SLAG BASED CONCRETE

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CERTIFICATION OF APPROVAL

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CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

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ABSTRACT

Ladle furnace slag is a by-product of iron- and steelmaking industry produced in the final stages of steelmaking during the separation of the molten iron and steel from impurities. The increase in the steel consumption is thus the cause of the slag generating process. As Ladle furnace slag considered a heavy metals wastewaters adsorption agent as it is a significant savings in the natural resources by having high adsorption capacity, and low cost process due to their abundance in nature and less processing requirements. However, this way of using this by-product consider as a setback because it does not consume all the LFS properties. Steel slag is typically composed of silicates (3CaO·SiO2 and 2CaO·SiO2 phase), oxides (CaO–FeO–MnO–MgO) these types of chemical composition consider as a good cement replacement material. Concrete is the single most widely used material in the world and the Concrete production contributes 5 percent of annual anthropogenic global CO2 production.

This research is to create the optimum mix design of LFS based concrete using trial and error method that can assemble all the mixing proportions. The Experiment will be conducted in to two stages. In the first stage the mixing will be mortar mix to get a specific range of the optimum mix while the next stage will be concrete casting in the range that have been specified in the first stage. Ladle furnace slag is used to replace (5%, 10%, 15%, 20%, 25%, and 30%) for mortar and (5%, 10%, 15%, and 20%) for concrete with 0.5 w/c for mortar and 0.6 w/c for concrete.

The compressive strength test for the mortar showed that present stable increase in the compressive strength until it reach 5% of LFS mix then it dramatically decrease. That increase is 9% more than control mix number 1 as 0% LFS in the mortal. As for the tensile strength increase dramatically when the until it reach 15% of LFS then decrease.

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INTRODUCTION

1.1 BACKGROUND OF STUDY

As time goes by, people start to understand the importance of concrete as to improve the properties and behavior of concrete to get the best results of construction work.

Until recent years, the overwhelming focus has been on concrete's compressive strength, which has been mainly related to the overall porosity of the cement paste matrix and the amount and structure of the aggregates. Mechanical strength depends on defects and not on any overall average property, and so is very difficult to relate to microstructure. This has caused relatively little attention to be paid to the details of the pore space. The requirement for increased powder content in OPC has been addressed either by increasing the binder content or by using other types cement replacement materials.

The use of concrete containing high volume cement Replacement material has recently gained popularity as a resource efficient, durable and sustainable option for variety of concrete application. Materials that can be substituted for a portion of the Portland cement in a concrete mixture (cement-replacement materials) are either themselves of low cementations value, such as blast-furnace slags and natural cements, or they are materials that develop cementations properties by chemical reaction with the products of hydration of Portland cement, such as pozzolans.

For example, the use of fly ash in concrete at proportions ranging from 30 percent to 65 percent of total cementations binders has been studied extensively over the last twenty years. These cement replacement materials reduce greenhouse gas emission proportionately and result in a more "green concrete", through reduction of energy consumptions (energy required to produce cement) and prevent the depletion of natural resources.

The comparison between normal concrete and adding cement replacement material concrete in different factors: CO_2emission, Recycling, Waste and Resource depletion.

CO_2	Direct annual CO_2 emissions have reduced by nearly 40% since 1990 in absolute terms. The cement industry met the UK's 2010 Climate Change Agreement target four years in advance and is continuing its commitment to improvement. This compares favorably with the UK construction industry, which overall recorded an increase in CO_2 of more than 30% over the same period.
Recycling	In 2008, the sector replaced 26.5% of its fuel from waste-derived material including scrap tires, pelletized sewage sludge and meat and bone meal.
Biodiversity	All cement plants and quarries have, or are linked to, biodiversity action plans.
Resource depletion	The consumption of natural raw materials needed to make cement has reduced significantly in the last ten years. Between 1998 and 2008, the sector has increased the use of waste-derived raw materials by over 50%
Waste	The cement sector is a net user of waste. Waste-derived materials are actively sought as replacements for natural raw materials and fossil fuels. The sector uses over 1.4 million tons of waste in this way and produces 45,000 tons of waste per year.
Emissions	The cement industry has worked hard to reduce its emissions to air by investing in new technologies. From

