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Project Report on

“EFFECTS OF PARTIAL REPLACEMENT OF CEMENT WITH IRRADIATED PLASTIC IN CONCRETE”

Submitted in partial fulfilment for the award of the degree of

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CHAPTER 1

INTRODUCTION

CHAPTER-1

INTRODUCTION

1.1 General Introduction

The problem of disposing and managing solid waste materials in all countries has become one of the major environmental, economical, and social issues. A complete waste management system including source reduction, reuse, recycling, land-filling, and incineration needs to be implemented to control the increasing waste disposal problems. The use of recycled plastics in concrete has been explored as means of improving concrete's mechanical properties while all providing an efficient way to both repurpose waste plastic and Partially displace cement for the purpose of reducing carbon emissions. The task remains, however, develop a cement design that allows for both the addition of plastic and the preservation of high compressive strength. This study explores the effectiveness of gamma-irradiated plastic as an additive in cement paste (Portland cement + additives + water) samples for improving the compressive strength. Irradiated plastic is paired with different mineral additives, which are commonly used to achieve high strength, with the goal of finding an optimal combination. An Internal microstructure analysis is presented in order to provide some insight into the aspects of the materials' chemical compositions that contribute to the observed variation in strength. The objective is to determine whether or not irradiated plastic is an effective partial replacement for cement; achieving a high/medium-strength concrete using this additive would imply the ability to produce a lower carbon footprint concrete variety that could even act as a permanent storage option for plastic waste.

1.2 Abstract:

- Concrete production contributes heavily to greenhouse gas emissions, thus a need exists for the development of durable and sustainable concrete with a lower carbon footprint.
- This can be achieved when cement is partially replaced with another material, such as waste plastic, though normally with a tradeoff in compressive strength.
- This study discusses progress toward a high/medium strength concrete with a dense, cementitious matrix that contains an irradiated plastic additive, recovering the compressive strength while displacing concrete with waste materials to reduce greenhouse gas generation.
- Irradiating plastic at a high dose is a viable potential solution for regaining some of the strength that is lost when plastic is added to cement paste.
- X-ray Diffraction (XRD) can explain the mechanisms for strength retention when using irradiated plastic as a filler for cement paste. .

1.3 Objectives

- To examine the effectiveness of irradiated plastic as an additive for enhancing the compressive strength of concrete.
- Understanding the effect of the waste plastic’s radiation dose on concrete strength.
- This work also seeks to optimize the combination of plastic and industrial additive — plastic and either fly ash or GGBS.
- Phase identification through X-ray diffraction (XRD) analysis is utilized to collectively assess the internal structure of the samples and to help determine which aspects of the materials compositions contribute to variability in strength.

CHAPTER 2

LITERATURE REVIEW

CHAPTER-2

LITERATURE REVIEW

2.1 General

The purpose of this lesson is to have a broad understanding of using alternative materials with the replacement of Cement using irradiated plastic powder (PVC POWDER).

2.1.1 Irradiated recycled plastic as a concrete additive for improved chemo-mechanical properties and lower carbon footprint

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Concrete production contributes heavily to greenhouse gas emissions, thus a need exists for the develop-ment of durable and sustainable concrete with a lower carbon footprint. This can be achieved when cement is partially replaced with another material, such as waste plastic, though normally with a tradeoff in compressive strength. This study discusses progress toward a high/medium strength concrete with a dense, cementitious matrix that contains an irradiated plastic additive, recovering the compressive strength while displacing concrete with waste materials to reduce greenhouse gas generation. Compressive strength tests showed that the addition of high dose (100 kGy) irradiated plastic in multiple concretes resulted in increased compressive strength as compared to samples containing regular, non-irradiated plastic. This suggests that irradiating plastic at a high dose is a viable potential solution for regaining some of the strength that is lost when plastic is added to cement paste. X-ray Diffraction (XRD), Backscattered Electron Microscopy (BSE), and X-ray microtomography explain the mechanisms for strength retention when using irradiated plastic as a filler for cement paste. By partially replacing Portland cement with a recycled waste plastic, this design may have a potential to contribute to reduced carbon emissions when scaled to the level of mass concrete production.

2.1.2 Irradiated recycled plastic as a concrete additive for improved chemo-mechanical properties and lower carbon footprint:-

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Concrete production contributes heavily to greenhouse gas emissions, thus a need exists for the development of durable and sustainable concrete with a lower carbon footprint. This can be achieved when cement is partially replaced with another material, such as waste plastic, though normally with a tradeoff in compressive strength. This study discusses progress toward a high/medium strength concrete with a dense, cementitious matrix that contains an irradiated plastic additive, recovering the compressive strength while displacing concrete with waste materials to reduce greenhouse gas generation. Compressive strength tests showed that the addition of high dose (100 kGy) irradiated plastic in multiple concretes resulted in increased compressive strength as compared to samples containing regular, non-irradiated plastic. This suggests that irradiating plastic at a high dose is a viable potential solution for regaining some of the strength that is lost when plastic is added to cement paste. X-ray Diffraction (XRD), Backscattered Electron Microscopy (BSE), and X-ray microtomography explain the mechanisms for strength retention when using irradiated plastic as a filler for cement paste. By partially replacing Portland cement with a recycled waste plastic, this design may have a potential to contribute to reduced carbon emissions when scaled to the level of mass concrete production

2.1.3 Concrete reinforced with irradiated nylon fibers

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Polymeric fibers have been used since the 1980s for improvement of the concrete. However, high mechanical performance has been obtained at high cost and using complex technologies. At least two parameters are important here: dimensions and surface characteristics of the fibers. We have modified nylon 6,12 fiber surfaces by 5, 10, 50, and 100 kGy gamma irradiation dosages. Tensile strength of the irradiated fibers was determined and then the fibers mixed at 1.5%, 2.0%, and 2.5% in volume with Portland cement, gravel, sand, and water. The compressive strength of the fiber reinforced concrete (FRC) was evaluated and the results were compared with results for similar materials reported before. The highest values of the compressive strength of FRC are seen for fibers at 50 kGy and 2.0% in volume of fiber; the strength is 122.2 MPa, as compared to 35 MPa for simple concrete without fibers. We advance a mechanism by which the fiber structure can be affected by gamma irradiation resulting in the compressive strength improvement of the concrete.

and the feasibility of utilizing E plastic particles as partial replacement of coarse aggregate has been presented.

