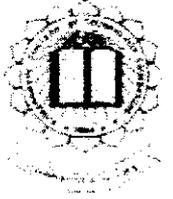


P-2617



Influence of the Proportion of Spent Foundry Sand on Mechanical Properties of Concrete



A Project Report

Submitted by

V. Nanthini

-

0720101008

*in partial fulfillment for the award of the degree
of*

**Master of Engineering
In
Structural Engineering**



**DEPARTMENT OF CIVIL ENGINEERING
KUMARAGURU COLLEGE OF TECHNOLOGY
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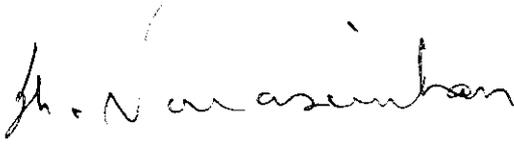
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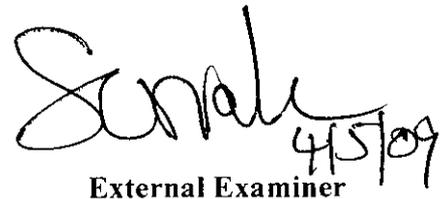
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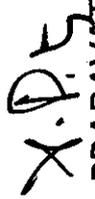
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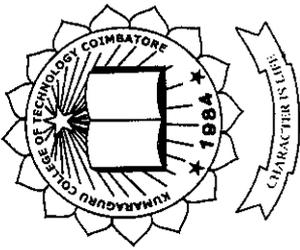
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National Conference on "ADVANCES AND INNOVATIONS IN CIVIL ENGINEERING"
organised by Department of Civil Engineering, on 25th March, 2009.

Title of the Paper: INFLUENCE OF THE PROPORTION OF SPENT FOUNDRY
SAND ON MECHANICAL PROPERTIES OF CONCRETE


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Title Study on strength properties of concrete
using foundry sand.


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ABSTRACT

The constant depletion of sand beds at all major sources of availability is a major concern and thus effects are taken in order to either abolish or replace sand in construction activities particularly in concrete. Foundry sand from casting industries is one of the waste materials which are dumped extensively and in this study an attempt has been made to use this waste material in the concrete to replace fine aggregate.

Waste is generated from all industries in different types and quantities throughout the life-cycle of it. The overall problem exists due to factors such as the use of materials and processes that create disposal problems, the use of materials that have no potential for future reuse or recycling and the use of inefficient materials. It is need to reduce or eliminate the wastes that follow the various paths leading to the landfill which creates pollution problems. Recycling the materials conserves resources and reduces pollution risks by keeping them out of disposal facility. There are many benefits to the increased used of recycled waste materials. Of many waste materials recycled and reused, foundry sand is one of the vital materials used in construction industry. Foundry sand is produced as waste from metal casting industries. Foundry sand can be used in concrete to improve strength and other durability factors.

In the present study, effect of foundry sand as fine aggregate replacement on the compressive strength, flexural strength and split tensile strength of concrete having mix proportions of 1:1.28:2.56:0.45 was investigated. The percentage of replacements are 10%,20%,30%,40%,50%,75% and 100% by weight of fine aggregate. Tests were performed for compressive strength, flexural strength and split tensile strength for all replacement levels of fine aggregate at different curing periods (7-days & 28-days). Test results showed some increase in compressive strength, flexural strength and split tensile strength compared to normal concrete for all the replacement levels. So foundry sand can be safely used in concrete for durability and strength purposes. Making concrete from recycled materials saves energy and conserves resources and it is concluded that the more material reused, the fewer resources are consumed which leads to a safe environment.

ACKNOWLEDGEMENT

First and foremost, I am deeply thankful to **The Almighty** for blessing me and making me to complete the project successfully.

I extend my heartfelt thanks to my Thesis guide **Dr.P.Eswaramoorthi, Ph.D.**, Professor, Dept. of civil Engineering, for his uplifting ideas and valuable suggestions throughout the thesis.

I take this opportunity to thank **Dr.S.L.Narashiman, Ph.D.**, Head of the Department, Civil Engineering, for his total support and encouragement throughout the project.

I express my sincere gratitude to the Principal, Kumaraguru College of Technology, Coimbatore for his kind patronage.

I sincerely express my gratitude and heartfelt thanks to the teaching and non teaching members of Civil Engineering Department for helping me in various ways to successfully complete the thesis.

I also owe a huge debt of gratitude to my **parents, sisters and friends**. They have always been there whenever I needed them. They have provided me for more than I could ever give them.

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INTRODUCTION

CHAPTER 1

INTRODUCTION

1.1 OVERVIEW

The disposal of the wastes has become a severe social and environmental problem in the territory which leads to an acute shortage of landfill space. As natural resource raw materials become more costly with ever higher global demand caused by developing nations undergoing economic expansion, the incentive to explore and locate low cost, environmentally beneficial alternative uses of production by-products becomes an ever more near term goal. The use of properly processed, valuable waste materials will achieve this goal while also preserving natural resources. These attributes, coupled with the wide-scale savings connected with exploration and processing of minerals while minimizing the need to transform large areas of the natural landscape for mining or land filling offer significant beneficial opportunities.

Recycling involves processing used materials into new products in order to prevent the waste of potentially useful materials, reduce the consumption of fresh raw materials, reduce energy usage, reduce air & water pollution by reducing the need for conventional waste disposal, lower green house gas emissions as compared to virgin production.

Utilization/Recycling of by-products/waste has become an attractive alternative to disposal. Several types of by-products and waste materials are generated. Each of these waste products has specific effects on the properties of cement based materials. The utilization of such materials in concrete not only makes it economical, but also do help in reducing disposal problems.

Industrial wastes and by-products are often undesired materials formed during the processing of raw materials for industrial or other useful endeavors such as power

generation. Many, if not properly handled, may be harmful and/or strenuous to the environment. These industrial by-product materials which include oils, slag, ashes, mineral products and metals are, however, much more homogeneous than the composition of municipal waste thus making them strong candidates for beneficial re-use in other applications. The various waste materials used are crushed glass, crushed tiles, plastics, crumb rubber, recycled concrete waste, paper sludge, saw dust, tyres, stone powder and rice husk ash.

