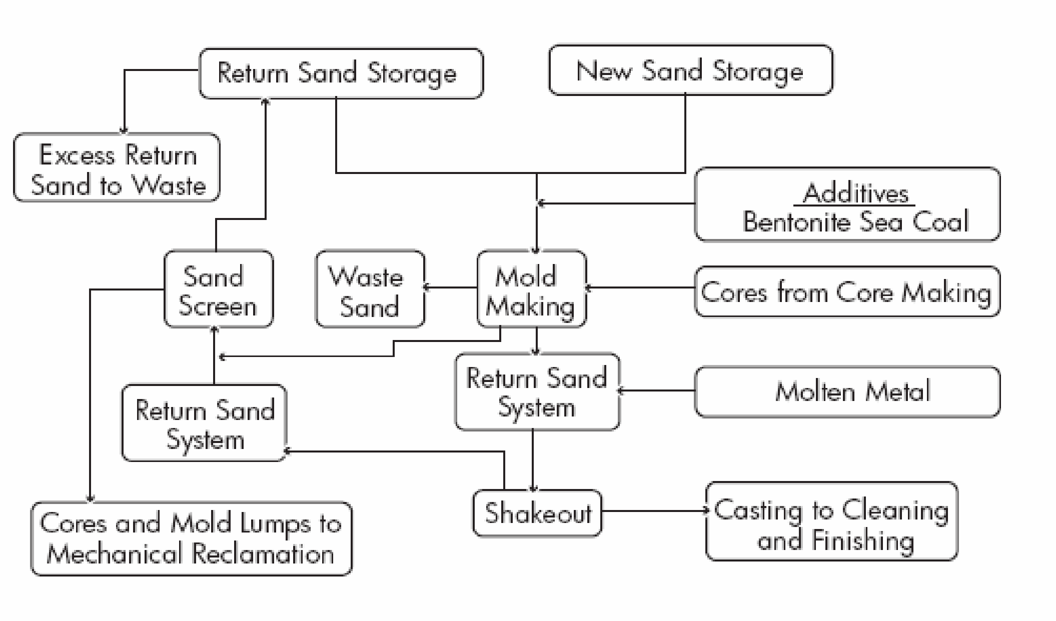

Fig.-1.3 Recycling of Foundry Sand

Little information is available regarding the amount of foundry sand that is used for purposes other than in-plant reclamation, but spent foundry sand has been used as a fine aggregate substitute in construction applications and as kiln feed in the manufacture of Portland cement.

1.8.2 Disposal

Most of the spent foundry sand from green sand operations is land filled, sometimes being used as a supplemental cover

1.8.3 Market Sources

Foundry sand can be obtained directly from foundries. Foundry sand, prior to use, is a uniformly graded material. The spent material, however, often contains metal from the casting and oversized mold and core material containing partially degraded binder. Spent foundry sand may also contain some leach able contaminants, including heavy metals and phenols that are absorbed by the sand during the molding process and casting operations. Phenols are formed through high-temperature thermal decomposition and rearrangement of organic binders during the metal pouring process. Heavy metals are of greater concern in nonferrous foundry sands generated from nonferrous foundries. Spent foundry sand from brass or bronze foundries, in particular, may contain high concentrations of cadmium, lead, copper, nickel, and zinc.

Chapter-2

LITERATURE REVIEW

Naik et al.,2001 conducted a project to evaluate performance and leaching of CLSM in which both clean and used foundry sands were incorporated. The clean sand was obtained from a sand mining company in Berlin, Wisconsin and the used foundry sand was obtained from a steel company (Maynard Steel Casting Corp.) in Milwaukee, Wisconsin. For purposes of comparison, properties of regular concrete sand (meeting ASTM C 33 requirements for use in making concrete) were also measured. Physical properties of these three foundry sands were determined using the appropriate ASTM standard .However a modified ASTM C 88 was used to measure soundness of foundry sands.The properties of used foundry sand vary due to the type of foundry processing equipments used, the type of additive for mold making, the number of times the sand is reused, and the type and amount of binder used. The unit weight of the used sand was greater than that of clean sand, which may be attributed to the finer gradation, attached particles of such materials as steel pallets bonded to the sand during the foundry process, bentonite clay binder material, etc. Both the clean and used foundry sand was significant. The materials finer than No.200 (75µm) sieve were slightly higher for the used foundry sand relative to the clean foundry sand. The sieve analysis plots exhibit that both the clean and the used foundry sands are finer than regular concrete sands and they are outside the ASTM limits for the use in making concrete. The grading curves show that the foundry sands contain predominantly finer particles compared with those of regular concrete sand.Approx.50-60% of the clean and used sand passed through the No.-50 sieve.

However, when regular concrete sand was replaced with 30%foundry sand, the resulting curve was close to the upper allowable ASTM limit.

Naik et al., 2001 reported several plastic properties of CLSM mixtures, such as flow/spread, temp., unit wt., settlement, bleed water, shrinkage cracks and condition of set. For each CLSM mixture, testing specimens of 150mm×300mm diameter cylinders were made to measure the plastic properties. The cylinders were tested for bleed water, 50 mm long nail penetration, settlement, and shrinkage cracks. Each slurry mixture was placed in 150mm ×300mm cylindrical mold (6 × 12 in.) for measurements of these parameters. The depth of water that accumulated on the surface of the solidified cylindrical mass was taken as a measurement of bleeding. The condition of the set was determined in accordance with a criteria based on the depth of penetration of a 50 mm long nail (Naik et al. 1990). These parameters were determined at 1 hour and 1, 3, 5, 7, 10, and 14 day's age. The nail penetration test was performed by applying moderate pressure (22–44 N) on the 50mm (2 in.) long nail. The settlement was determined by measuring decrease in the height of the solidified cylindrical mass. The unit wt. of slurry material was found to vary in the range of 1570-2115 kg/m^3. The mixtures made with Fly ash F1 showed some bleed water at the one-hour age and decreased generally with time up to 14 days. In the case of Fly ash F2 mixtures, all the mixtures except 85% foundry sand mixtures, exhibited absence of bleed water even at an hour age. This may be due to the greater fineness of fly ash F2 and lower amount of water used cylinders. All the fly ash F2 mixtures become hard at the age of 5 days. Generally because of setting and hardening of mixtures, the depth of nail penetration decreased with age. Test data showed a slight increase in settlement up to 3 days. Thereafter the settlement became approx. constant the total settlement was found to be less than 18mm for the F1 mixture and 3.2 mm for the F2 mixtures with and without foundry sand up to 14 days. In order to have settlement less than or equal to 3mm the water content of mixture should be maintained so as to have a flow of 275mm or less. All the test specimens showed absence of shrinkage cracks up to the 14-day age.

Naik et al., 1997 reported that compressive strength increased with age. To determine the compressive strength, 150mm × 300mm diameter cylinders were made for each flowable slurry mixtures. The compressive strength for all slurry mixtures with and without foundry sand varied from 0.17 to 0.4 MPa at the age of 7 days. The compressive strength values ranged from 0.27 to 0.55MPa for the fly ash F1 mixtures and 0.3 to 0.6 to MPa for the fly ash F2 mixtures at 28 days. Compressive strength increased with an increasing amount of foundry sand up to certain limit, and then decreased. The strength data revealed that excavatable flowable slurry with up to 85% fly ash replacement with clear and used foundry sand can be manufactured without significantly affecting the strength of the reference mixtures. To obtain a relatively high strength at the age of 28 days and beyond for mixtures tested, fly ash replacement with foundry sand should be maintained between 30 & 50%. The amounts of foundry sand corresponding to the maximum compressive strength values were 50% for clean and clear sand for fly ash F1 mixture, 30% for used sand for fly ash F1 mixture, 70% for clean sand for fly ash F2 mixture and 30% for used sand for fly ash F2 mixture at the age of 91 days. The max. Compressive strength for both fly ash mixtures were obtained at 30% fly ash replacement with the used foundry in spite of variation in the mixture design and source of fly ash.