	1998 to 2008, significant reductions have been achieved. SO_x emissions have reduced by 75%, dust emissions by 68 per cent and NO_x by 51%
Health and safety	The sector has reduced accident rates of its employees by 80% in the last ten years. The target is to achieve a further 50% reduction in accident rates by 2015.

Additional cement replacement materials

CO_2	The use of 50% CRM can reduce embodied CO_2 by over 40%, compared with a traditional 100 per cent Portland cement concrete mix. 30% fly ash can reduce embodied CO_2 by over 20% Limestone fines can reduce embodied CO_2 by 15%
Recycling	The concrete industry recycles by-products from other industrial processes. LFS, a by-product of iron production, and fly ash from electric generating plants can both be used as additional cementations material in concrete mixes.
Resource depletion	Every ton of additional cementations material used in concrete mixes saves about 1.4 tons of raw materials.
Waste	LFS and fly ash are by-products of other industries. These products can be diverted from landfill by being used as additional cementations material in concrete mixes. As a proportion of total cementations materials used in ready-mixed and precast concrete, 31.8% is additional cementations materials.

Table 1: comparison between normal concrete and adding cement replacement material concrete

This current study focuses on the use of ladle furnace slag (LFS), a by-product of the steel production process, as a means for increasing the total powder content in OPC.

In 2010, the EU steelmaking industries generated about 21.8 million tons of different types of slag. About 13 % of this amount was generated as secondary metallurgical slag, arising from various secondary metallurgy processes. One of the secondary processes in the production of high-alloyed steel is known as ladle refining or ladle metallurgy. Ladle refining consists, generally, of a ladle furnace (LF) and vacuum oxygen decarburization (VOD). The slag resulting from this process is called ladle slag (LS) and is also known as basic, refining, reducing, or falling slag, and as white slag. The use of industrial by-products requires the knowledge of the characteristics of the materials. Using metallurgical by-products that fulfil the relevant requirements can save natural resources, as well as helping to avoid impairment of the landscape through their excavation and, thus, minimizing the adverse landfilling of such materials.

The steel production is done by two processes: the (BOF) Basic Oxygen Furnace process and (EAF) Electric Arc Furnace (furnace that heats recycled material by means of an electric arc)

Process flow:

1. Scrap charge
2. EAF- Electric Arc Furnace operation
3. Ladle refining
4. Continuous casting (strand casting).

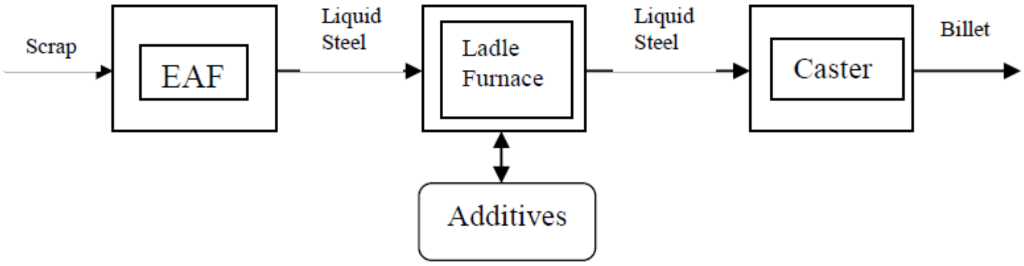

Figure 1: Steel production process

Although the process looks simple enough, each process step consists of many sub-processes and parameters which make the overall operation complex, time consuming and expensive.