The term “industrial sands” refers to any sand-like material that is a by-product of industrial processes. It includes manufactured sands or natural sands that have been used in some facet of industrial operations. There are a number of different types of industrial sands, including filter sands, quarry settling pond sands and foundry sands. Of these, foundry sands represent the largest volume and most geographically dispersed type of industrial sand. Foundry sands are produced during the metal casting process. Foundry sands have been used in a number of different road construction applications, including the production of cement. However, highway embankments and flowable fill are the most common uses.

1.2 OBJECTIVE

The main objective of testing is to know the behavior of concrete in which fine aggregate in concrete is replaced with foundry sand at room temperature. The main parameters studied are compressive strength, split tensile strength and flexural strength and their results are compared with control mix concrete.

1.3 METHODOLOGY

Basic strength characteristics such as compressive strength, split tensile strength, and flexural strength of concrete with foundry sand are the main focuses in this study. Strength is one of the most important properties of concrete since the first consideration in structural design is that the structural elements must be capable of carrying the imposed loads. Furthermore, strength characteristic is also vital because

it is related to several other important properties which are more difficult to measure directly.

Accordingly the development of compressive strength, split tensile strength and flexural strength of concrete are studied. The mix of concrete used in this study is grade 25. Based from results of the study, fine aggregate in concrete can be replaced using foundry sand upto 50% where the strength increases gradually. Beyond that if used the strength will get reduced and hence not safe to use in concrete. Concrete mix with 0% waste material is the control mix and water cement ration is equal to 0.45 which is according to the Indian Standard specification. Strength tests are conducted on the concrete specimens at the specific ages. All the strength tests are limited to 7days and 28days age. Besides, the physical and chemical properties of the waste material are also studied.

OVERVIEW OF FOUNDRY SAND

CHAPTER 2

OVERVIEW OF FOUNDRY SAND

A foundry is a manufacturing facility that produces metal castings by pouring molten metal into a preformed mould to yield the resulting hardened cast.

All foundries produce castings by pouring molten metal into molds. The characteristics of the residuals vary from foundry to foundry and depend on

- the type of metal being poured (iron, steel, aluminum, brass/bronze)
- the type of casting process (sand casting, investment casting)
- the technology employed, particularly the type of furnace
- And the type of finishing process (grinding, blast cleaning, coating).

Metal foundries use large amounts of sand as part of the metal casting process. Foundries successfully recycle and reuse the sand many times in a foundry. When the sand can no longer be reused in the foundry, it is removed from the foundry and is termed as “foundry sand.” Like many waste products, foundry sand has beneficial applications to other industries.

2.1 FOUNDRY SAND

It is high quality silica sand with uniform physical characteristics. It is a byproduct of ferrous and nonferrous metal casting industries, in which sand has been used for centuries as a molding material because of its thermal conductivity.

The physical and chemical characteristics of foundry sand will depend 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. 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.

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, sand 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 many 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. 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 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.

2.2 SPENT FOUNDRY SAND

It is a standard foundry practice to reuse molding and core making sands. Residual sand is routinely screened and returned to the system for reuse. Spent foundry sands are generated by the metal casting industry. Foundries purchase new, virgin sand to make casting molds, and the sand is reused numerous times within the foundry. However,

heat and mechanical abrasion eventually render the sand unsuitable for use in casting molds, and a portion of the sand is continuously removed and replaced with virgin sand. That is as the sands are repeatedly used, the particles eventually become too fine for the molding process and combined with heat degradation from repeated pourings,

requires periodic replacement of 'spent' foundry sand with fresh sand. The spent foundry sand, that is, the sand that is removed, is either recycled in a non-foundry application or land filled. The recycling of non hazardous, spent foundry sand can save energy, reduce the need to mine virgin materials, and may reduce costs for both producers and end users. For example, in cold weather climates, use of spent foundry sands as construction site base material extends the construction season because such sands won't freeze as readily as most soils. This 'spent sand' is typically non-hazardous, black in color, and contains a large amount of fines (particles of 100 sieve size or less).

2.3 RECYCLING IN THE FOUNDRY INDUSTRY

- Purchase recycled materials and components as feedstock
- Use and reuse a variety of materials within the melting and molding stage
- Produce recyclable products for the customer
- Supply secondary markets with usable by-products generated by various facilities in the Foundry Industry.

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.2.1 shows how the sand is reused and becomes foundry sand.

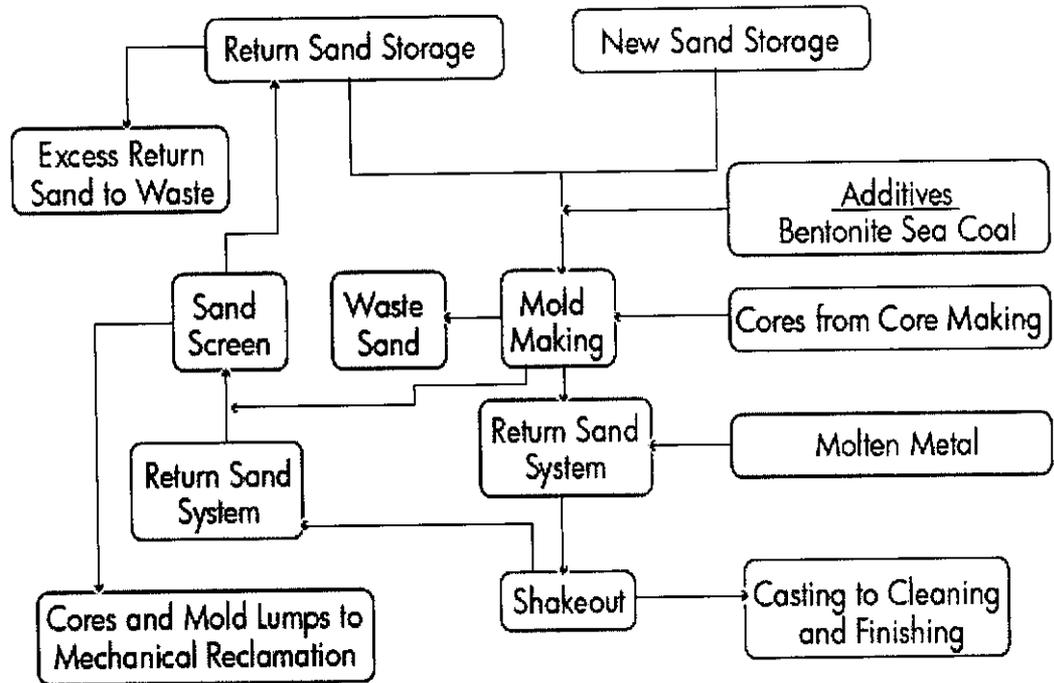


Fig 2.1 Recycling of Foundry Sand

2.4 TYPES OF FOUNDRY SAND

There are two basic types of foundry sand available:

-green sand (often referred to as molding sand) that uses clay as the binder material and

-chemically bonded sand that uses polymers to bind the sand grains together.