Tikalsky et al., 2000 reported that CLSM mixtures containing only Portland cements had compressive strength that exceeded the upper limit of acceptable compressive strength range i.e. 700 KPa. This was found for all four sands i.e. three from casting facilities and one from a commercial aggregate producer. The cement was ASTM C 150 type 1/2 cement and the fly ash was an ASTM C 618 class F fly ash. Text mixtures were prepared in accordance with mixing recommendations developed by ACI committee 229.Mixtures were prepared in a 0.06 m^3 constant speed shear mixer. Three specimens from each CLSM mixture were tested at 3,7,14 & 28 days. A neoprene capping system was used to transfer load evenly to test specimen loading was applied to 75×150 mm cylindrical specimens at a uniform strain rate until failure using a strain controlled testing machine. All the mixtures containing fly ash maintained a compressive strength below upper limit and one CLSM mixture did not reach the lower limit. The data supports the concept that by-product foundry sand can be successfully used in CLSM. The foundry sand assists in keeping the strength from exceeding the upper compressive strength limit.

Reddi et al., 1995 reported that compressive strength of stabilized foundry sands decreases as the replacement proportion of foundry sand increases in the mixes and the strength is achieved relatively faster with fly ash than with cement. Cement and fly ash mixtures were prepared using 0%, 25%, 50%, 75%, & 100% levels of replacement of silica sand by foundry sand. . Initial experiments with class F fly ash were unsuccessful because it lacked cementitious properties to form a stable mix therefore subsequent experiments were restricted to class C fly ash only. The ratio of water to the cementious binder was chosen to be 1.0 in the case of Portland cement and 0.35 in the case of fly ash. . The samples were founded in PVC pipes, 2.85 cm in dia.and 5.72 cm long. The mixtures of sands and the binders were poured into these pipes and then vibrated on a vibrating table to minimize air pockets. For each of the replacement levels, compressive strengths were obtained after 3, 7, 14, 28, & 56 days in order to evaluate the difference due to curing time. The clay bonded foundry sand reduced the strength of the stabilized mixes more than the resin- bonded foundry sands. A similar observation is made in context of fly ash stabilization. The drastic reduction in strength with an increase in clay-bonded foundry sand replacement is apparent in the cases of both fly ash & cement. Cement – stabilized mixes acquired their strength considerably slower than fly ash stabilized mixes. After 7 days of curing the cement-stabilized RBS reached only 30% of peak strength whereas its fly ash counterpart achieved 80% of its peak strength.

Naik et al., 2003 performed an investigation to develop technology for manufacturing cast-concrete products using Class F fly ash, coal-combustion bottom ash, and used foundry sand. A total of 18 mixture proportions with and without the by-products was developed for manufacture of bricks, blocks, and paving stones. Tests for compressive strength were performed acc. to ASTM C140 for which 3-6 specimens were tested for each brick or paving stone mixture at 5, 28, 56, 91 & 288 days. Three compression specimens were tested for each block mixture at 7, 14, 28, & 91 days.

The bricks with partial replacement of cement with fly ash (FA) show slightly higher strength than the control while considerable reduction in strength was observed when a part of sand was substituted with bottom ash (BA). Substitution of part of the sand with use foundry sand (UFS) in brick mixtures caused a small reduction in strength. All mixtures, except for those with partial substitution of sand with BA, met the compressive strength requirement of ASTM C 55 for Grade N (24 MPa) bricks from about three to 18 days of age. Mixtures containing BA met the strength requirement for Grade S (17 MPa) bricks from about 18 days of age. According to ASTM C 55, Grade N bricks are ‘‘for use where high strength and resistance to moisture penetration and severe frost action are desired.’’ Grade S bricks are ‘‘for general use where moderate strength and resistance to frost action and moisture penetration are required.’

In case of paving stones all the mixtures showed considerable strength gain with time. Paving stones with FA showed higher strength than the control throughout the test. Partial replacement of sand with BA caused a large reduction in compressive strength. Unlike bricks and blocks, partial replacement of sand with UFS, as in paving stones caused considerable reduction in strength. Overall, none of the paving stones met the compressive strength requirement of ASTM C 936 for solid concrete paving units (55 MPa).

In case of blocks all the mixtures except one exceeded minimum compressive strength requirement of ASTM C 90 (13 MPa). That exception mixture blocks exceeded the requirement from about 17 days of age. Blocks containing FA showed a higher rate of strength gain than the control. Overall, partial replacement of cement with FA, sand with BA and sand with UFS resulted in considerable increase, considerable decrease and slight decrease respectively in the compressive strength of blocks. Since they meet the strength requirement of ASTM, they could still be used for construction of interior walls in cold regions.

The results of this investigation show that partial replacement of cement with FA consistently improved the strength and durability of concrete masonry units and up to 25% of sand in blocks could be replaced with either BA or UFS in cold regions; and up to 35% of sand in bricks and blocks could be replaced with either BA or UFS for use where frost action is not a concern.

Naik et al., 2004 conducted a research towards establishing the use of high volumes of fly ash, bottom ash and used foundry sand in the manufacture of precast molded concrete products such as wet-cast concrete bricks and paving stones. ASTM class fly ash was used as a partial replacement 0 (reference), 25, and 35 % of Portland cement. Bottom ash combined with used foundry sand replaced 0 (reference), 50 and 70 % of natural sand. Three wet- cast brick mixtures and three wet-cast paving stone mixtures were proportioned in which the proportions of cementious material, fine aggregates and coarse aggregates were approx. 1:3.4:1.4 for bricks and 1:2.9:1.2 for paving stones. Tests for compressive strength were done as per ASTM C 140, which showed that at the age of 3 days the average compressive strength of wet-cast bricks made with control mixture was 32% higher than the compressive strength requirement of ASTM C 55 for Grade N bricks (min. 24 MPa). Overall the test showed that concrete with cylinder strength as low as 14 MPa can be used as in producing wet-cast bricks that meet the ASTM requirements for Grade N bricks. Wet- cast bricks made from other mix proportions than control met the compressive strength requirement of ASTM C 55 for Grade S bricks at approx. 7 and 22 days, respectively. The cylinder strength and the brick strength are linearly related up to approx. 25MPa cylinder strength and 40 MPa brick strength. Within this range brick strengths were almost twice the equivalent cylinder strengths. After this level the brick strength did not increase as rapidly as equivalent cylinder strength.

While in case of paving stone compressive strength the strength development of cylinders followed the similar trend as in brick concrete mixtures. The compressive strength of paving stones continued to increase with age but fell short of the ASTM C 936 requirements (min. 55 MPa). For producing paving stones that meet the ASTM strength requirements the increase in amounts of cementious materials may be needed. For early age strength gain the use of lower w/cm, HRWRA, and accelerating admixtures should be used for commercial production purposes. The paving- stone strength was higher than the corresponding cylinder strength, which was approx. 1.5 times the equivalent cylinder strength.