2.1.4 “Utilization of e-waste and plastic bottle waste in concrete” Ankit Arora, UG student

Dr. Urmil V. Dave, Senior Professor, Institute of Technology, Nirma University, Ahmedabad (2013)

E-waste and plastic waste are the major problem in today scenario as these are non-biodegradable. Attempts were made in past to use them in concrete by grinding them. But it failed to give good strength because grinded particle has flattened shape. Grinded plastic and e waste mixed with concrete is a good way to dispose them with cheap concrete production.

The following paper deals with the grinding, rubbing and mixing technique to use e-waste and plastic waste in concrete. E-waste from electrical and electronic equipment, that may be old or might have reached end of life and plastic waste from plastic mineral and cold drink bottles were collected and grinded to size of 2 mm using pulverizing machine. The grinded pieces were rubbed against each other with friction roller machine designed and fabricated by the authors. It is done to develop roughness and make grinded pieces shape irregular so that they can bond well with cement when mixed with it. A mix design was done for M20 grade of concrete by IS method. Ordinary Portland cement of 43 grade was selected. Grinded E-waste and plastic waste were replaced by 0%, 2%, and 4% of the fine aggregates. Compressive strength and flexural strength were tested and compared with control concrete. Experiments done shows increase in compressive strength by 5% and reduce cost of concrete production by 7% at optimum percentage of grinded waste. Grinded waste greater than 3.2.75mm in certain proportion act as a good filler material in concrete and on-going experiments are done to apply gap gradation by grinding the waste into specific sizes. This will ensure better packing density and hence good strength. Moreover decorative tiles were made with the grinded waste and white cement which give appealing look to the wall and are cheaper than the vitrified tiles.

2.2 Summary of the literature review

Concrete is the most widely used man made construction material in the world and its second only to water as the most utilized substance in the planet. Seeking aggregates for concrete and to dispose of the plastic waste is the present concern. Today sustainability has got top priority in construction industry. In the present study the recycled plastics were used to prepare the coarse aggregates thereby providing a sustainable option to deal with the plastic waste. There are many recycling plants across the world, but as plastics are recycled they lose their strength with the number of recycling. So these plastics will end up as earth fill. In this circumstance instead of recycling it repeatedly, if it is utilized to prepare aggregates for concrete, it will be a boon to the construction industry.

Hence in the present study, it is aimed at concrete mix with partial replacement of fine aggregate by irradiated plastic. This mix in the form of cubes and cylinders were subjected to compression and split tension to ascertain the behavior and strength parameter.

CHAPTER 3

MATERIALS AND METHODOLOGY

CHAPTER-3

MATERIALS AND METHODOLOGY

3.1 Irradiated Plastic

3.1.1 Introduction

Irradiated Plastic :- Gamma irradiation of PVC POWDER One potential solution for recovering some of the strength back that is lost when plastic is added to concrete is to make use of irradiation to improve the concrete's strength properties

PVC POWDER is a semi-crystalline polyester that exhibits an isotropic microstructure due to its glassy amorphous composition. For this reason, it is one of the most studied polymers. Upon irradiation, the two effects of greatest importance for PVC POWDER are chain scission and crosslinking. It has been shown that, due to the chain scission effect, the degree of crystallinity in PVC POWDER increases with gamma radiation dose. The number of chain scissions increases with dose, thereby decreasing the molecular weight. This reduced weight accounts for improved molecular mobility, which facilitates the ordered arrangement of molecules in crystalline structures.

Thus the increase in mobility as a result of chain scission leads to greater crystallizability when PVC POWDER is irradiated by gamma rays. The extent of crystallinity has a significant impact on several mechanical properties of PVC POWDER. Higher crystallinity PVC POWDER has been shown to have higher modulus, toughness, stiffness, strength, and hardness. Alternatively, crosslinking is the chemical bonding of one polymer chain to another. It can be induced by radiation and has the effect of strengthening the chemical structure of the compound. Thus both chain scission and crosslinking (which can occur simultaneously) in PVC POWDER can result in its improved strength.

3.1.2 Preparation Of Irradiated Plastic:-

Preparation of irradiated plastic additive For considerations of dose level in the context of this design, previous studies were used to determine the effect of gamma irradiation on the strength properties of plastic at varying doses. Literature review showed that different types of strength were maximized in different dose ranges (Plester, 1973). These dosestrength relationships are summarized in Appendix B. Specifically, one study showed that tensile strength increased up to 10 kGy (Plester, 1973), while another reported that radiation-induced crosslinking improved strength for doses up to 150 kGy (Martínez-Barrera et al., 2015). Consequently, it was decided that a high dose of 100 kGy and a low dose of 10 kGy should be tested and compared. These levels determine the length of irradiation time for the desired high- and low-dose plastic additives. Plastic flakes obtained from a recycling facility were used for the plastic additive. Due to imperfections in recycling facilities' sorting processes, the sample originally contained pieces of metal and other non-plastic impurities. In an effort to eliminate the possibility that these impurities would contaminate or ruin the future cement samples, the plastic was manually sorted to remove all materials that were clearly not plastic. Half of the plastic was then irradiated in a cobalt-60 irradiator facility that operates at 58 Gy/min. The low dose sample was left in the machine for 2.9 h for a total of 10 kGy. The high dose sample was left in the machine for 28.7 h for a total dose of 100 kGy. The flakes were then further crushed using both a high-energy ball mill and a mortar and pestle. Previous studies have shown that the compressive strength of PVC enhanced cement decreases with PET particle size (for samples with a 28-day cure) (Ávila Córdoba et al., 2013). The objective for the crushing process was therefore to achieve a particle size that was as small as possible. Each 18-gram sample was processed for 2 h in the ball mill followed by 20 min with the mortar and pestle. The actual particle size at the end of the process was not uniform, and an average particle size of 170 mm was measured using an optical microscope.

3.1.3 Categories of Plastic

- Polyester (PES) – Fibres, textiles.
- Polyethylene terephthalate (PET) – Carbonated drinks bottles, peanut butter jars, plastic film, microwavable packaging.
- Polyethylene (PE) – Wide range of inexpensive uses including supermarket bags, plastic bottle.