Green sand consists of 85-95% silica, 0-12% clay, 2-10% carbonaceous additives such as seacoal and 2-5% water. Green sand is the most commonly used molding media by foundries. Green sands also contain trace chemicals such as MgO, K₂O, and TiO₂.

The silica sand is the bulk medium that resists high temperatures while the coating of clay binds the sand together. The water adds plasticity. The carbonaceous additives prevent the “burn-on” or fusing of sand onto the casting surface. Chemically bonded sand consists of 93-99% silica and 1-3% chemical binder. Silica sand is thoroughly mixed with the chemicals; a catalyst initiates the reaction that cures and hardens the mass. There are various chemical binder systems used in the foundry industry. The most common chemical binder systems used are phenolic-urethanes, epoxy-resins, furfuryl alcohol and sodium silicates.

2.5 MATERIAL PROPERTIES

2.5.1 Physical Characteristics of Foundry Sand⁴:

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.

Green sands are typically black, or gray. Non green chemically bonded sand is typically a medium tan or off-white color. Fig 2.2 and Fig 2.3 shows the unprocessed foundry sand and green sand respectively.

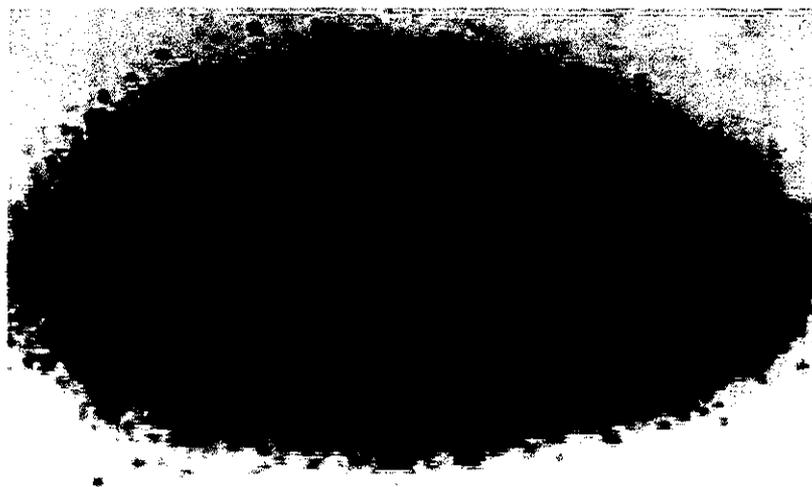


Fig 2.2 Unprocessed Foundry Sand

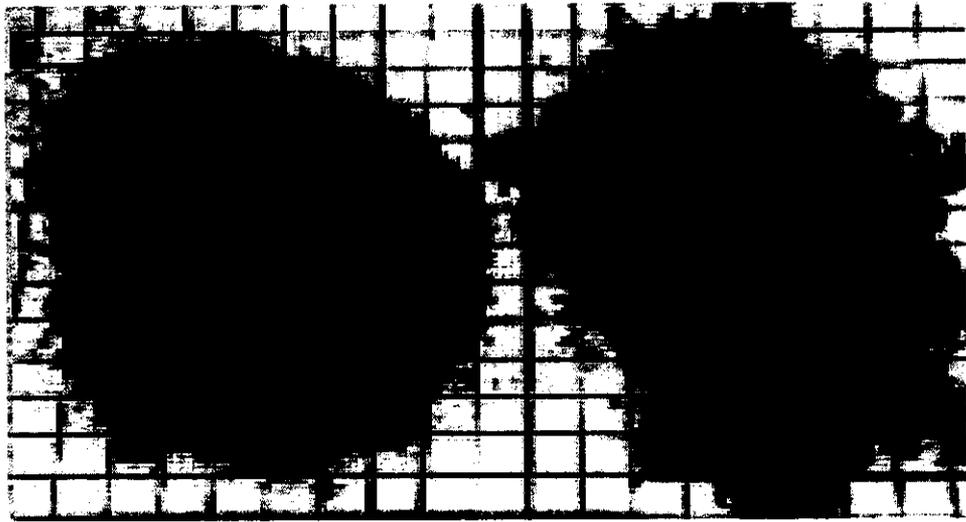


Fig.-2.3 Green Sands



2.5.2 Physical Properties⁴:

Typical physical properties of spent foundry sand from green sand systems are given in Table-2.1. 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). 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 non-plastic. 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).

Table 2.1 Typical physical properties of spent green foundry sand

Property	Results	Test Method
Specific Gravity	2.39 – 2.55	ASTM D854
Bulk Relative Density, Kg/m ³ (lb/ft ³)	2589 (160)	ASTM48/AASTHO T84
Absorption %	0.45	ASTM C128
Moisture content %	0.1 – 10.1	ASTM D2216
Clay lumps and friable particles	1-44	ASTM C124/AASTHO T112
Coefficient of permeability	10 ⁻³ - 10 ⁻⁶	AASTHO T125/ ASTM D2434
Plastic limit / plastic index	Non plastic	AASTHO T90/ASTM D4318

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 fineness 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-2.1 is a direct result of the fraction of fines in the samples collected. 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.

2.5.3 Mechanical Properties⁴:

Typical mechanical properties of spent foundry sand are listed in Table 2.2. 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 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 sulphate 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 2.2 Typical mechanical properties of spent foundry sand

Property	Results	Test Method
Micro-Deval 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

2.5.4 Environmental Characteristics:

Trace element concentrations present in most clay-bonded iron and aluminium 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 not 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.

2.5.5 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. Anti stripping 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 leachable 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.