Naik et al., 2003 conducted an investigation to see the effects of freezing and hawing on bricks and paving stones for which five specimens of each mixture with plain water were made and tests were performed according to ASTM C 1262. Freezing and thawing tests on bricks and paving stones were started at 74 days of age and for blocks, the test started at 154 days of age .In this work, a weight loss of roughly 0.2% based on the estimated initial oven-dry weight of bricks was taken as a critical value, after which the bricks in general showed rapid or sudden increase in weight loss leading to rupture. Bricks reached the critical value of weight loss at about 92, 150, 30, 18, 40, and 12 cycles of F&T, respectively. On the basis of these numbers, bricks with FA, showed about 1.6 times longer F&T life than the control. When BA was used as a partial substitution for sand in bricks, a sharp drop in F&T life was observed. Partial substitution of sand with UFS also caused a sharp drop in F&T life of bricks, in spite of its nearly negligible effect on strength, density, and absorption. This might have something to do with the nature of the UFS. Weight loss of roughly 0.2% based on estimated initial oven-dry weight of the paving stones was taken as a critical value. All mixtures of paving stones reached the critical value of weight loss at about 190, 200, 150, 120, 95, and 45 cycles of F&T, respectively. Overall, the F&T life of the paving stones was about 2.3 times that of the bricks. This was attributed to the lower water-cementitious materials ratio (W/Cm) of paving stones, which resulted in higher values of compressive strength compared to bricks. Partial replacement of cement with FA, sand with BA, and sand with UFS resulted in slight increase, some reduction, and large reduction in F&T life of paving stones. The very large decrease in F&T life of paving stones containing UFS could be attributed to the plastic and slippery nature of moist UFS. For blocks a weight loss of roughly 1.1% based on estimated initial oven-dry weight of specimens was taken as a critical value. Blocks of all mixtures reached the critical value of weight loss at about 250, 350 (estimated by extrapolation), 200, 10, 170, and 30 cycles, respectively.

Partial replacement of cement with FA caused considerable increase in the F&T life of blocks. Blocks with 25% replacement of sand with either BA or UFS showed a large reduction in F&T life compared to FA. Blocks with 35% replacement of sand with either BA or UFS showed a very sharp reduction in F&T life compared with FA. Although the strength of blocks containing UFS was considerably higher than that of blocks containing BA, the F&T lives of the two groups of blocks were about the same. This could again be attributed to the plastic and slippery nature of moist UFS.

Naik et al., 2004 conducted tests for freezing and thawing of bricks and paving stones in accordance with ASTM C 140 for which water saturated brick and paving stone specimens, each with a 10mm layer of one bearing surface immersed in H_2O were subjected to cycles of freezing to -17°C (0° F) and thawing to 24ºC (75ºF) and the mass of each specimen was determined. The resistance to cycles of freezing and thawing decreased with increasing amounts of the three byproduct materials (fly ash, bottom ash, and used foundry sand in case of bricks. In case of paving stones the wet-cast paving stones made with control mix showed a significant amount of mass loss due to surface spelling between 60 and 150 cycles of freezing and thawing.

Naik et al., 2003 conducted an investigation to measure the drying shrinkage of bricks and blocks in accordance with ASTM C 426 using three specimens for each mixture. The test started roughly at 300 days of age for bricks and at 270 days of age for blocks. The drying shrinkage values for all specimens of bricks were about 0.023, 0.041, 0.031, 0.034, 0.041, and 0.036%, respectively. Lower drying shrinkage of bricks implies less likelihood of development of drying shrinkage cracks in masonry brick walls. Bricks containing FA, BA, and UFS shrunk more than the control bricks upon drying. Overall, bricks with UFS shrunk more than those with BA. However, all the bricks met the maximum drying shrinkage requirement of ASTM C 55 (0.065%). While the drying shrinkage values for all blocks were 0.023, 0.020, 0.031, 0.028, 0.038, and 0.040%, respectively. Blocks containing either BA or UFS shrunk more than the control upon drying. As in the case of bricks, blocks with UFS shrunk more than those with BA. However, all the blocks met the maximum drying shrinkage requirement of
ASTM C 90 (0.065%).

Naik et al., 2001 reported that the min. permeability was observed at 30% fly ash replacement with foundry sand. All specimen preparations were done in accordance with ASTM C192. The permeability of mixtures was evaluated in accordance with ASTM D 5084. The permeability of fly ash F1 slurry mixtures varied from 4×10^{-6}cm/s to 72×10^{-6}cm/s and for fly ash F2 the slurry mixture varied from 5×10^{-6}cm/s to 69×10^{-6}cm/s. The permeabilities for both the fly ash mixtures were only slightly affected by the increasing foundry sand content for up to 70% fly ash replacement at the age of 30 days. The min. permeability value was observed at 30% fly ash replacement level with foundry sand. However it increased abruptly when the replacement levels for the fly ashes with foundry sand were increased to 85% from 70%. The increase may be attributed to the increase in voids produced by the increase in the amount of foundry sand and to the decrease in the amount of finer particles of fly ash in the mixture. There was no significant effect of foundry sands (clean or used) on the permeability values of mixtures tested. So the permeabilities of test mixtures were not significantly influenced by inclusion of foundry sand up to 70% fly ash replacement and at 85% replacement of foundry sand a sharp increase in permeability was observed.

Naik et al., 2003 conducted the tests for abrasion of paving stones and bricks according to ASTM C 418 using three specimens for each mixture at about 350 days of age. The abrasion coefficient values for all specimens of paving stones were about 4.8, 3.7, 5.7, 7.3, 6.8, and 8.5 mm^3/mm^2 or (mm), respectively. All these values exceeded the limit of 3 mm specified in ASTM C 936 for concrete interlocking paving units. This might be due to the use of the brick mold and casting method in manufacturing the paving stones in this research. However, the test results were still considered valuable in comparing the performance of different paving stone mixtures. Partial replacement of cement with FA, sand with BA, and sand with UFS resulted in considerable reduction, large increase, and very large increase in depth of cavity on paving stones upon abrasion by sand blasting.

Naik et al., 2001 conducted tests on various samples to determine the leachability of CLSM mixtures. For this purpose the ASTM leach method was selected because it simulates mobility (leaching) of substances in CLSM that can occur through permeation of water under field conditions. Additionally, the WDNR uses ASTM leach data for granting permits for commercial applications of new construction materials incorporating by-products. In this method (ASTM D 3987), an extract of each by-product materials and CLSM mixture was obtained Each test sample, weighing about 70 grams, was prepared and added to a two-liter container having a watertight closure Since these materials contained very little organics, leachate derived The clean foundry sand met both the WDNR preventive action limit (PAL) and the enforcement standards (ES) of GWQS. The used foundry sand met all parameters of the ES, but it exceeded the PAL for lead and chromium from each material was analyzed for inorganic constituents in accordance with WDNR requirements However, the used foundry sand met all requirements, except for Fe, for the public welfare-related GWQS Except for selenium, these mixtures satisfied the drinking water standards (DWS). Fly ash F2 and the cement contributed the amounts of selenium in the CLSM mixtures. Generally, addition of both clean and used foundry sand caused reduction in the selenium concentration of the CLSM mixture. Therefore, addition of foundry sand appears to provide favorable environmental performance for the CLSM mixture.

Tikalsky et al., 1998 reported that the swelling potential and instability of bentonite-stabilized mixes render the leachable quality unpredictable. The data on total phenolics obtained from leachability experiments were normalized to account for difference in volumes of leachates collected for each stabilized mix. In the experiments with cement & fly ash mixtures were prepared using 0%, 25%, 50%, 70%, &100% levels of silica sand by foundry sand. This normalization was important for unequal amounts of foundry sand used with each of four binders. To provide a basis for comparison among the four binders, treatment efficiencies were calculated representing the percentage of total phenolics immobilized due to stabilization process. The treatment efficiencies (TE) were used in the existing literature and involve normalizing the contaminants leached from stabilized products w.r.t. contaminant leached from untreated waste.

The results showed that fly ash is more effective than cement in stabilizing the phenolics. Faster setting times were consistently observed for all mixtures of fly ash compared with corresponding mixtures of cement. Treatment efficiencies increased as the percentage replacement of foundry sands increased. In other words the total phenolics leached from each stabilized gram of foundry sands decreased as higher proportions of clean sand were replaced by foundry sand. So the swelling potential and instability of bentonite-stabilized mixes render the leachate quality unpredictable.