- High-density polyethylene (HDPE) – Detergent bottles, milk jugs, and moulded plastic cases.
- Polyvinyl chloride (PVC POWDER) – Plumbing pipes and guttering, shower curtains, window frames, flooring.
- Polyvinylidene chloride (PVDC) (Saran) – Food packaging.
- Low-density polyethylene (LDPE) – Outdoor furniture, siding, floor tiles, shower curtains, clamshell packaging.
- Polypropylene (PP) – Bottle caps, drinking straws, yogurt containers, appliances, car fenders (bumpers), plastic pressure pipe systems.
- Polystyrene (PS) – Packaging foam/"peanuts", food containers, plastic tableware, disposable cups, plates, cutlery, CD and cassette boxes.
- High impact polystyrene (HIPS) -: Refrigerator liners, food packaging, and vending cups.
- Polyamides (PA) (Nylons) – Fibres, toothbrush bristles, tubing, fishing line, low strength machine parts: under-the-hood car engine parts or gun frames.
- Acrylonitrile butadiene styrene (ABS) – Electronic equipment cases (e.g., computer monitors, printers, keyboards), drainage pipe.
- Polyethylene/Acrylonitrile Butadiene Styrene (PE/ABS) – A slippery blend of PE and ABS used in low-duty dry bearings.
- Polycarbonate (PC) – Compact discs, eyeglasses, riot shields, security windows, traffic lights, lenses.
- Polycarbonate/Acrylonitrile Butadiene Styrene (PC/ABS) – A blend of PC and ABS that creates a stronger plastic. Used in car interior and exterior parts, and mobile phone bodies.
- Polyurethanes (PU) – Cushioning foams, thermal insulation foams, surface coatings, printing rollers (Currently 6th or 7th most commonly used plastic material, for instance the most commonly used plastic in cars).

3.1.4 Health hazard

Pure plastics have low toxicity due to their insolubility in water and because they are biochemically inert, due to a large molecular weight. Plastic products contain a variety of additives, some of which can be toxic. For example, plasticizers like adipates and phthalates are often added to brittle plastics like polyvinyl chloride to make them pliable enough for use in food packaging, toys, and many other items. Traces of these compounds can leach out of the product. Owing to concerns over the effects of such leachates, the European Union has restricted the use of DEHP (di-2-ethylhexyl phthalate) and other phthalates in some applications, and the United States has limited the use of DEHP, DPB, BBP, DINP, DIDP, and DnOP in children's toys and child care articles with the Consumer Product Safety Improvement Act. Some compounds leaching from polystyrene food containers have been proposed to interfere with hormone functions and are suspected human carcinogens. Other chemicals of potential concern include alkylphenols.

Whereas the finished plastic may be non-toxic, the monomers used in the manufacture of the parent polymers may be toxic. In some cases, small amounts of those chemicals can remain trapped in the product unless suitable processing is employed. For example, the World Health Organization's International Agency for Research on Cancer (IARC) has recognized vinyl chloride, the precursor to PVC POWDER, as a human carcinogen. Some polymers may also decompose into the monomers or other toxic substances when heated. In 2011, it was reported that "almost all plastic products" sampled released chemicals with estrogenic activity, although the researchers identified plastics which did not leach chemicals with estrogenic activity.

Most plastics are durable and degrade very slowly; the very chemical bonds that make them so durable tend to make them resistant to most natural processes of degradation. However, microbial species and communities capable of degrading plastics are discovered from time to time, and some show promise as being useful for bio remediating certain classes of plastic waste.

Since the 1950s, one billion tons of plastic have been discarded and some of that material might persist for centuries or much longer, as is demonstrated by the persistence of natural materials such as amber.

Serious environmental threats from plastic have been suggested in the light of the increasing presence of micro plastics in the marine food chain along with many highly toxic chemical pollutants that accumulate in plastics. They also accumulate in larger fragmented pieces of plastic called nurdles. In the 1960s the latter were observed in the guts of seabirds, and since then have been found in increasing concentration. In 2009, it was estimated that 10% of modern waste was plastics, although estimates vary according to region. Meanwhile, 50-80% of debris in marine areas is plastic. Before the ban on the use of CFCs in extrusion of polystyrene (and in general use, except in life-critical fire suppression systems; see Montreal Protocol), the production of polystyrene contributed to the depletion of the ozone layer, but current extrusion processes use non-CFCs.

3.1.5 Climate change

The effect of plastics on global warming is mixed. If the plastic is incinerated, it increases carbon emissions; if it is placed in a landfill, it becomes a carbon sink although biodegradable plastics have caused methane emissions. Due to the lightness of plastic versus glass or metal, plastic may reduce energy consumption.

3.1.6 Recycling

Thermoplastics can be re-melted and reused, and thermoset plastics can be ground up and used as filler, although the purity of the material tends to degrade with each reuse cycle. There are methods by which plastics can be broken back down to a feedstock state.

The greatest challenge to the recycling of plastics is the difficulty of automating the sorting of plastic wastes, making it labour-intensive. Typically, workers sort the plastic by looking at the resin identification code, although common containers like waste pipes can be sorted from memory.

While containers are usually made from a single type and colour of plastic, making them relatively easy to be sorted, a consumer product like a cellular phone may have many small parts consisting of over a dozen different types and colours of plastics. In such cases, the resources it would take to separate the plastics far exceed their value and the item is discarded. However, developments are taking place in the field of active disassembly, which may result in more consumer product components being re-used or recycled. Recycling certain types of plastics can be unprofitable, as well. For example, polystyrene is rarely recycled because it is usually not cost effective. These unrecycled wastes are typically disposed of in landfills, incinerated or used to produce electricity at waste-to-energy plants.

3.2 Cement

3.2.1 Introduction

A **cement** is a binder, a substance that sets and hardens and can bind other materials together. The word "cement" traces to the Romans, who used the term *opus caementicium* to describe masonry resembling modern concrete that was made from crushed rock with burnt lime as binder. The volcanic ash and pulverized brick supplements that were added to the burnt lime, to obtain a hydraulic binder, were later referred to as *cementum*, *cimentum*, *cäment*, and *cement*. Cements used in construction can be characterized as being either **hydraulic** or **non-hydraulic**, depending upon the ability of the cement to be used in the presence of water. **Non-hydraulic cement** will not set in wet conditions or underwater, rather it sets as it dries and reacts with carbon dioxide in the air. It can be attacked by some aggressive chemicals after setting.