2.5.6 Foundry Sand Engineering 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.

2.6 APPLICATIONS

Foundry sand is basically a fine aggregate. It can be used in many ways as natural or manufactured sands. This includes many civil engineering applications such as embankments, flowable fill, hot mix asphalt and Portland cement concrete. Foundry sands have also been used extensively agriculturally as topsoil.

There is a range of options that are available for the beneficial reuse or recycling of the Foundry-Sand materials. Possible uses include concrete production, bitumen production, flowable fill, agricultural soil conditioner, loam production, cement production, road base/crushed rock, brick & paver manufacture. Some of its applications are briefly explained below.

Structural/Base/Sub-base Fill: Projects where foundry by-products have been beneficially used as structural fill, embankment material, granular backfill, roadway sub-base and roadway base material.

Flowable Fill: Projects where foundry by-products have been used in the production of controlled low strength materials (i.e., flowable fill)

Concrete and related products: Projects where foundry by-products have been used in the production of concrete bricks, pre-cast concrete such as blocks and construction of concrete pavements.

Asphalt: Projects where foundry by-products have been used in asphaltic concrete.

Soil Amendments: Projects where foundry by-products have been used in agricultural applications

Portland cement: Projects where foundry by-products have been used in the production of Portland cement

Landfill Liners and covers: Projects where foundry by-products have been used in landfill liner and cover construction

Other Applications: Contains other applications such as pipe bedding, clay bricks, landfill drainage layers, etc.

LITERATURE SURVEY

CHAPTER 3

LITERATURE SURVEY

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 H₂O were subjected to cycles of freezing and thawing 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 spalling between 60 and 150 cycles of freezing and thawing.

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 cementitious material, fine aggregates and coarse aggregates were approximately 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.24MPa). Overall the test showed that concrete with cylinder strength as low as 14MPa 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 mix met the compressive strength requirement of ASTM C 55 for Grade S bricks at approximately 7 and 22 days

respectively. The cylinder strength and the brick strength are linearly related up to approximately 25MPa cylinder strength and 40MPa 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.55MPa). For producing paving stones that meet the ASTM strength requirements the increase in amounts of cementitious 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 approximately 1.5 times the equivalent cylinder strength.

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 mm³/mm² or (mm), respectively. All these values exceeded the limit of 3mm 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.

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., (2003) conducted an investigation to see the effects of freezing and thawing 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., (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 (17MPa) 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 (55MPa). In case of blocks all the mixtures except one exceeded minimum compressive strength requirement of ASTM C 90 (13MPa). 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.

J.M.Khalib and D.J. Ellis et al., (2001) The properties of concrete containing foundry sand as a partial replacement of fine aggregate were investigated. Three types of sand used in foundries were considered, the white fine sand without addition of clay and coal, foundry sand before casting (blended) and foundry sand after casting (spent). The standard sand (class M) was partially replaced by (0%, 25%, 50%, 75%, 100%) these types of sand. Thirteen concrete mixtures were employed to conduct this study. Concrete strength upto 90 days and length change (dry shrinkage and expansion) upto 60days were determined. As replacement level of standard sand with sand used in foundries increased, strength of concrete decreased. Concrete containing white sand showed somewhat similar strength to those containing spent sand at a replacement levels. The presence of high percentage of blended sand in concrete mixture caused a reduction in strength as compared with concrete incorporating white or spent sand. Increase in strength was not observed at low replacement levels (less than 50%). The length change of concrete increased as replacement level of standard sand with three types of sand increased. Drying shrinkage values were higher in concrete containing spent sand and lower in concrete containing white sand. Expansion was generally lower in concrete containing white sand as compared with other two types(blended an spent) ay a low sand replacement level of 25% and different trend was obtained at higher levels.

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?0-6cm/s to 72 ?0- 6cm/s and for fly ash F2 the slurry mixture varied from 5?0-6cm/s to 69?0-6cm/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 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., (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 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/m³. 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., (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 (75 μ m) 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.

Paul Tikalsky, Mike Gaffney, Ray Regan et al., (2000) this research study was performed to document and evaluate engineering properties of controlled low strength materials containing byproduct foundry sand (FS-CLSM). Mixture containing clay-bonded chemically bonded sand was compared in the plastic and hardened states to CLSM mixtures containing uniformly graded crushed limestone sand. The data presented show that by-product foundry sand can be successfully used in CLSM and it provides similar or better properties to that of CLSM containing crushed limestone sand. The foundry sand assisted in keeping the strength from exceeding the desired upper limit of 700KPa. Clay bonded sand retarded the setting

time and chemically bonded sand required a reduction in water to control bleeding. CLSM containing a combination of fly ash and chemically bonded sands was shown to have excellent characteristics for flowable backfill and excavatable base material.

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. 700KPa. 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 ½ 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 m³ 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.

Tikalsky et al., (1998) reported that the swelling potential and instability of bentonite stabilized mixes render the leachable quality unpredictable. The data on total phenolic obtained from leachability experiments were normalized to account for difference in volumes of leachate collected for each stabilized mix. In the experiments 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 phenolic 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 phenolic. 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 phenolic 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.

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 0.4MPa 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.

Tarun R.Naik, Shiw S.Singh, Mathew P.Tharaniyil and Robert B.Wendorf et al (1996): Research was undertaken to evaluate performance of foundry by-product in concrete and masonry products. Two series of experiments were carried out. The first series of experiments were towards the use of an air cooled foundry slag in concrete as a partial replacement of coarse aggregate. The second series of work involved use of foundry sand as a partial replacement of fine aggregate

for making masonry blocks paving stones. First series of tests were carried out to evaluate the performance characteristics of a foundry slag concrete under laboratory conditions. A reference concrete without foundry slag was proportioned to obtain 28-days compressive of 6000 psi. Two other mixes containing 50% and 100% foundry slag as a replacement of regular aggregate were also proportioned. The 100% slag mix showed compressive strength comparable to reference mix. However Modulus of elasticity of concrete containing 100% slag was higher than reference concrete. Four mixes with and without foundry sand were proportioned for manufacture of masonry blocks with a design strength of 1500psi at 28-days age. Additionally , four mixes, three with and one without foundry sand, were also proportioned for manufacture of paving stones with a design strength of 8000psi at 28-days age in all mixes,35% regular sand was replaced with new/used foundry sand obtained from different sources no admixtures were added to the mixes. Test results indicated that masonry blocks made with 35% used foundry sand passed ASTM requirements for compressive strength, absorption and bulk density. However paving mixes used in this study did not meet target strength of 8000psi and showed slightly higher absorption than ASTM limit for paving stones.