CHAPTER 3

EXPERIMENTAL PROGRAMME

3.1 Object of testing

The main objective of testing was to know the behavior of concrete with replacement of ordinary sand with foundry sand at room temperature.

The main parameters studied were compressive strength, split tensile strength, modulus of elasticity. The materials used for casting concrete samples along with tested results are described.

3.2 Test Results of Materials Used In Present Work

3.2.1 Cement

IS mark 43 grade cement (Brand-ACC cement) was used for all concrete mixes. The cement used was fresh and without any lumps. Testing of cement was done as per IS: 8112-1989. The various tests results conducted on the cement are reported in Table 3.1.

Table 3.1 Properties of cement

S. No.	Characteristics	Values obtained	Standard value
1.	Normal consistency	34%	-
2.	Initial setting time (minutes)	48 min.	Not less than 30

3.	Final setting time (minutes)	240 min.	Not greater than 600
4.	Fineness (%)	3.5 %	<10
5.	Specific gravity	3.07	-

3.2.2 Coarse aggregates

Locally available coarse aggregates having the maximum size of 10 mm and 20mm were used in the present work. Testing of coarse aggregates was done as per IS: 383-1970. The 10mm aggregates used were first sieved through 10mm sieve and then through 4.75 mm sieve and 20mm aggregates were firstly sieved through 20mm sieve. They were then washed to remove dust and dirt and were dried to surface dry condition. The results of various tests conducted on coarse aggregate are given in Table 3.2, Table 3.3 & Table 3.4

Table 3.2 Properties of Coarse aggregates

S. No.	Characteristics	Value
1.	Type	Crushed
2.	Maximum size	20 mm
3.	Specific gravity (10 mm)	2.704
4.	Specific gravity (20 mm)	2.825
5.	Total water absorption (10 mm)	1.6432 %
6.	Total water absorption (20 mm)	3.645 %
7.	Moisture content (10 mm)	0.806 %
8.	Moisture content (20 mm)	0.7049 %
9.	Fineness modulus (10 mm)	6.46
10.	Fineness modulus (20 mm)	7.68

Table 3.3 Sieve analysis of 10 mm aggregates

S. No.	Sieve No.	Mass Retained (kg)	Percentage Retained, %	Percentage Passing, %	Cumulative %age Retained
1.	80 mm	-	0.00	100	0.00
2.	40 mm	-	0.00	100	0.00
3.	20 mm	-	0 .00	100	0.00
	12.5 mm	0.555	18.5	81.5	18.5
4.	10 mm	0.8905	29.68	51.82	48.18
5.	4.75 mm	0.9565	31.88	19.94	80.06
11.	Pan	0.5970	19.90	0.04	99.96
				ΣC =	146.74

Fineness Modulus of Coarse aggregate (10 mm) = ΣC+500/100 = 146.74+500/ 100 = 6.46.

Table 3.4 Sieve analysis of 20 mm aggregates

S. No.	Sieve No.	Mass Retained (kg)	Percentage Retained, %	Percentage Passing, %	Cumulative %age Retained
1.	80 mm	-	0.00	100	0.00
2.	40 mm	-	0.00	100	0.00
3.	20 mm	0	0 .00	100	0.00

4.	12.5 mm	2.1865	72.883	27.117	72.883
5.	10 mm	0.6745	22.483	4.634	95.366
6.	4.47 mm	0.1390	4.633	0.01	99.999
11.	Pan	0	0.00	-	-
				ΣC =	268.244

Fineness Modulus of Coarse aggregate (20mm)= ΣC+500/100 = 268.244+500/ 100 = 7.68.

3.2.3 Fine Aggregate

The sand used for the experimental programme was locally procured and conformed to grading zone III as per IS: 383-1970.

The sand was first sieved through 4.75 mm sieve to remove any particles greater than 4.75 mm and then was washed to remove the dust. Properties of the fine aggregate used in the experimental work are tabulated in Table 3.5 and Table 3.6.

Table 3.5 Properties of fine aggregates

S. No.	Characteristics	Value
1.	Type	Uncrushed (natural)
2.	Specific gravity	2.68
3.	Total water absorption	1.02 %
4.	Moisture content	0.16 %
5.	Net water absorption	0.86 %
6.	Fineness modulus	2.507
7.	Grading zone	III

Table 3.6 Sieve analysis of fine aggregate

S. No.	Sieve No.	Mass	Percentage	Percentage	Cumulative

		Retained (gms)	**Retained, %**	**Passing, %**	**%age Retained**
1.	4.75 mm	95.0	9.5	90.5	9.5
2.	2.36 mm	42.5	4.25	86.25	13.75
3.	1.18 mm	110.5	11.05	75.2	24.8
4.	600 µm	128.5	12.85	62.35	37.65
5.	300 µm	308.0	30.8	31.55	68.45
6.	150 µm	281.0	28.1	3.45	96.55
7.	Pan	34.5	3.45	-	
				ΣF =	250.7

Fineness Modulus of fine aggregate = ΣF/100 = 250.7/100 = 2.507

3.2.4 Foundry Sand

Investigations were made on foundry sand procured from Janta Foundries, Mandi Gobindgarh, Punjab. The chemical and physical properties of the foundry sand used in this investigation are listed in Table 3.7 and Table 3.8 respectively. Tables 3.9 to 3.12 shows the sieve analysis for various replacement levels of sand with foundry sand.

Table 3.7 Physical Properties of Foundry Sand

Property	**Results**	**Test Method**
Specific Gravity	2.47	ASTM D854
Bulk Relative Density, kg/m^3	2589	ASTMC48/AASTHO T84
Absorption, %	0.45	ASTM C128
Moisture content, %	0.1-10.1	ASTM D2216
Clay Lumps and Friable Particles	1- 44	ASTM C142/AASTHO T112
Coefficient of Permeability (cm/sec)	10^{-3}-10^{-6}	AASTHO T215/ASTM D2434
Plastic Limit/Plastic Index	Nonplastic	AASTHO T90/ASTM D4318

Table 3.8 Foundry sand sample chemical oxide composition

Constituent	**Value (%)**
SiO_2	87.91
Al_2O_3	4.70
Fe_2O_3	0.94
CaO	0.14
MgO	0.30
SO_3	0.09
Na_2O	0.19
K_2O	0.25
TiO_2	0.15
P_2O_5	0.00
Mn_2O_3	0.02
SrO	0.03
LOI	5.15
TOTAL	99.87

Table 3.9 Sieve Analysis of Fine Aggregates at 0% replacement level

S. No.	Sieve No.	Mass Retained (gms)	Percentage Retained, %	Percentage Passing, %	Cumulative %age Retained
1.	4.75 mm	95.0	9.5	90.5	9.5
2.	2.36 mm	42.5	4.25	86.25	13.75
3.	1.18 mm	110.5	11.05	75.2	24.8
4.	600 µm	128.5	12.85	62.35	37.65
5.	300 µm	308.0	30.80	31.55	68.45
6.	150 µm	281.0	28.10	3.45	96.55
7.	Pan	34.5	3.45	-	-
				ΣF =	250.7

Fineness Modulus of mixture = 250.7/100=2.5

Table 3.10 Sieve analysis of Fine Aggregates at 10% replacement level

S. No.	Sieve No.	Mass Retained (gms)	Percentage Retained, %	Percentage Passing, %	Cumulative %age Retained
1.	4.75 mm	37.0	3.7	96.3	3.7
2.	2.36 mm	10.5	1.05	95.25	4.75

3.	1.18 mm	43.0	4.3	90.95	9.05
4.	600 µm	67.5	6.75	84.2	15.8
5.	300 µm	23.90	2.390	60.3	39.7
6.	150 µm	54.90	5.490	5.4	94.6
7.	Pan	5.15	0.515	0.25	99.75
				ΣF =	267.35

Fineness Modulus of fine aggregates with 10% foundry sand = ΣF/100 =267.35/100 = 2.6