3.2.2 Types of cements

i. Portland cement
ii. Energetically modified cement
iii. Portland cement blends
iv. Portland blast furnace cement
v. Portland fly ash cement
vi. Portland Pozzolana cement
vii. Portland silica fume cement
viii. Masonry cements
ix. Expansive cements
x. White blended cements
xi. Colored cements
xii. Very finely ground cements
xiii. Pozzolana-lime cements
xiv. Slag-lime cements
xv. Super-sulphated cements
xvi. Calcium sulfo aluminate cements
xvii. Natural cements
xviii. Geo polymer cements

3.2.3 Curing

Cement sets or cures when mixed with water which causes a series of hydration chemical reactions. The constituents slowly hydrate and crystallize; the interlocking of the crystals gives cement its strength. Maintaining a high moisture content in cement during curing increases both the speed of curing, and its final strength. Gypsum is often added to Portland cement to prevent early hardening or "flash setting", allowing a longer working time. The time it takes for cement to cure varies depending on the mixture and environmental conditions; initial hardening can occur in as little as twenty minutes, while full cure can take over a month. Cement typically cures to the extent that it can be put into service within 24 hours to a week.

3.2.4 Safety issues

Bags of cement routinely have health and safety warnings printed on them because not only is cement highly alkaline, but the setting process is exothermic. As a result, wet cement is strongly caustic and can easily cause severe skin burns if not promptly washed off with water. Similarly, dry cement powder in contact with mucous membranes can cause severe eye or respiratory irritation. Some ingredients can be specifically allergenic and may cause allergic dermatitis. Reducing agents are sometimes added to cement to prevent the formation of carcinogenic chromate in cement. Cement users should wear protective clothing.

3.2.5 Cement production in world

In 2010, the world production of hydraulic cement was 3,300 million tonnes. The top three producers were China with 1,800, India with 220, and USA with 63.1.5 million tonnes for a combined total of over half the world total by the world's three most populated states. For the world capacity to produce cement in 2010, the situation was similar with the top three states (China, India, and USA) accounting for just under half the world total capacity. Over 2011 and 2012, global consumption continued to climb, rising to 3585 Mt in 2011 and 3736 Mt in 2012, while annual growth rates eased to 4.4.3% and 3.2.2%, respectively. China, representing an increasing share of world cement consumption, continued to be the main engine of global growth. By 2012, Chinese demand was recorded at 2160 Mt, representing 58% of world consumption. Annual growth rates, which reached 16% in 2010, appear to have softened, slowing to 5–6% over 2011 and 2012, as China's economy targets a more sustainable growth rate. Outside of China, worldwide consumption climbed by 3.2.4% to 1462 Mt in 2010, 5% to 1535 Mt in 2011, and finally 2.7% to 1576 Mt in 2012.Iran is now the 3rd largest cement producer in the world and has increased its output by over 10% from 2008 to 2011. Due to climbing energy costs in Pakistan and other major cement-producing countries, Iran is a unique position as a trading partner, utilizing its own surplus PVC POWDER roleum to power clinker plants. Now a top producer in the Middle-East, Iran is further increasing its dominant position in local markets and abroad. The performance in the rest of the world, which includes many emerging economies in Asia, Africa and Latin America and representing some 1020 Mt cement demand in 2010, was positive and more than offset the declines in North America and Europe. Annual consumption growth was recorded at 4.4% in 2010, moderating to 3.3.1% and 3.2.3% in 2011 and 2012, respectively.

3.2.6 Environmental impacts

Cement manufacture causes environmental impacts at all stages of the process. These include emissions of airborne pollution in the form of dust, gases, noise and vibration when operating machinery and during blasting in quarries, and damage to countryside from quarrying. Equipment to reduce dust emissions during quarrying and manufacture of cement is widely used, and equipment to trap and separate exhaust gases are coming into increased use. Environmental protection also includes the re-integration of quarries into the countryside after they have been closed down by returning them to nature or re-cultivating them. Carbon concentration in cement spans from ≈5% in cement structures to ≈8% in the case of roads in cement. Cement manufacturing releases CO_2 in the atmosphere both directly when calcium carbonate is heated, producing lime and carbon dioxide, and also indirectly through the use of energy if its production involves the emission of CO_2. The cement industry produces about 5% of global man-made CO_2 emissions, of which 50% is from the chemical process, and 40% from burning fuel. The amount of CO_2 emitted by the cement industry is nearly 900 kg of CO_2 for every 1000 kg of cement produced. In the European Union the specific energy consumption for the production of cement clinker has been reduced by approximately 30% since the 1970s. This reduction in primary energy requirements is equivalent to approximately 11 million tonnes of coal per year with corresponding benefits in reduction of CO_2 emissions. This accounts for approximately 5% of anthropogenic CO_2.The high proportion of carbon dioxide produced in the chemical to reduce the transport of heavier raw materials and to minimize the associated costs, it is more economical for cement plants to be closer to the limestone quarries rather than to the consumer centres. In certain applications, lime mortar reabsorbs the same amount of CO_2 as was released in its manufacture, and has a lower energy requirement in production than mainstream cement. Newly developed cement types from Novacem and Eco-cement can absorb carbon dioxide from ambient air during hardening. Use of the Kalina cycle during production can also increase energy efficiency.

3.2.7 Green cement

Green cement is a cementitious material that meets or exceeds the functional performance capabilities of ordinary Portland cement by incorporating and optimizing recycled materials, thereby reducing consumption of natural raw materials, water, and energy, resulting in a more sustainable construction material. The manufacturing process for green cement succeeds in reducing, and even eliminating, the production and release of damaging pollutants and greenhouse gasses, particularly CO_2.Growing environmental concerns and increasing cost of fuels of fossil origin have resulted in many countries in sharp reduction of the resources needed to produce cement and effluents (dust and exhaust gases).PVC POWDER er Trimble, a design student at the University of Edinburgh has proposed 'DUPE' based on sporosarcina pasteurii, a bacterium with binding qualities which, when mixed with sand and urine produces a concrete said to be 70% as strong as conventional materials. The idea has been commercialized in the USA

3.3 Aggregates: Fine Aggregates

3.3.1 Introduction

Fine aggregate (Sand) is a naturally occurring granular material composed of finely divided rock and mineral particles. It is defined by size, being finer than gravel and coarser than silt. **Sand** can also refer to a textural class of soil or soil type; i.e. a soil containing more than 85% sand-sized particles (by mass).

The composition of sand varies, depending on the local rock sources and conditions, but the most common constituent of sand in inland continental settings and non-tropical coastal settings is silica (silicon dioxide, or SiO_2), usually in the form of quartz. The second most common type of sand is calcium carbonate, for example aragonite, which has mostly been created, over the past half billion years, by various forms of life, like coral and shellfish. It is, for example, the primary form of sand apparent in areas where reefs have dominated the ecosystem for millions of years like the Caribbean.