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 cementitious 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.

EXPERIMENTAL PROGRAMME

CHAPTER 4

EXPERIMENTAL PROGRAMME

4.1 TEST RESULTS OF MATERIALS

4.1.1 Cement:

Portland Pozzolana cement is used for all concrete mixes. The cement used is fresh and without any lumps. Testing of cement is done as per IS: 8112-1989.

4.1.2 Coarse Aggregate:

Locally available coarse aggregates are used in the present work. Testing of coarse aggregate is done as per IS: 383-1970. Initially the various properties of coarse aggregate are tested and their values are tabulated in Table 4.1.

Table 4.1 Properties of Coarse aggregate

S. No.	Characteristics	Value
1	Maximum Size	20mm
2	Specific gravity	2.58
3	Total water absorption	0.4%
4	Fineness Modulus	6

4.1.3 Fine Aggregate:

The sand used for the experimental programme is locally procured and conformed to grading zone II as per IS: 383-1970. The sand is first sieved through 4.75 mm sieve to remove any particles greater than 4.75 mm. Properties of the fine aggregate used in the experimental work are tabulated in Table 4.2.

Table 4.2 Properties of Fine aggregate

S.No	Characteristics	Value
1	Type	Medium
2	Specific gravity	2.6
3	Bulk Density	1607
4	Fineness modulus	2.7

4.1.4 Foundry Sand:

The physical and chemical properties of the foundry sand used in this project are listed in Table 4.3 and Table 4.4 respectively. Tables from 4.5 to 4.9 shows the sieve analysis for various replacement levels of fine aggregate with foundry sand.

Table 4.3 Physical Properties of Foundry Sand

Property	Results	Test Method
Specific Gravity	2.47	ASTMD845
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)	$10^{-3} - 10^{-6}$	ASTM T215/ASTM D2434
Plastic Limit	Non plastic	ASTM T90/ASTM D4318

Table 4.4 Foundry sand sample chemical oxide composition

Constituent	Value (%)
SiO ₂	68
Al ₂ O ₃	4.23
Fe ₂ O ₃	7.12
Ca O	0.10
Mg O	0.24
SO ₃	0.92
Na ₂ O	0.37
K ₂ O	0.51
P ₂ O ₅	0.0
Mn ₂ O ₃	0.14
TiO ₂	0.51
SrO	0.10
LOI	17.56
Total	99.8

Tested at SITRA (South Indian Textile Research Association, Coimbatore)

Table 4.5 Sieve analysis of Fine Aggregate at 10% replacement level

I.S.Sieve Size (mm)	Weight retained (gm)	Cumulative Weight Retained (gm)	Percentage retained	Percentage passing
40	0	0	0.00	100.00
20	0	0	0.00	100.00
10	0	0	0.00	100.00
4.75	0	0	0.00	100.00
2.36	0.015	0.015	3.05	96.95
1.18	0.067	0.082	16.67	83.33
0.6	0.08	0.162	32.93	67.07
0.3	0.217	0.379	77.03	22.97
0.15	0.1	0.479	97.36	2.64
Pass	0.013	0.492	100.00	0.00

Fineness Modulus: 3.2

Table 4.6 Sieve analysis of Fine Aggregate at 20% replacement level

I.S.Sieve Size (mm)	Weight retained (gm)	Cumulative Weight Retained (gm)	Percentage retained	Percentage passing
40	0	0	0.00	100.00
20	0	0	0.00	100.00
10	0	0	0.00	100.00
4.75	0	0	0.00	100.00
2.36	0.013	0.013	2.62	97.38
1.18	0.049	0.062	12.47	87.53
0.6	0.062	0.124	24.95	75.05
0.3	0.212	0.336	67.61	32.39
0.15	0.139	0.475	95.57	4.43
Pan	0.022	0.497	100.00	0.00

Fineness Modulus: 3.0

Table 4.7 Sieve analysis of Fine Aggregate at 30% replacement level

I.S.Sieve Size (mm)	Weight retained (gm)	Cumulative Weight Retained (gm)	Percentage retained	Percentage passing
40	0	0	0.00	100.00
20	0	0	0.00	100.00
10	0	0	0.00	100.00
4.75	0	0	0.00	100.00
2.36	0.012	0.012	2.40	97.60
1.18	0.046	0.058	11.60	88.40
0.6	0.063	0.121	24.20	75.80
0.3	0.202	0.323	64.60	35.40
0.15	0.152	0.475	95.00	5.00
Pan	0.025	0.5	100.00	0.00

Fineness Modulus: 3.0

Table 4.8 Sieve analysis of Fine Aggregate at 40% replacement level

I.S.Sieve Size (mm)	Weight retained (gm)	Cumulative Weight Retained (gm)	Percentage retained	Percentage passing
40	0	0	0.00	100.00
20	0	0	0.00	100.00
10	0	0	0.00	100.00
4.75	0	0	0.00	100.00
2.36	0.01	0.01	2.00	98.00
1.18	0.05	0.06	12.00	88.00
0.6	0.062	0.122	24.40	75.60
0.3	0.217	0.339	67.80	32.20
0.15	0.153	0.492	98.40	1.60
Pan	0.008	0.5	100.00	0.00

Fineness Modulus: 3.0

Table 4.9 Sieve analysis of Fine Aggregate at 50% replacement level

I.S.Sieve Size (mm)	Weight retained (gm)	Cumulative Weight Retained (gm)	Percentage retained	Percentage passing
40	0	0	0.00	100.00
20	0	0	0.00	100.00
10	0	0	0.00	100.00
4.75	0	0	0.00	100.00
2.36	0.01	0.01	2.02	97.98
1.18	0.049	0.059	11.92	88.08
0.6	0.059	0.118	23.84	76.16
0.3	0.202	0.32	64.65	35.35
0.15	0.151	0.471	95.15	4.85
Pan	0.024	0.495	100.00	0.00

Fineness Modulus: 3.0

4.2 MOULDS

Cubical mould of size 150mm*150mm*150mm are used to prepare the concrete specimens for the determination of compressive strength of foundry sand concrete at various replacement levels. Care is taken during casting and vibrator is used for proper compaction. Cylindrical mould of size 150 mm diameter, 300 mm height and beam mould of size 500mm*100mm*100m are used to prepare the concrete specimens for the determinations of split tensile strength and flexural strength of foundry sand concrete respectively. All the specimens are prepared in accordance with Indian Standard Specifications IS: 516-1959. All the moulds are cleaned and oiled properly. They are securely tightened to correct dimensions before casting. Care is taken so that no gaps are left from where there is any possibility of leakage out of slurry.