Table 3.11 Sieve Analysis of Fine Aggregates at 20% replacement levels

S. No.	Sieve No.	Mass Retained (gms)	Percentage Retained, %	Percentage Passing, %	Cumulative %age Retained
1.	4.75 mm	35.5	3.55	96.45	3.55
2.	2.36 mm	28	2.8	93.65	6.35
3.	1.18 mm	45	4.5	89.15	10.35
4.	600 µm	97.5	9.75	79.4	20.6
5.	300 µm	230	23.0	56.4	43.6
6.	150 µm	500.5	50.05	6.35	93.65
7.	Pan	57.05	5.70	94.3	99.4
				ΣF =	277.5

Fineness Modulus of fine aggregates with 20% replacement = ΣF/100 = 277.5/100 = 2.7

Table 3.12 Sieve Analysis of Fine Aggregates at 30% replacement level

S. No.	Sieve No.	Mass Retained (gms)	Percentage Retained, %	Percentage Passing, %	Cumulative %age Retained
1.	4.75 mm	31.0	3.1	96.9	3.1

2.	2.36 mm	10.0	1.0	95.9	4.1
3.	1.18 mm	30.5	3.05	92.85	7.15
4.	600 µm	46.0	4.6	88.25	11.75
5.	300 µm	206.5	20.65	67.65	32.35
6.	150 µm	609.0	60.90	6.75	93.25
7.	Pan	63.0	6.3	0.45	99.55
				ΣF =	251.25

Fineness Modulus of fine aggregates with 30% replacement = ΣF/100 = 251.5/100 = 2.5

3.2.5 Water

Potable tap water was used for the concrete preparation and for the curing of specimens.

3.2.6 Superplasticizer

Conplast – SP 430, a concrete superplasticizer based on Sulphonated Napthalene Polymer was used as a water-reducing admixture and ton improve the workability of concrete containing foundry sand. Conplast - SP 430 has been specially formulated to give high water reductions up to 25% without loss of workability or to produce high quality concrete of reduced permeability. Conplast - SP 430 is non-toxic.

Superplasticizer complies with IS: 9103: 1999, ASTM C – 494 Type F, BS 5057 part Ш. The dosage of superplasticizer varied from 0.5% to 2% by weight of cement in plain concrete, concrete incorporating foundry sand. Technical data of Superplasticizer are listed in Table 3.13

Table 3.13 Technical data of Superplasticizer

S. No	Characteristics	Value
1.	Colour	Dark Brown liquid
2.	Specific gravity @ 30˚ C	1.220 to 1.225
3.	Air entrainment	Maximum 1%
4.	Chloride content	Nil

3.3 Moulds

Cubical mould of size 150mm*150mm were used to prepare the concrete specimens for the determination of compressive strength of foundry sand concrete at various replacement levels. Care was taken during casting and vibrator was used for proper compaction.

Cylindrical mould of size 150 mm*300 mm were used to prepare the concrete specimens for the determinations of split tensile strength and modulus of elasticity of foundry sand concrete. All the specimens were prepared in accordance with Indian Standard Specifications IS: 516-1959.All the moulds were cleaned and oiled properly. These were securely tightened to correct dimensions before casting. Care was taken that there is no gaps left from where there is any possibility of leakage out of slurry.

3.4 Mix designation

Concrete mix has been designed based on Indian Standard Recommended Guidelines IS: 10262-1982. The proportions for the concrete, as determined were 1:1.45:2.2:1.103 with a water cement ratio of 0.5 by weight. The mix designation and quantities of various materials for each designed concrete mix have been tabulated in Table 3.14 and 3.15 for cubes and cylinders.

Table 3.14 Mix Designation

Table 3.15 Proportion of M-20 Grade Concrete

	Cement Kg/m^3	Fine Aggregate kg/m^3	Course Aggregate (10mm) Kg/m^3	Course Aggregate (20mm) Kg/m^3	Foundry Sand Kg/m^3	Water (Lts/m^3)	Plasticizer (lts/m^3)
M-1	372	538.45	410.4	818.85	0	186	0.288
M-2	372	538.45	410.4	818.85	3.425	186	0.384
M-3	372	538.45	410.4	818.85	6.851	186	0.384
M-4	372	538.45	410.4	818.85	10.275	186	0.384

Grade of concrete	Concrete Type	Designation	Percentage binder ratio		Slump Test (mm)
			Sand (%)	Foundry Sand (%)	Results
M-20	Control Mix	M-1	100	0	80
	Foundry Sand concrete	M-2	90	10	80
		M-3	80	20	80
		M-4	70	30	80

3.5 Batching, Mixing and Casting of Specimens

A careful procedure was adopted in the batching, mixing and casting operations. The coarse aggregates and fine aggregates were weighed first with an accuracy of 0.5 grams. The concrete mixture was prepared by hand mixing on a watertight platform. PPC having 43 grades was used in casting. Three proportions of fine aggregates are replaced with foundry sand and thoroughly mixed. After that coarse aggregates are added to it. Superplasticizer as per requirement was added to required quantity of water separately in different containers. Then water was added carefully so that no water was lost during mixing. Six clean and oiled moulds for each category were then placed on the vibrating table respectively for the cubical samples for compression strength testing and twelve cylindrical moulds for split tensile and modulus of elasticity testing were filled in three layers. Vibrations were stopped as soon as the cement slurry appeared on the top surface of the mould.

The specimens were allowed to remain in the steel mould for the first 24 hours at ambient condition. After that these were demoulded with care so that no edges were broken and were placed in the curing tank at the ambient temperature for curing. The ambient temperature for curing was 27 ± 2^0

CHAPTER – 4

RESULTS AND DISCUSSION

4.1 General

Various properties of concrete incorporating foundry sand at various replacement levels with fine aggregate were studied, results were compared and checked for compressive strength, split tensile strength and modulus of elasticity of foundry sand mix with ordinary mix.

4.2 Compressive Strength

In this research the values of compressive strength for different replacement levels of foundry sand contents (0%, 10%, 20% and 30%) at the end of different curing periods (28 days, 56 days) are given in Table 3.1. These values are plotted in figs. 4.1&

4.2, which show the variation of compressive strength with fine aggregate replacements at different curing ages respectively.

. It is evident from Fig. 4.1 & 4.2 that compressive strength of concrete mixtures with 10%, 20% and 30 % of foundry sand as sand replacement was higher than the control mixture (M-1) at all ages and that the strength of all mixtures continued to increase with the age.

Fig. 4.1 shows that compressive strength increases with the increase in foundry sand. The compressive strength increases by 4.2%, 5.2%, & 9.8% when compared to ordinary mix without foundry sand at 28-days.

Figs. 4.2 show the compressive strength ratio (at 28 and 56 days) with respect to percentage replacement of sand by foundry sand. Compressive strength at 56 days increases by 1.0 %, 5.18 %, & 14.3% compared to ordinary mix. Compressive strength at 56 days was 15%, 12%, 15%, & 20% higher than the 28 days compressive strength.

Figs. 3.3 show the compressive strength ratio (at 28 and 56 days) with respect to different replacement levels. Compressive strength increases with age at different replacement levels.