3.3.2 Composition

In terms of particle size as used by geologists, sand particles range in diameter from 0.0625 mm (or $^1\!/_{16}$ mm) to 2 mm. An individual particle in this range size is termed a *sand grain*. Sand grains are between gravel (with particles ranging from 2 mm up to 64 mm) and silt (particles smaller than 0.0625 mm down to 0.004 mm). The size specification between sand and gravel has remained constant for more than a century, but particle diameters as small as 0.02 mm were considered sand under the Albert Atterberg standard in use during the early 20th century. A 1953 engineering standard published by the American Association of State Highway and Transportation Officials set the minimum sand size at 0.074 mm. A 1938 specification of the United States Department of Agriculture was 0.05 mm. Sand feels gritty when rubbed between the fingers (silt, by comparison, feels like flour).

ISO 14688 grades sands as fine, medium and coarse with ranges 0.063 mm to 0.2 mm to 0.63 mm to 2.0 mm. In the United States, sand is commonly divided into five sub-categories based on size: very fine sand ($^1\!/_{16}$ – ⅛ mm diameter), fine sand (⅛ mm – ¼ mm), medium sand (¼ mm – ½ mm), coarse sand (½ mm – 1 mm), and very coarse sand (1 mm – 2 mm). These sizes are based on the Krumbein phi scale, where size in $\Phi = -\log_2 D$; D being the particle size in mm. On this scale, for sand the value of Φ varies from -1 to $+4$, with the divisions between sub-categories at whole numbers.

The most common constituent of sand, in inland continental settings and non-tropical coastal settings, is silica (silicon dioxide, or SiO_2), usually in the form of quartz, which, because of its chemical inertness and considerable hardness, is the most common mineral resistant to weathering.

The composition of mineral sand is highly variable, depending on the local rock sources and conditions. The bright white sands found in tropical and subtropical coastal settings are eroded limestone and may contain coral and shell fragments in addition to other organic or organically derived fragmental material, suggesting sand formation depends on living organisms, too. The gypsum sand dunes of the White Sands National Monument in New Mexico are famous for their bright, white colour. Arkose is a sand or sandstone with considerable feldspar content, derived from weathering and erosion of a (usually nearby) granitic rock outcrop. Some sands contain magnetite, chlorite, glauconite or gypsum. Sands rich in magnetite are dark to black in colour, as are sands derived from volcanic basalts and obsidian. Chlorite-glauconite bearing sands are typically green in colour, as are sands derived from basaltic (lava) with a high olivine content. Many sands, especially those found extensively in Southern Europe, have iron impurities within the quartz crystals of the sand, giving a deep yellow colour. Sand deposits in some areas contain garnets and other resistant minerals, including some small gemstones.

3.3.3 Study

The study of individual grains can reveal much historical information as to the origin and kind of transport of the grain. Quartz sand that is recently weathered from granite or gneiss quartz crystals will be angular. It is called Grus in geology or *sharp sand* in the building trade where it is preferred for concrete, and in gardening where it is used as a soil amendment to loosen clay soils. Sand that is transported long distances by water or wind will be rounded, with characteristic abrasion patterns on the grain surface. Desert sand is typically rounded.

3.3.4 Uses

- Agriculture: Sandy soils are ideal for crops such as watermelons, peaches and peanuts, and their excellent drainage characteristics make them suitable for intensive dairy farming.
- Aquaria: Sand makes a low cost aquarium base material which some believe is better than gravel for home use. It is also a necessity for saltwater reef tanks, which emulate environments composed largely of aragonite sand broken down from coral and shellfish.
- Artificial reefs: Geotextile bagged sand can serve as the foundation for new reefs.
- Artificial islands in the Persian Gulf for instance.
- Beach nourishment: Governments move sand to beaches where tides, storms or deliberate changes to the shoreline erode the original sand.
- Brick: Manufacturing plants add sand to a mixture of clay and other materials for manufacturing bricks.
- Cob: Coarse sand makes up as much as 75% of cob.
- Mortar: Sand is mixed with masonry cement or Portland cement and lime to be used in masonry construction.
- Concrete: Sand is often a principal component of this critical construction material.
- Hydraulic Fracturing: A drilling technique for natural gas, which uses rounded silica sand as a "proppant", a material to hold open cracks that are caused by the hydraulic fracturing process.
- Glass: Sand is the principal component in common glass.
- Landscaping: Sand makes small hills and slopes (for example, in golf courses).
- Paint: Mixing sand with paint produces a textured finish for walls and ceilings or non-slip floor surfaces.

- Railroads: Engine drivers and rail transit operators use sand to improve the traction of wheels on the rails.
- Recreation. Playing with sand is a favourite beach time activity. One of the most beloved uses of sand is to make sometimes intricate, sometimes simple structures known as sand castles. Such structures are well known for their impermanence. Sand is also used in children's play. Special play areas enclosing a significant area of sand, known as sandboxes, are common on many public playgrounds, and even at some single family homes.
- Roads: Sand improves traction (and thus traffic safety) in icy or snowy conditions.
- Sand animation: Performance artists draw images in sand. Makers of animated films use the same term to describe their use of sand on frontlit or backlit glass.
- Sand casting: Casters moisten or oil molding sand, also known as foundry sand and then shape it into moulds into which they pour molten material. This type of sand must be able to withstand high temperatures and pressure, allow gases to escape, have a uniform, small grain size and be non-reactive with metals.
- Sand castles: Shaping sand into castles or other miniature buildings is a popular beach activity.
- Sandbags: These protect against floods and gunfire. The inexpensive bags are easy to transport when empty, and unskilled volunteers can quickly fill them with local sand in emergencies.
- Sandblasting: Graded sand serves as an abrasive in cleaning, preparing, and polishing.
- Thermal Weapon: While not in widespread use anymore, sand used to be heated and poured on invading troops in the classical and medieval time periods.
- Water filtration: Media filters use sand for filtering water.
- Zoanthid "skeletons": Animals in this order of marine benthic cnidarians related to corals and sea anemones, incorporate sand into their mesoglea for structural strength, which they need because they lack a true skeleton.

3.3.5 Resources and environmental concerns

Only some sands are suitable for the construction industry, for example for making concrete. Because of the growth of population and of cities and the consequent construction activity there is a huge demand for these special kinds of sand, and natural sources are running low. In 2012 French director Denis Delestrac made a documentary called "Sand Wars" about the impact of the lack of construction sand. It shows the ecological and economic effects of both legal and illegal trade in construction sand.