4.3 MIX DESIGN

Concrete mix has been designed based on Indian Standard Recommended Guidelines IS: 10262-1982. The proportions for the concrete, as determined are 1:1.28:2.56:0.45. The quantities of various materials for each designed concrete mix have been tabulated in Table 4.10, Table 4.11 and Table 4.12 for cubes, beam and cylinder respectively.

Table 4.10 Quantities (Kg/m³) of materials for six cubes @ all replacement levels

Replacement Level (%)	Cement	Coarse Aggregate	Fine Aggregate		Water
			Ordinary Sand	Foundry sand	
0	11.21	28.6	11.67		5.04
10	11.21	28.6	10.50	1.17	5.04
20	11.21	28.6	9.34	2.33	5.04
30	11.21	28.6	8.17	3.50	5.04
40	11.21	28.6	7.00	4.67	5.04
50	11.21	28.6	5.83	5.83	5.04
75	11.21	28.6	2.92	8.75	5.04
100	11.21	28.6	-	11.67	5.04

Table 4.11 Quantities (Kg/m³) of materials for beam @ all replacement levels

Replacement Level (%)	Cement	Coarse Aggregate	Fine Aggregate		Water
			Ordinary Sand	Foundry sand	
0	2.77	7.08	2.88		1.24
10	2.77	7.08	2.59	0.29	1.24
20	2.77	7.08	2.31	0.58	1.24
30	2.77	7.08	2.02	0.86	1.24
40	2.77	7.08	1.73	1.15	1.24
50	2.77	7.08	1.44	1.44	1.24
75	2.77	7.08	0.72	2.16	1.24
100	2.77	7.08	-	2.88	1.24

Table 4.12 Quantities (Kg/m³) of materials for cylinder (@ all replacement levels

Replacement Level (%)	Cement	Coarse Aggregate	Fine Aggregate		Water
			Ordinary Sand	Foundry sand	
0	2.93	7.50	3.06		1.015
10	2.93	7.50	2.75	0.31	1.015
20	2.93	7.50	2.45	0.61	1.015
30	2.93	7.50	2.14	0.92	1.015
40	2.93	7.50	1.83	1.22	1.015
50	2.93	7.50	1.53	1.53	1.015
75	2.93	7.50	0.76	2.29	1.015
100	2.93	7.50	-	3.05	1.015

4.4 BATCHING, MIXING AND CASTING OF SPECIMENS

A careful procedure has been adopted in the batching, mixing and casting operations. The coarse aggregates and fine aggregates are weighed first with an accuracy of 0.5 grams. The concrete mixture has been prepared by hand mixing on a watertight platform. Portland Pozzolana cement is used in casting. Fine aggregates are replaced with foundry sand at various replacement levels and thoroughly mixed. After that coarse aggregates are added to it. Then water is added carefully so that no water is lost during mixing. Six clean and oiled moulds for each category are then placed on the vibrating table respectively for the cubical samples for compression strength testing and one cylindrical mould and one beam mould for split tensile and flexural strength testing respectively. Vibrations are stopped as soon as the cement slurry appeared on the top surface of the mould. The specimens are allowed to remain in the mould for the first 24 hours at ambient condition. After, they are demoulded with care so that no edges were broken and are placed in the curing tank for curing.

RESULTS AND DISCUSSIONS

CHAPTER 5

RESULTS AND DISCUSSIONS

5.1 GENERAL

The strength properties of concrete incorporating foundry sand at various replacement levels with fine aggregate has been studied, results are compared with control mix concrete and checked for compressive strength, split tensile strength and flexural strength of concrete.

5.2 COMPRESSIVE STRENGTH

The compressive strength for different replacement levels of foundry sand contents (0%, 10%, 20%, 30%, 40%, 50%, 75% and 100%) at the end of 7-days and 28-days results are given in Table-5.1. These values are plotted in Figures 5.1 and 5.2 which shows the variation of compressive strength with fine aggregate replacements of foundry sand at different curing periods.

Table 5.1 Compressive strength @ 7 and 28 days

Foundry Sand Content (%)	Compressive Strength, MPa	
	7 days	28 days
0	17.9	27.34
10	18.67	28.65
20	19.15	30.01
30	21.1	31.2
40	22.05	32.15
50	23.1	33.2
75	16.2	23.24
100	13.9	22.1