Table 4.1: Compressive Strength (MPa) of Concrete with Foundry Sand

Foundry Sand Content, %	**Designation**	**Compressive Strength, MPa**	
		28 days	**56 days**
0	M-1	28.5	32.8
10	M-2	29.7	33.13
20	M-3	30.0	34.5
30	M-4	31.3	37.5

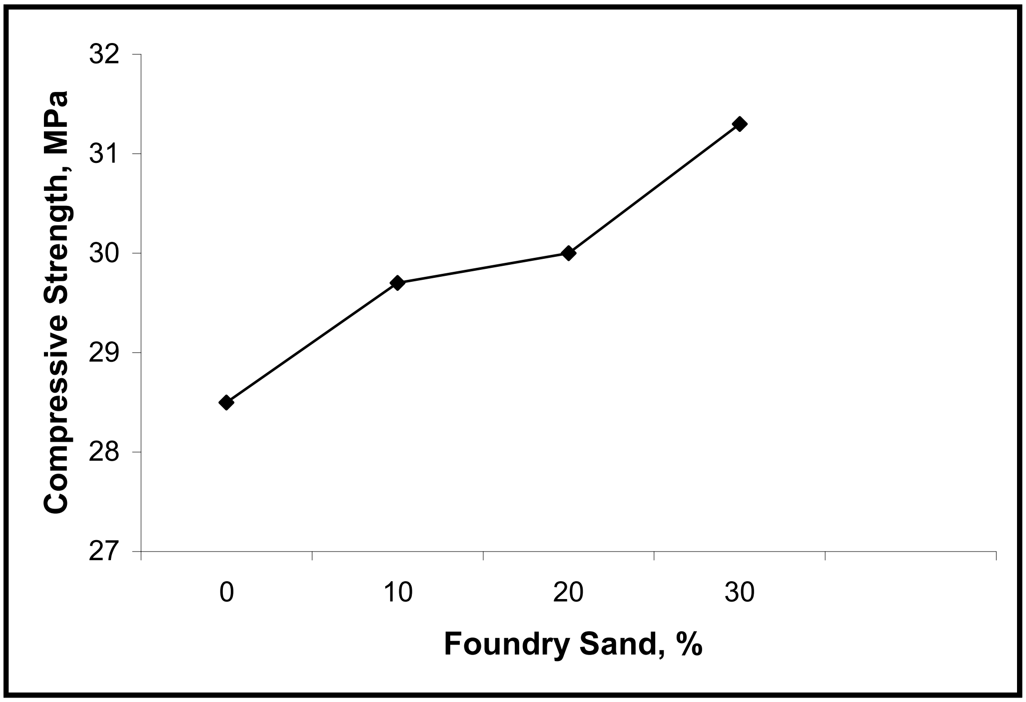
32
31
30
29
28
27
Compressive Strength, MPa
0
10
20
30
Foundry Sand, %

Fig 4.1Compressive strength vs. replacement of foundry sand at 28-days

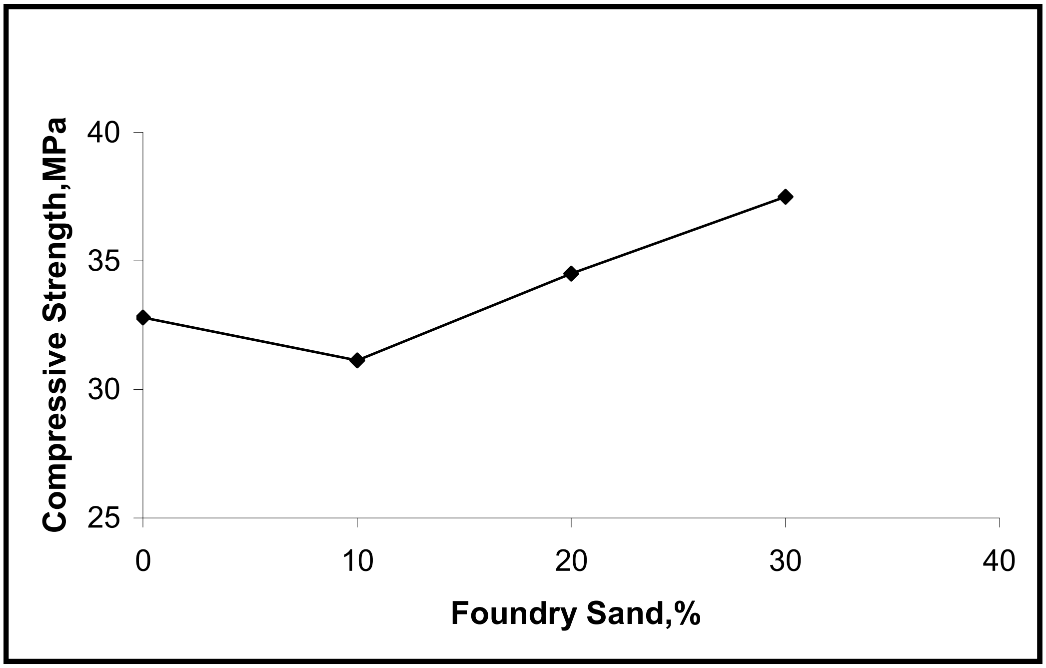

Fig 4.2 Compressive strength vs. replacement of foundry sand at 56-days

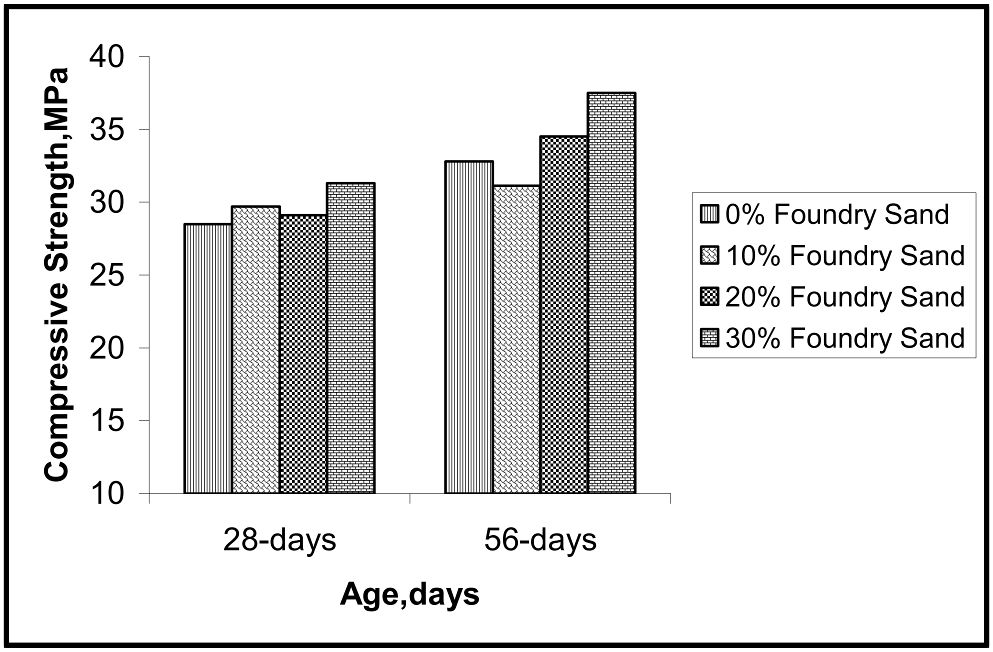

Fig 4.3 Compressive strength vs. Age at various replacement levels of foundry sand

4.3 Split tensile strength

It was found that split tensile strength of concrete incorporating foundry sand (using 10 %, 20 % and 30 % replacement levels with fine aggregate and a w/c of 0.5) depended on the percentage of foundry sand used The variation of split tensile strength was shown in Table 4.2.

Fig. 4.4 shows the variation of split tensile strength with replacements of foundry sand with various levels of fine aggregate at 28-days. Fig. 4.5 shows that split tensile strength increases with the increase in replacement of percentage of sand with foundry sand at 56-days. For control mix, split tensile strength was increase by 12%, 14%, and 20% with respect to different replacement levels of sand with foundry sand at 28 days. At 56 days the split tensile strength varies as 6%, 10% & 20% than control mix without foundry sand to the various replacement levels.

Figs. 4.6 show the split tensile strength ratio (at 28 and 56 days) with respect to age at various replacement levels of fine aggregates by foundry sand.