1.2 PROBLEM STATEMENT

It is important to remember that Concrete is the single most widely used material in the world and the Concrete production contributes 5 percent of annual anthropogenic global CO_2 production. The production of Portland cement is not only costly and energy intensive, but it also produces large amounts of carbon emissions. The production of one ton of Portland cement produces approximately one ton of CO_2 in the atmosphere. Carbon dioxide emission has been a serious problem in the world due to the greenhouse effect. Today many countries agreed to reduce the emission of CO_2. Many phases of cement and concrete technology can affect sustainability. Cement and concrete industry is responsible for the production of 7% carbon dioxide of the total world CO_2 emission.

The World Steel Association (WSA) has noted that there has been a substantial increase in the demand for steel with crude steel production in 2011 reaching 1,527 megatons (Mt), an increase of 6.8% compared to 2010. The WSA also indicated that around 62 countries reported that a total of 136 million tons of steel were manufactured in March 2012. WSA forecasted that steel use would increase by 3.6% in 2012. Many million tons of slag are generated as it is a by-product of iron- and steelmaking industry during the separation of the molten iron and steel from impurities.

Steel slags are divided according to the type of aggregate in which they were created. There are four types of iron and steel industry slags, namely, the blast furnace (BF) iron slag, the basic oxygen furnace (BOF) the steel slag, the electric arc furnace (EAF) steel slag, and the ladle furnace (LF) basic slag, also called the secondary refining slag or the white slag.

The ladle furnace basic slag is produced in the final stages of steelmaking. Furnace slags are generated during steel production in a part of metallurgical process so called primarily metallurgy. Ladle slags are products from secondary metallurgy and these are formed in ladles. Furnace slags are used in production of artificial heavy aggregates and they are also recycled in aggregates where they were primarily formed. Ladle slags are mostly stored on landfills.

The most important functions of the secondary refining processes are the final desulfurization, the degassing of oxygen, nitrogen, and hydrogen, the removal of impurities, and the final decarburization (done for ultralow carbon steels).

The increase in steel consumption is thus the cause of the slag generating process, and, consequently, the growth in slag volume had impact on developing various methods of slag utilization. Slags from iron and steel production have long been regarded as useful materials in building and civil works. Steel slag can be utilized in many different areas such as soil conditioners, fertilizers, and sinter material, production of cement and concrete, and so forth. Each type of slag has its own characteristics such as the use of ground granulated BF iron slag, as an addition to the Portland cement. Furthermore, BOF slag and EAF slag are used in asphaltic mixes and road-base layers. The practical application of the LF slag differs from the latter due to its specific characteristics that will be tested as an additional component to the Portland cement in this paper.

The slag as an alternative adsorbent has been used to remove heavy metals in the environmental field due to its unique properties by reuse it as a component to the concrete, this method will protect the environment of their harmful effect as well as consider a useful way to consume the unique properties of the slag. but this way of using the slag consider to be a fall back because it does not consume all the LFS properties Another thing had to be considered is the pozzolanic reaction that occurs in Portland cement upon the addition of pozzolans .

The term pozzolana was defined as siliceous/aluminous materials, either natural or artificial, which react chemically with calcium hydroxide (CH) or with materials that can release calcium hydroxide (Portland cement clinker) in the presence of water to form compounds that possess cementations properties. Fly ash (FA), rice husk ash (RHA), silica fume (SF), slag and also calcined clay in the form of metakaolin (MK) are good examples of pozzolanic materials. In chemical terms, the pozzolanic reaction occurs between calcium hydroxide, also known as portlandite ($Ca(OH)_2$), and silicic acid (written as H_4SiO_4 or as $Si(OH)_4$):

$$Ca(OH)_2 + H_4SiO_4 \rightarrow CaH_2SiO_4 \cdot 2\,H_2O$$

The electric arc furnace slag (EAFS) has a chemical composition more close to that of the cement clinker compared to the ground granulated blast-furnace slag (GGBFS). Hence, recently it was shown that it has potential application as a partial substitute for raw materials in clinker production.