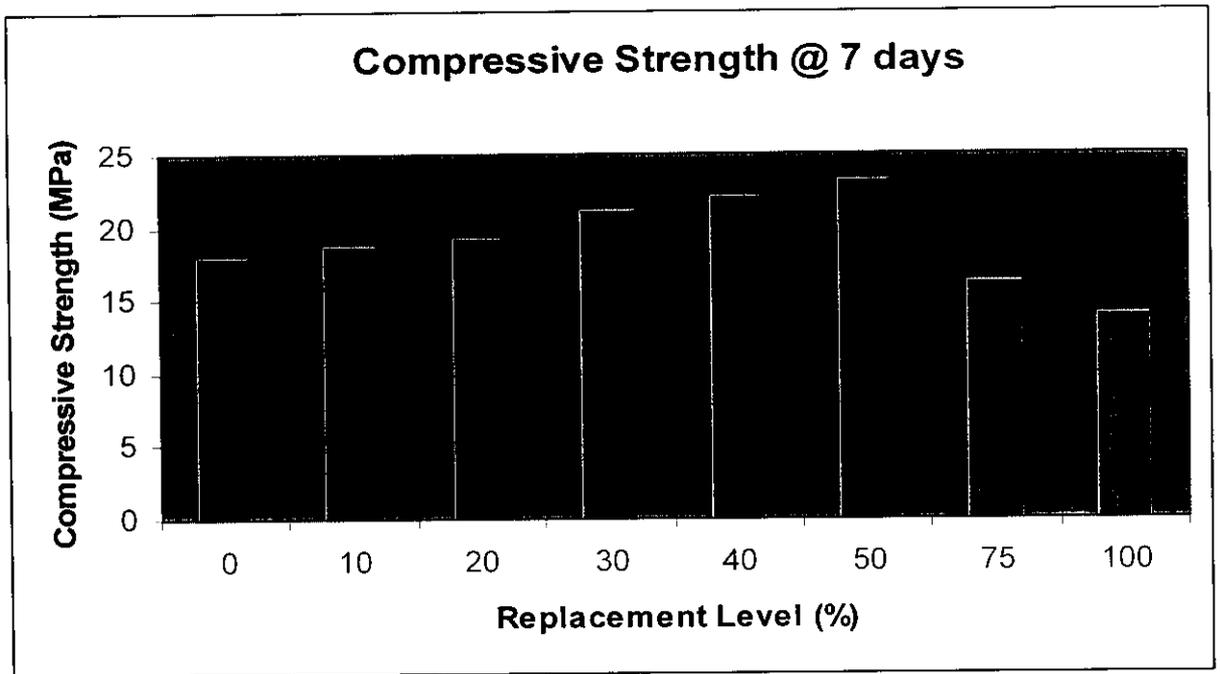


Fig 5.1 Compressive strength of concrete at 7 days

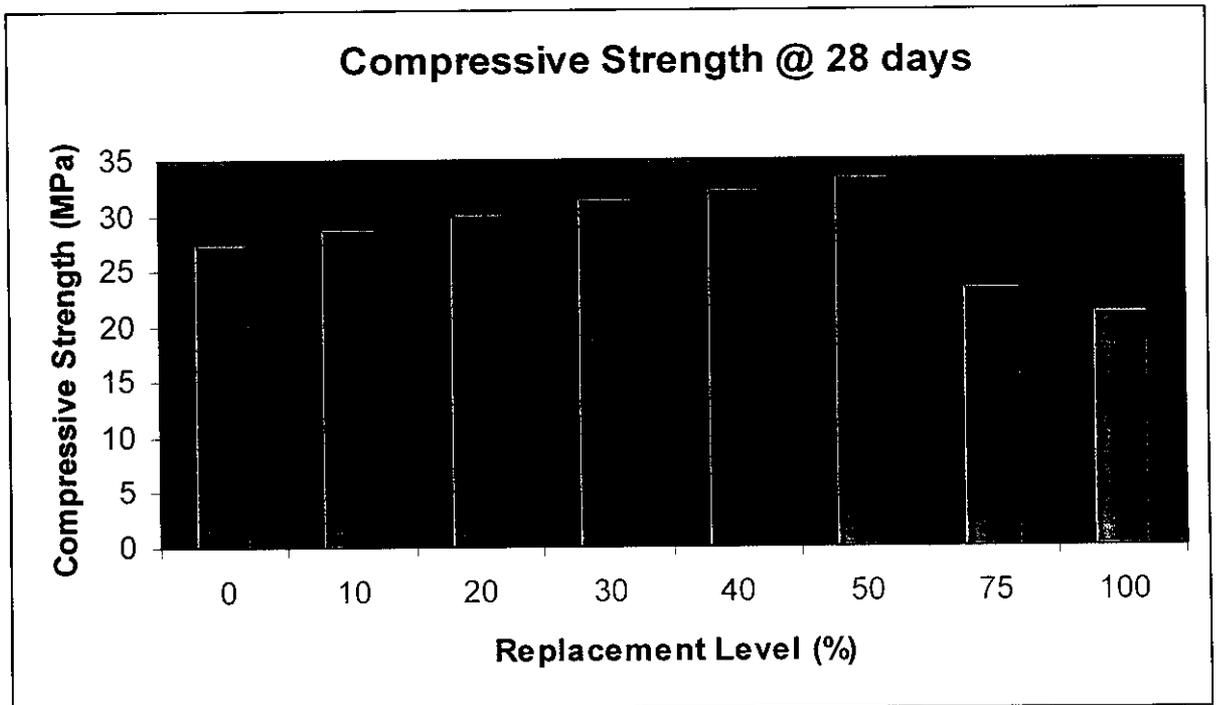


Fig 5.2 Compressive strength of concrete at 28 days

It is evident from the results that the compressive strength of concrete mixture with 10% 20%, 30%, 40%, 50% , 75% and 100% of foundry sand as fine aggregate replacement was higher than the control mix concrete upto 50% at all ages and that the strength of all mixtures continued to increase with the age.

5.3 SPLIT TENSILE STRENGTH

It was found that split tensile strength of concrete incorporating foundry sand depended on the percentage replacement. The variation of split tensile strength is shown in Table-5.2. Fig 5.3 shows the variation of split tensile strength with replacements of foundry sand at various levels of fine aggregate at 28-days.

Table 5.2 Split tensile strength @ 28 days

Foundry Sand Content (%)	Split tensile Strength, (N/mm ²) 28 days
0	2.54
10	2.63
20	2.72
30	2.94
40	3.0
50	3.43
75	2.74
100	2.53