Table 4.2: Split tensile strength (MPa) of concrete with various levels of replacement of foundry sand

Foundry Sand Content, %	Designation	Split tensile strength, MPa	
		28 days	56 days
0	M-1	2.5	3.0
10	M-2	2.8	3.2
20	M-3	2.85	3.3
30	M-4	3.0	3.6

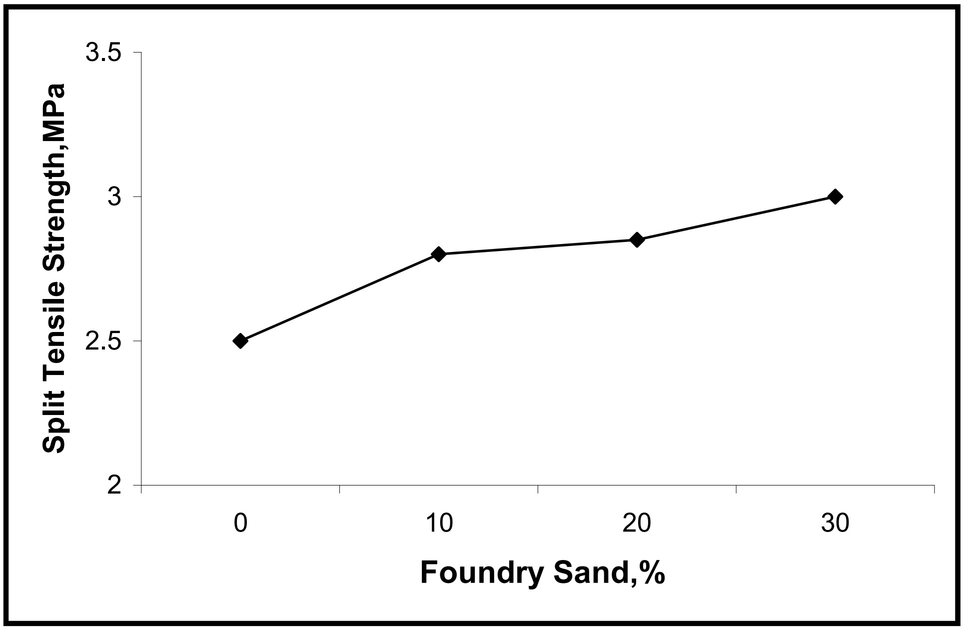

Fig.-4.4 Split tensile strength vs. replacement levels of foundry sand at 28-days

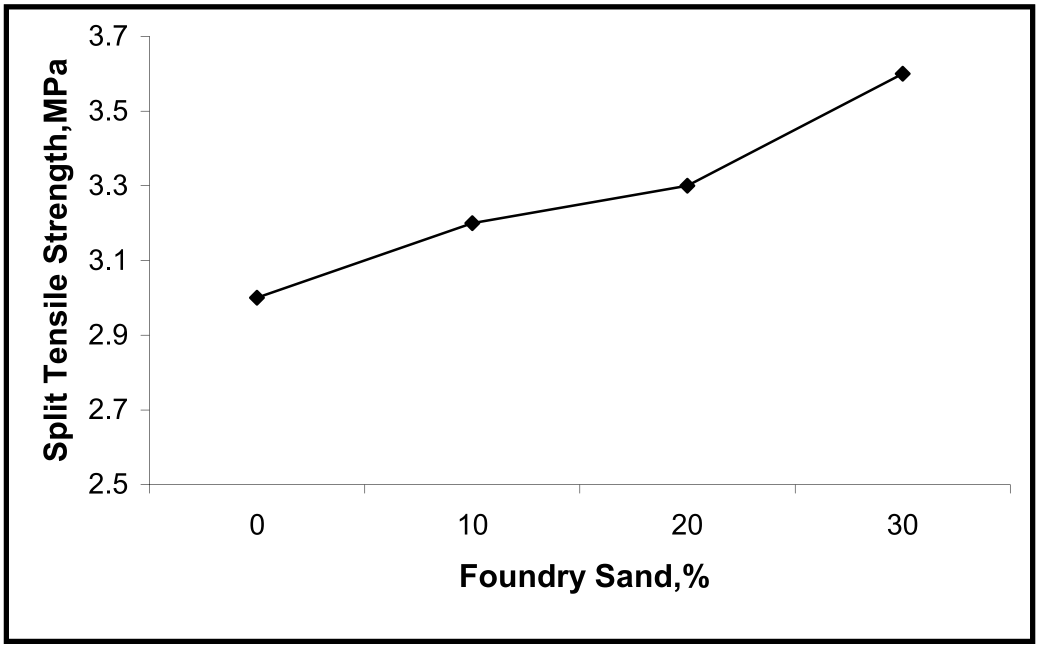

Fig.-4.5 Split tensile strength vs. replacement levels of foundry sand at 56-days

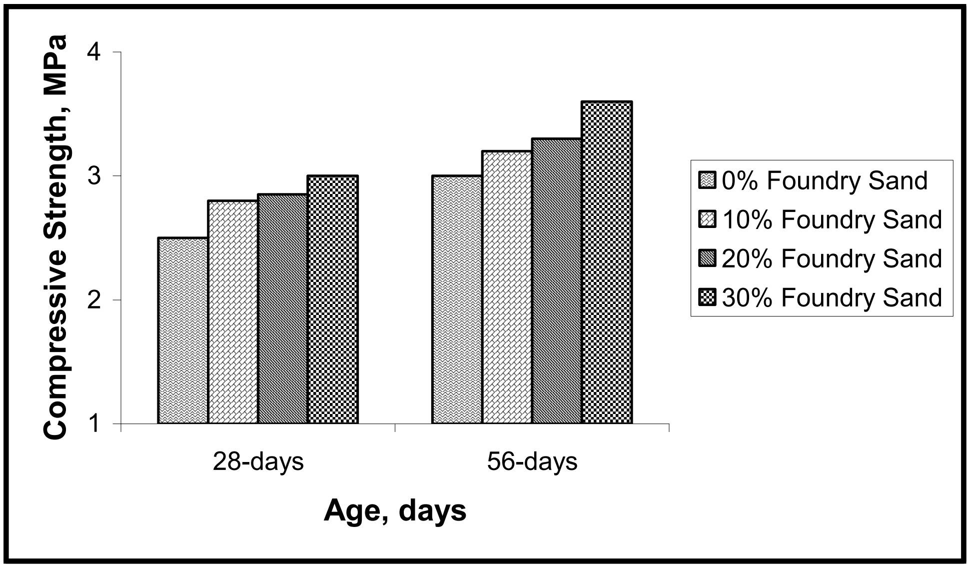

Fig.-4.6 Split tensile strength vs. Age at various levels of replacement of foundry sand

4.4 Modulus of Elasticity

In this investigation, the modulus of elasticity of concrete mixtures were determined at the age of 28 & 56 days at various levels of replacement of fine aggregates with foundry sand with w/c ratio of 0.5.At 28-days, control mix M-1 (with 0% replacement level of foundry sand) achieved modulus of elasticity of 25.10 GPa, whereas mixtures M-2 (10% foundry sand), M-3 (20% foundry sand), and M-4 (30% foundry sand) achieved modulus of elasticity of 26.74,29.11, and 31.11 GPa, respectively. However at 56-days it also showed a increase in values of modulus of elasticity by achieving the values of 27.19, 29.11, 31.12 and 33.20 GPa for mixtures M-1, M-2, M-3, & M-4 respectively. So the results show that modulus of elasticity increase with age as well as replacement of foundry sand. Table-4.3 shows the results for modulus of elasticity of concrete for various levels of Replacement of Foundry Sand. Variation of Modulus of Elasticity at various replacement levels of foundry sand is shown in Fig.- 4.7 & 4.8 at 28-days and 56-days, respectively. Fig.-4.9 shows the variation of modulus of elasticity at (at 28 and 56 days) with respect to age at various replacement levels of fine aggregates by foundry sand.