Sand's many uses require a significant dredging industry, raising environmental concerns over fish depletion, landslides, and flooding. Countries such as China, Indonesia, Malaysia and Cambodia ban sand exports, citing these issues as a major factor.

3.3.6 Hazards

While sand is generally non-toxic, sand-using activities such as sandblasting require precautions. Bags of silica sand used for sandblasting now carrylabels warning the user to wear respiratory protection to avoid breathing the resulting fine silica dust. Material safety data sheets (MSDS) for silica sand state that "excessive inhalation of crystalline silica is a serious health concern".

In areas of high pore water pressure sand and salt water can form quicksand, which is a colloid hydrogel that behaves like a liquid. Quicksand produces a considerable barrier to escape for creatures caught within, who often die from exposure (not from submersion) as a result.

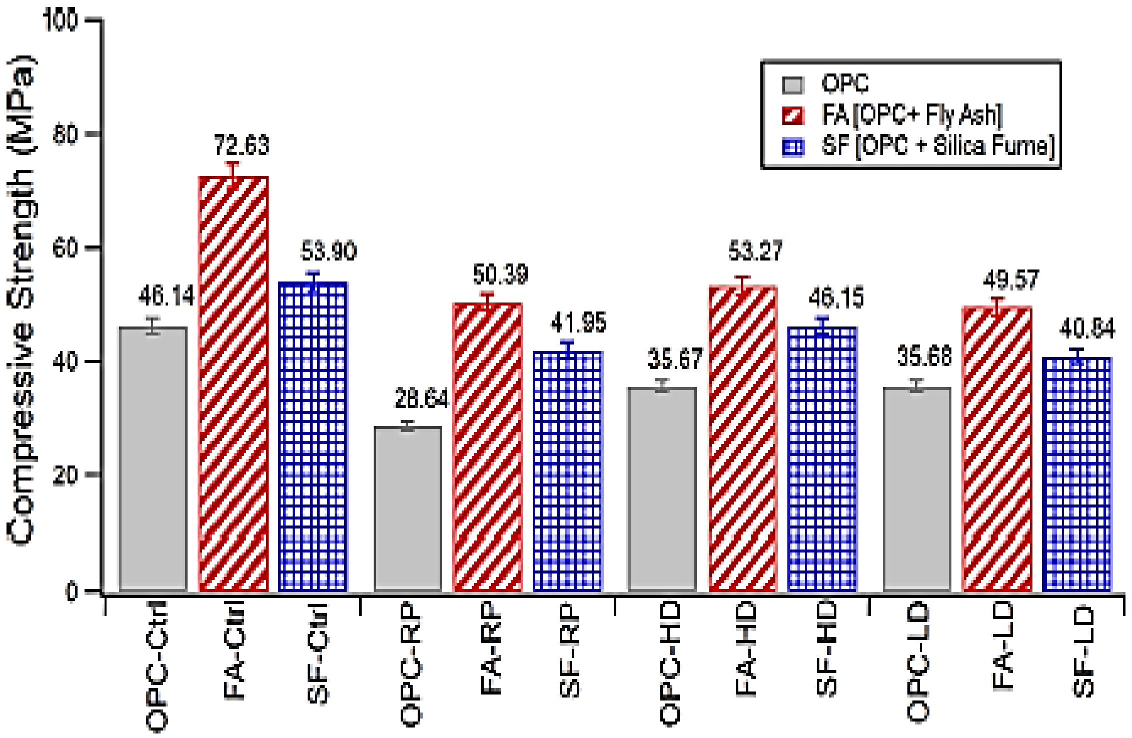
METHADOLOGY

3.4 METHODOLOGY

3.4.1 Mix Design

Cement mortar mix		**in grams**					
Sl No.		Total dry mass	OPC	Sand	Plastic	FA	GGBS
1	OPC + No plastic	800	200	600	0	0	0
2	OPC + Regular plastic	800	197.5	600	2.5	0	0
3	OPC+HD plastic	800	197.5	600	2.5	0	0
4	OPC+LD plastic	800	197.5	600	2.5	0	0
5	FA + No plastic	800	170	600	0	30	0
6	FA + Regular plastic	800	167.5	600	2.5	30	0
7	FA+HD plastic	830	197.5	600	2.5	30	0
8	FA+LD plastic	800	167.5	600	2.5	30	0
9	GGBS + No plastic	800	170	600	0	0	30
10	GGBS + Regular plastic	800	167.5	600	2.5	0	30
11	GGBS +HD plastic	800	167.5	600	2.5	0	30
12	GGBS+LD plastic	800	167.5	600	2.5	0	30

3.4.2 Comparison bar chart



CHAPTER 4

Results and discussion

CHAPTER-4

RESULTS AND OBSERVATIONS

4.1 Tests on cement

4.1.1 Standard consistency of cement

Standard consistency is defined as the percentage water requirement of cement paste at which viscosity of the paste becomes such that the plunger in a specially designed apparatus (known as Vicat's apparatus) penetrates a depth 5 to 7mm, measured from the bottom of the mould. Practical importance of Standard consistency value is to determine amount of water needed to make paste for other tests of cement.

Apparatus: Vicat's Apparatus with plunger, needles, stop watch etc.

Procedure:

(1) Prepare a paste of weighed quantity of cement (approx. 400 gms) with weighed quantity of water (start from 20%-25%) taking care that mixing (gauging) remains between 3 to 5 minutes and mixing shall be completed before any signs of setting becomes visible.
(2) Fill the Vicat's mould with the paste, mould should rest on non-porous base.
(3) Place the mould under Vicat's apparatus. The plunger attached to a movable rod is gently lowered on the paste.
(4) Settlement of plunger is noted, penetration from bottom is equal to the difference of mould height and settlement of plunger. If penetration of the plunger is within 5-7mm from bottom, then water added is correct. Otherwise, water is added and process is repeated.

Observations:

Mass of cement taken= 400 gms

Table 4.1 Normal Consistency of cement

S. No	% water	Initial reading	Final reading	Height not penetrated(mm)
1.	20			
2.	24			
3	28			
4.	30			

Standard consistency of cement = 30%

4.1.2 Setting time of cement

Two stiffening states of cements are (i) initial and (ii) final setting time. Initial setting time is defined as the time taken by the paste to stiffen to an extent such that the Vicat *needle* is not permitted to move down through the paste within 5 ± 0.5 mm measured from the bottom of the mould. Time is measured from the instant water is added to the paste.