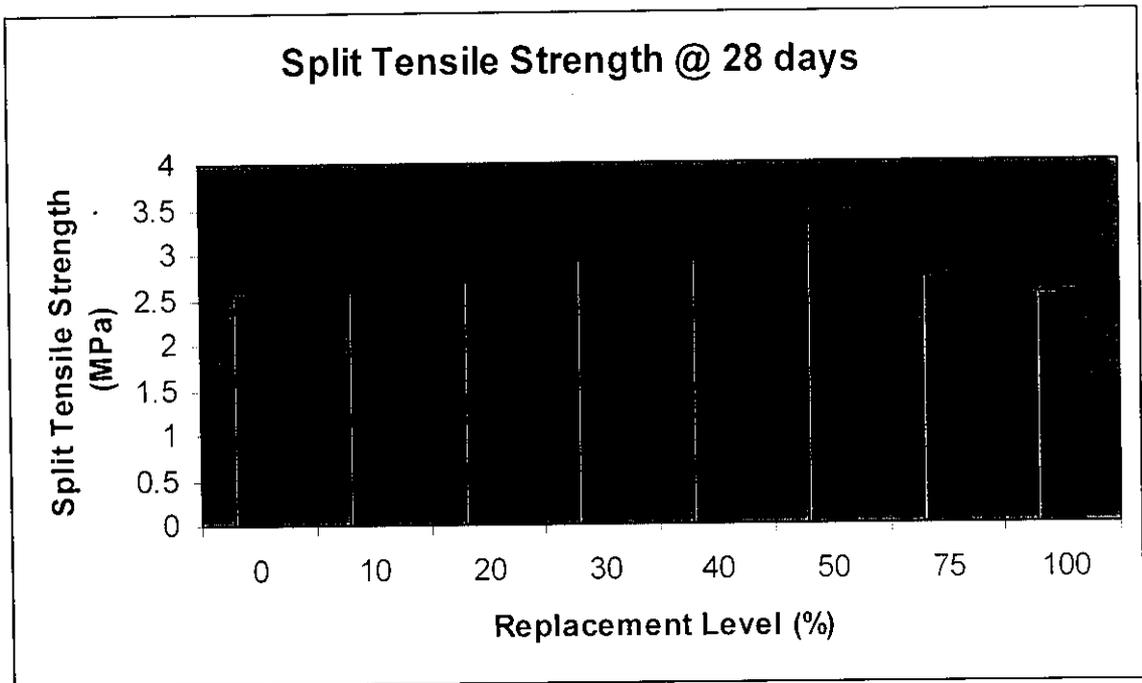


Fig 5.3 Split tensile strength of concrete at 28 days

5.4 FLEXURAL STRENGTH

The flexural strength property of concrete incorporating foundry sand at various replacement levels with fine aggregate has been studied and results are compared with control mix concrete. The following Table-5.3 and Figure-5.4 shows the flexural strength of concrete whose values increased with increase in replacement of fine aggregate with foundry sand upto 50%.

Table 5.3 Flexural strength @ 28 days

Foundry Sand Content (%)	Flexural Strength, (N/mm ²) 28 days
0	3.96
10	4.11
20	5.32
30	7.41
40	7.82
50	8.02
75	6.01
100	4.93

Flexural Strength @ 28 days

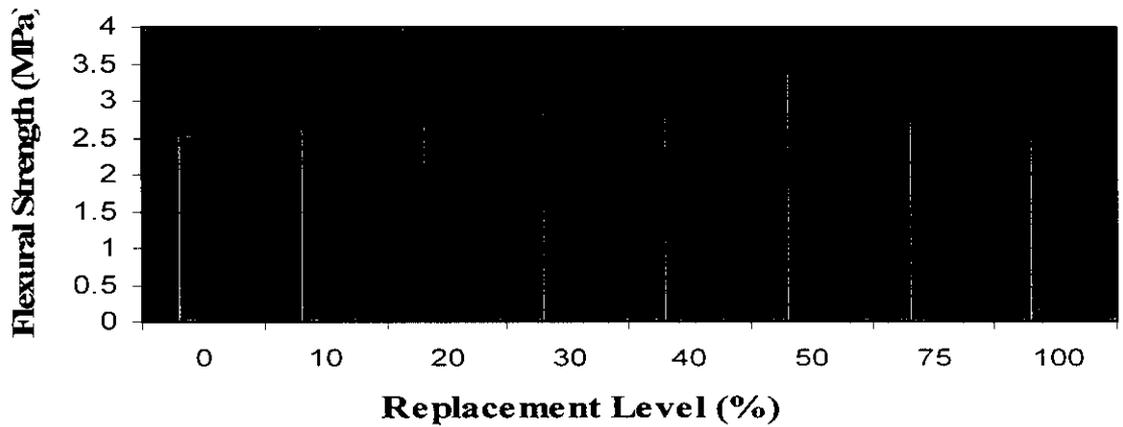


Fig 5.4 Flexural strength of concrete at 28 days

5.5 DISCUSSION

- ◆ Compressive strength of concrete increased with the increase in fine aggregate replacement by foundry sand upto 50% and beyond that for 75% and 100% replacement level the strength gets reduced.
- ◆ The compressive strength increased by 4%, 7%, 17%, 23%, 29% upto 50% replacement level of fine aggregate but for 75% and 100% replacement levels the strength gets reduced by 10% and 22% compared to control mix concrete without foundry sand at 7-days.
- ◆ Similarly compressive strength at 28-days increased by 5 %, 9 %, 14%, 18%, 21% upto 50% replacement level of fine aggregate but gets reduced by 15% and 19% for 75% and 100% replacement levels compared to control mix concrete.
- ◆ Split Tensile Strength also showed an increase with increase in replacement levels of foundry sand with fine aggregate upto 50% beyond that for 75% and 100% the strength got reduced.
- ◆ At 28-days, control mix concrete (with 0% replacement level of foundry sand) achieved flexural strength of 3.96MPa whereas mixtures of 10, 20, 30, 40 and 50% fine aggregate replacement by foundry sand achieved flexural strength of 4.11, 5.32, 7.41, 7.82, 8.02 respectively. And for 75% and 100% replacement levels the strength achieved are 6.01 and 4.93MPa which shows that flexural strength gets decreased after 50% replacement level.
- ◆ The increase in compressive strength, split tensile strength and flexural strength may be due to fineness of the foundry sand. The foundry sand fineness is high compared to normal fine aggregate, this may reduce the porous nature of the concrete that is fill the voids and there by increase in

density and strength. But if the replacement level increases beyond 50%, the strength get reduced because of more fines (excess fines) compared to controlled mix. The chemical analysis shows that the silica content and alkali content are more; hence there is a need to study the durability of this concrete. The alkali silica and alkali aggregate reaction may studied in detail.

CONCLUSION

CHAPTER 6

CONCLUSION

The following conclusions are drawn from this study:

- ◆ The replacement level of fine aggregate with foundry sand upto 50% is desirable as there is increase in compressive strength, split tensile strength and flexural strength.
- ◆ Beyond 50% replacement level (75% and 100%), the compressive strength, split tensile strength and flexural strength decreases.
- ◆ Hence it can be concluded the replacement level of fine aggregate with foundry sand above 50% is not desirable.
- ◆ The replacement of natural sand with used foundry sand is desirable as it is cost effective, reduces the amount of virgin fine aggregate, reduces landfill problems and hence preserves nature.
- ◆ Making concrete from recycled materials (foundry sand) saves energy and conserves resources and it is concluded that the more material reused, the fewer resources are consumed which leads to a safe environment.

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