Table-4.3 Modulus of Elasticity (GPa) of Concrete with Various levels of Replacement of Foundry Sand

Foundry Sand Content, %	**Designation**	**Modulus of Elasticity, GPa**	
		28 days	**56 days**
0	M-1	25.10	27.19
10	M-2	26.75	29.11
20	M-3	29.11	31.12
30	M-4	31.11	33.20

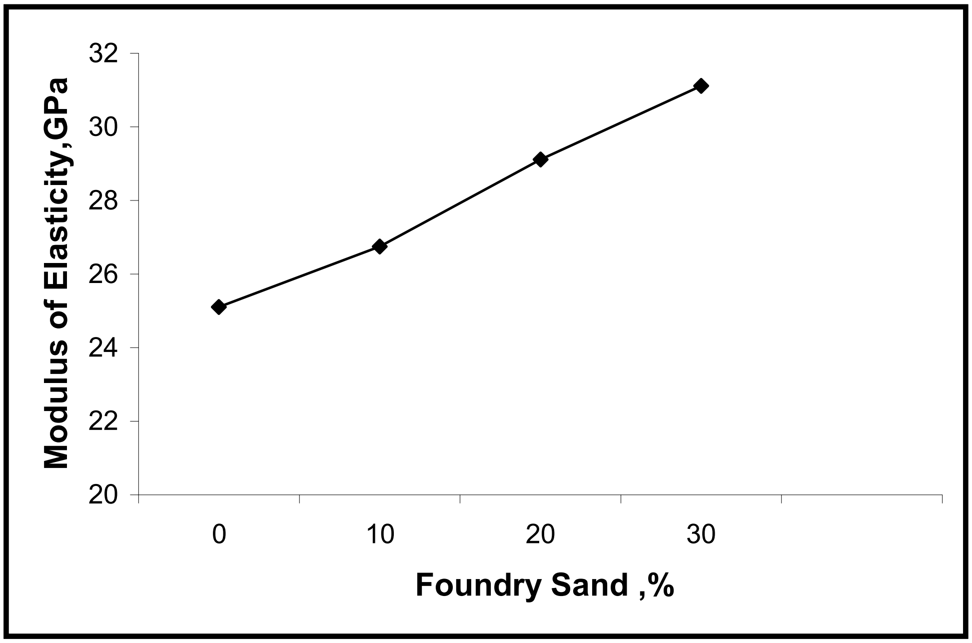

Fig.-4.7 Modulus of elasticity vs. replacement levels of foundry sand at 28-days

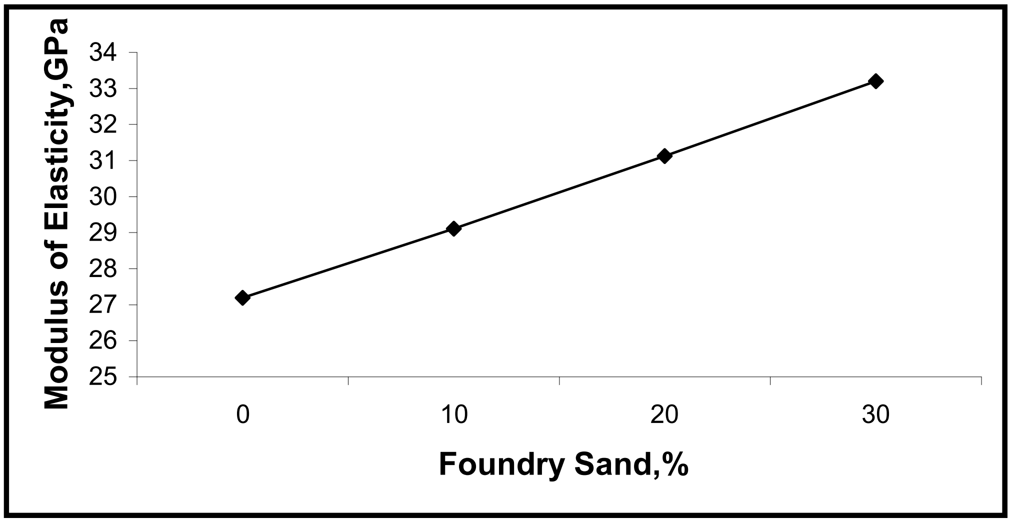

Fig.-4.8 Modulus of elasticity vs. replacement levels of foundry sand at 56-days

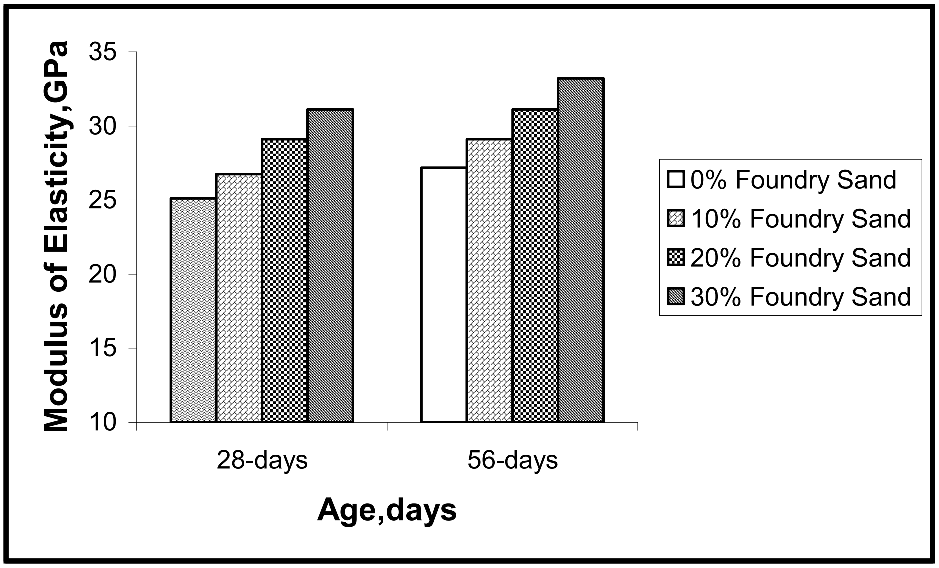

Fig.-4.9 Modulus of elasticity vs. Age at various levels of replacement levels of foundry sand

CHAPTER- 5

CONCLUSIONS

The following conclusions are drawn from this study:

1. Compressive strength of concrete increased with the increase in sand replacement with different replacement levels of foundry sand. However, at each replacement level of fine aggregate with foundry sand, an increase in strength was observed with the increase in age.

2. The compressive strength increased by 4.2%, 5.2%, & 9.8% when compared to ordinary mix without foundry sand at 28-days.

3. Compressive strength at 56 days increased by 1.0 %, 5.18 %, & 14.3% compared to ordinary mix.

4. Split Tensile Strength also showed an increase with increase in replacement levels of Foundry Sand with fine aggregate.

3. Split Tensile Strength also increased with increase in age.

4. At 28-days, control mix M-1 (with 0% replacement level of foundry sand) achieved modulus of elasticity of 25.10 GPa, whereas mixtures M-2 (10% foundry sand), M-3 (20% foundry sand), and M-4 (30% foundry sand) achieved modulus of elasticity of 26.74,29.11, and 31.11 GPa, respectively.

5. At 56-days it also showed a increase in values of modulus of elasticity by achieving the values of 27.19, 29.11,31.12 and 33.20 GPa for mixtures M-1, M-2, M-3, & M-4 respectively. So the results showed that modulus of elasticity increase with age as well as replacement of foundry sand.

Picture-1   Compression Testing Machine

Picture-2 Compression Failure of cubes at various replacement levels of foundry sand

Picture-3: Splitting Tensile Failure of cylinder at various replacement levels of Foundry Sand

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