Final setting time is the time when the paste becomes so hard that the *annular attachment* to the needle under standard weight only makes an impression on the hardened cement paste

Initial Setting Time:

(1) Take approx. 400 gms of dry cement and add 0.85 P where P is the weight of water for standard consistency to make paste.
(2) Fill the mould with paste, attach square needle to moving rod of apparatus.
(3) The needle is quickly released and is allowed to penetrate cementpaste.
(4) Note down the time and penetration from bottom.
(5) Plot a curve between time (min) and penetration (mm).
(6) Find initial setting time (minutes) when penetration of needle (from bottom) is within 5 ±0.5mm.

Observations:

Mass of cement taken= 400 gm

(Size of cement particle passing 850µ size)

Needle dimension = 1 mm^2 area of 50mm long

Gauging time = 2-3 min

Qty. of water =

Table 4.2 Setting time of cement

S. No	Time (minutes)	Initial reading	Final reading	Height not penetrated(mm)

Final Setting Time:

(1) Attach needle with annular collar to the movable rod.

(2) Release the needle gently.

(3) The time when needle makes an impression only on the hardened cement paste is recorded.

Initial setting time =

Final setting time =

4.1.3 Specific gravity of cement

Specific gravity is determined by use of a Le Chatelier’s flask. In the determination of specific gravity of cement, kerosene is used as a medium instead of water, because water undergoes hydration reaction with cement, while kerosene does not react. The specific gravity of OPC is generally around3.1.13.3.

Procedure:

1. Weigh the specific gravity bottle dry. Let the mass of empty bottle be W1.
2. Fill the bottle with distilled water and weigh the bottle filled with water. Let the mass of bottle with distilled water be W2
3. Wipe and dry the bottle and fill it with kerosene and weigh. Let this mass be W3.1.
4. Weigh the dry cement sample. Let this mass beW3.2.
5. Pour some quantity of kerosene out and introduce a weighed quantity of cement (about 50gm) into the bottle. Roll the bottle gently in inclined position until no further air bubble rises to surface. Fill the bottle to the top with kerosene and weigh it. Let this mass be W3.3.
6. The specific gravity of OPC is given by $S=\frac{W4(W3-W1)}{(W4+W3-W5)(W2-W1)}$

Table 4.3 Specific gravity of cement

Description	Trial 1	Trial 2
1.Mass of empty bottle W1 gm.		
2.Mass of bottle +water W2 gm.		
3.Mass of bottle +kerosene W3 gm.		
4.Mass of cement W4 gm.		
5.Mass of bottle + cement + kerosene W5 gm.		
6.Specific gravity of cement $S=\frac{W4\,(W3-W1)}{(W4+W3-W5)(W2-W1)}$		

Specific gravity of cement = 3.15

Table 4.4 Properties of cement:

S. No.	Properties	Values obtained	Standard values
1.	Specific gravity		
2.	Normal consistency		
3.	Initial and Final setting time		

4.2 Tests on fine aggregates

4.2.1 Specific gravity of sand

Specific gravity is the ratio of the weight in air of a given volume of a material to the weight in air of an equal volume of distilled water. Specific gravity of river sand is around 2.5 and manufactured sand is around 2.7

Apparatus: Pycnometer bottle, Tray, Weighing balance

Procedure:

(1) Take a clean, dry pycnometer, and find its weight with its cap and washer (W1)

(2) Put about 200 g to 400 g of sand in the pycnometer and find its weight (W2)

(3) Fill the pycnometer and filled in sand as in step2, with distilled water and measure its weight (W3)

(4) Emptythe pycnometer, clean it thoroughly, and fill it with clean water only to the hole of the conical cap, and find its weight (W4)

(5) Repeat the same procedure at least for three differentsamples

Average Specific gravity of fine aggregate= 2.65

4.2.2 Water absorption test

Absorption is a measure of the amount of water that an aggregate can absorb into its pore structure. Pores that absorb water are also referred to as “water permeable voids”.

Apparatus: Beaker (1 *lit*), Hot air oven, weighing balance, tray.

Procedure:

1) Take 500 gms of saturated surface dry sand in the air. Note down the weight as W_1.
2) Dry the sample in oven at 100 C-110 C for 24 hrs. Note this weight as $W_{2.}$
3) Note down empty weight as $W_{3.1.}$
4) Calculate water absorption value as the percentage of oven dry weight.

   Percentage of water absorption=$^{\square 1-\square 2}\times 100\%$

Table 4.6 Water absorption of sand

Water Absorption	Trial 1	Trial 2	Trial 3
Wt. of tray + oven dry fine aggregate (W_2)			
Wt. of empty tray (W_3)			
Percentage of water absorption			

Percentage of water absorption = 1.01%

9) Plot particle size (log scale) and % passingand find out D_{10}, D_{30}, and D_{60}.

Table 4.7 Sieve analysis of Fine Aggregate

IS Sieve Size (mm)	(1) Weight retained (gm.)	(2) Percentage Weight retained	(3) Cumulative weight retained (gm.)	(4) Cumulative percentage weight retained	(5) Percentage finer 100-Col(4)
3.2.75mm	-	-	-	-	100
2.36mm					
1.18mm					
600µ					
300µ					
150µ					
Pan					

Result: Fineness Modulus = ∑ Col. (4)/100 =264.5.9/100 =2.699

Table 4.8 Properties of fine aggregates:

Properties	Values obtained
Specific gravity	
Water absorption	
Fineness Modulus	

4.2.3 Specific gravity and water absorption test

Specific gravity of an aggregate is a measure of strength or quality of the material. Stones having low specific gravity are generally weaker than those with higher specific gravity.

Water absorption indicates strength of rocks. Stones having more water absorption are more porous in nature and are unsuitable unless they are found to be acceptable based on strength, impact and hardness tests.

Apparatus: Beaker (1 *lt*), Hot air oven, weighing balance, tray

Procedure:

(1) Take about 2kg of coarse aggregate sample, wash thoroughly to remove finer particles and dust and immerse in water for 24 hours at a temperature between 22°C and 32°C with a cover of at least 5 cm of water above the top of the basket. Lift the basket 25 mm above the base of tank and allowing it to drop 25 times at the rate of more than one drop per second. The weight is noted while suspending in water=W_1.

(2) Remove the aggregate from basket and allow it to drain for few minutes. Weight of empty basket in water is measured as W_2.

(3) Take out the immersed aggregate and place in a dry cloth. It shall then be spread out not more than one stone deep, and best exposed to the atmosphere away from direct sunlight or any other source of heat for not less than 10 minutes, or until it appears to be completely surface dry. Measure weight of the aggregate (W3)

(4) The aggregate shall then be placed in the oven in the shallow tray, at a temperature of 100 to 110°C and maintained at this temperature for 24 hours. After 24 hours, It shall then be removed from the oven, cooled in the airtight container andweighed (W4).

(5) Specific gravity of aggregate= ________________________

Table 4.9 Specific gravity and water absorption of coarse aggregate

Description	Trial 1	Trial 2
Wt. of saturated aggregate suspended in water with basket=W_1 gm		
Wt. of basket suspended in water=W_2 gm		
Wt. of saturated aggregate in water=W_1-W_2=Ws gm		
Wt. of saturated surface dry aggregate in air=W_3 gm		
Wt. of water equal to the volume of aggregate=W_3-Ws gm		
Dry weight after 24 hours W_4 gm		
Specific gravity =$\frac{W_4}{W_3-W_s}$		
Water absorption=$\frac{W_3-W_4}{W_4}\times 100$		

Avg. specific gravity= 2.68

Avg. water absorption value= 0.8%

Table 4.10 Properties of coarse aggregates:

Properties	Values obtained
Specific gravity	
Water absorption	

4.3.1 Requirements of concrete mix design

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

a) The minimum compressive strength required from structural consideration
b) The adequate workability necessary for full compaction with the compacting equipment available.
c) Maximum water-cement ratio and/or maximum cement content to give adequate durability for the particular site condition to meet the site condition and meet strength.
d) Maximum cement content to avoid shrinkage cracking due to temperature cycle in mass concrete.

4.3.2 Types of Mixes

Nominal Mixes

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

Standard Mixes

The nominal mixes of fixed cement-aggregate ratio (by volume) vary widely in strength and may result in under- or over-rich mixes. For this reason, the minimum compressive strength has been included in many specifications. These mixes are termed standard mixes.

IS 456-2000 has designated the concrete mixes into a number of grades as M10, M15, M20, M25, M30, M35 and M40. In this designation the letter M refers to the mix and the number to the specified 28 day cube strength of mix in N/mm^2. The mixes of grades M10, M15, M20 and M25 correspond approximately to the mix proportions (1:3:6), (1:2:4), (1:1.5:3) and (1:1:2) respectively.

Designed Mixes

In these mixes the performance of the concrete is specified by the designer but the mix proportions are determined by the producer of concrete, except that the minimum cement content can be laid down. This is most rational approach to the selection of mix proportions with specific materials in mind possessing more or less unique characteristics. The approach results in the production of concrete with the appropriate properties most economically. However, the designed mix does not serve as a guide since this does not guarantee the correct mix proportions for the prescribed performance.

For the concrete with undemanding performance nominal or standard mixes (prescribed in the codes by quantities of dry ingredients per cubic meter and by slump) may be used only for very small jobs, when the 28-day strength of concrete does not exceed 30 N/mm^2. No control testing is necessary reliance being placed on the masses of the ingredients.

4.3.3 Factors affecting the choice of mix proportions

The various factors affecting the mix design are:

Compressive strength

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

Workability

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

Durability

The durability of concrete is its resistance to the aggressive environmental conditions. High strength concrete is generally more durable than low strength concrete. In the situations when the high strength is not necessary but the conditions of exposure are such that high durability is vital, the durability requirement will determine the water-cement ratio to be used.

Maximum nominal size of aggregate

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

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

Grading and type of aggregate

The grading of aggregate influences the mix proportions for a specified workability and water- cement ratio. Coarser the grading leaner will be mix which can be used. Very lean mix is not desirable since it does not contain enough finer material to make the concrete cohesive.

The type of aggregate influences strongly the aggregate-cement ratio for the desired workability and stipulated water cement ratio. An important feature of a satisfactory aggregate is the uniformity of the grading which can be achieved by mixingdifferent size fractions.

Quality control

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

CHAPTER 5

CONCLUSION AND RESULTS

CONCLUSION

5.1 Conclusion: -

This study clearly showed the benefits of using gamma irradiated recycled plastic in place of un irradiated plastic to partially recover the strength of fine aggregate, while simultaneously displacing cement volume, reducing its carbon footprint without associated drawbacks. A thorough micro- and pore-structural analysis was performed in order to provide insight at an angstrom level scale (through XRD) and at a micron-level scale (through BSE and micro tomography). It was determined that incorporating high dose irradiated plastic along with SCM's into cement paste samples led to decreased porosity and increased compressive strength, which was attributed to the formation of C-A-S-H gels along with secondary C-S-H, which forms during the hydration processes. By partially replacing fine aggregate with a recycled waste plastic, this design may have a potential to contribute to reduced carbon emissions when scaled to the level of mass concrete production.
Based on comparison with previous studies that used recycled plastic as an additive, it is clear that irradiation adds the benefit of increased compressive strength. Further research should be done to discover the true optimal combination of irradiated plastic and mineral additive for high strength. The groundwork however, has been laid for the continued development of the ideas presented here.

5.2 RESULTS :-

1. Irradiation of plastic.
2. Powdered PVC is subjected to irradiation.
3. The isotopes used in plastic irradiation is cobalt-60, which produces gamma rays at an energy of 1.33 MeV which is less than the binding energy of most of the nuclei and hence cannot result in induced radioactivity in plastic.
4. LD plastic – subjected to a dose of 10 kGy – 1 kg of plastic should absorb 10 kJ of radiation energy
5. HD plastic - subjected to a dose of 100 kGy – 1 kg of plastic should absorb 100 kJ of radiation energy

References: -

1. Irradiated recycled plastic as a concrete additive for improved chemo-mechanical properties and lower carbon footprint by Carolyn E. Schaefer.
2. Choi, Y.-W., Moon, D.-J., Chung, J.-S., Cho, S.-K., 2005. Effects of waste PET bottles aggregate on the properties of concrete. Cem. Concr. Res. 35, 776–781.
3. Hannawi, K., Kamali-Bernard, S., Prince, W., 2010. Physical and mechanical properties of mortars containing PET and PC waste aggregates. Waste Manage. 30, 2312–2320.
4. Martínez-Barrera, G., Vigueras-Santiago, E., Hernández-López, S., Brostow, W., Menchaca-Campos, C., 2005. Mechanical improvement of concrete by irradiated polypropylene fibers. Polym. Eng. Sci. 45, 1426–1431.