Addition of up to 20% EAFS in the kiln feed was found to improve burn ability index of the raw material mix. The cementations and pozzolanic behavior of electric arc furnace steel slag, both as received and treated, has been studied. The as received slag was completely crystalline as the predominant phase.

Treatment of this slag, re-melting and water quenching, results in several phases with marinate as the dominant phase with an increase in basicity index which is more hydraulic.

1.3 OBJECTIVE

The main objective of this research is to identify the optimum mix proportion of ladle furnace slag as cement replacement material.

The specific objectives are as follow:

1. Identification of LFS for pozzolanic reaction.
2. Determine the effect of ladle furnace slag on the mechanical properties of concrete.
3. Identify the optimum mix proportion of LFS concrete.

1.4 SCOPE OF STUDY

For this paper, it requires conducting an experiment of mixing different percentage of OPC and ladle furnace slag to identify the Optimum concrete mix that gives the best testing results. The best mix will be chosen after conducting a several trail mixes.

Ordinary Portland Cement %	Ladle Furnace Slag %
100	0
95	5
90	10
85	15
80	20

Table 2: Mixture table

The tests that will be conducted are (Compressive strength, Tensile strength)

CHAPTER 2

LITRATURE REVIEW

2.1 SLAG PRODUCTION

Slags are named based on the furnaces from which they are generated. for the iron and steelmaking processes and the types of slag generated from each process the main types of slags that are generated from the iron and steelmaking industries are classified as follow:

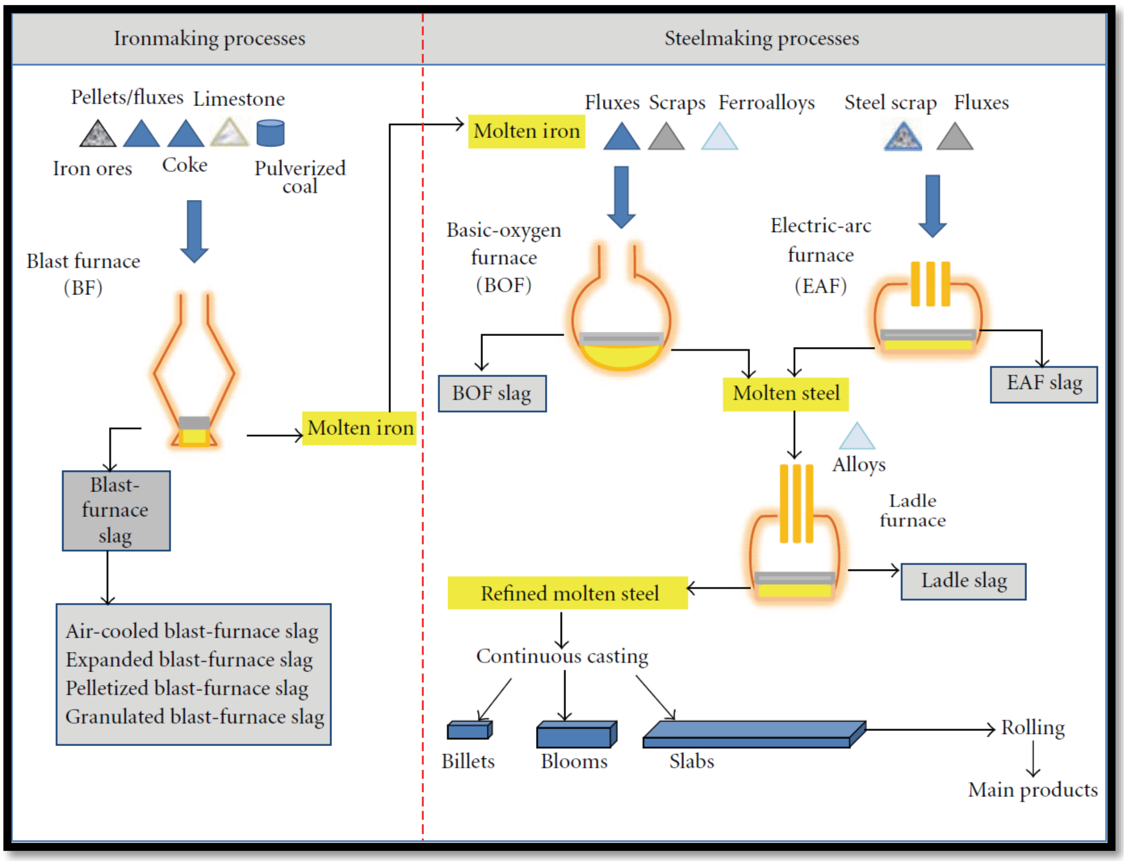

Figure 2: Flowchart of iron and steelmaking processes

2.1.1 Basic-Oxygen-Furnace

Process of Steelmaking and Slag Generation. Basic-oxygen furnaces, which are located at integrated steel mills in association with a blast furnace, are charged with the molten iron produced in the blast furnace and steel scraps. Typically, the proper basic-oxygen furnace charge consists of approximately 10–20% of steel scrap and 80–90% of molten iron.

The presence of steel scraps in the basic-oxygen furnace charge plays an important role in cooling down the furnace and maintaining the temperature at approximately 1600 $^\circ$C–1650 $^\circ$C for the required chemical reactions to take place.

Figure 3 shows a schematic representation of a basic-oxygen furnace. First, steel scrap is charged to the furnace and, immediately after this charge, a ladle of molten iron (~200 tons) is poured on top of it with the help of a crane. Then an oxygen lance, lowered into the furnace, blows 99% pure oxygen on the charge at supersonic speeds. During the blowing cycle, which lasts approximately 20–25 minutes, intense oxidation reactions remove the impurities of the charge.

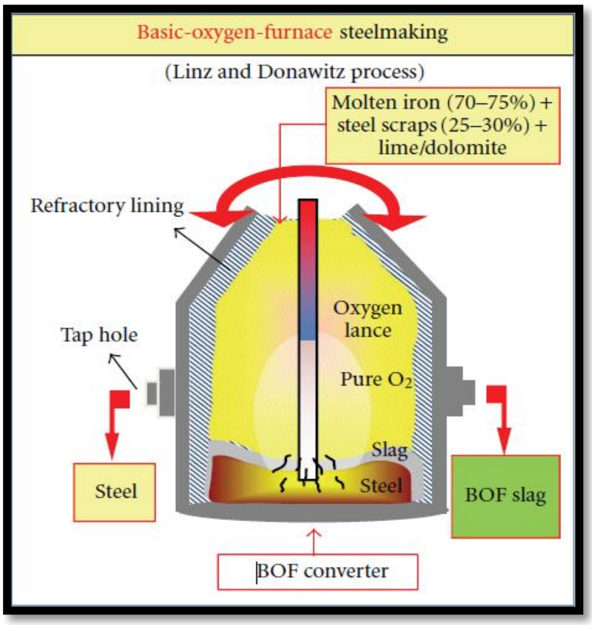

Figure 3: Schematic representation of the basic-oxygen furnace process

Carbon dissolved in the steel is burned to form carbon monoxide, causing the temperature to rise to 1600– 1700◦C (the temperature in the furnace is carefully monitored throughout the oxygen blowing period). The scrap is thereby melted, and the carbon content of the molten iron is lowered. To remove the unwanted chemical elements of the melt, the furnace is also charged with fluxing agents, such as lime (CaO) or dolomite (MgCa(CO3)2), during the oxygen blowing cycles. The impurities combine with the burnt lime or dolomite forming slag and reducing the amount of undesirable substances in the melt. Samples of the molten metal are collected near the end of the blowing cycle and tested for their chemical composition. Once the desired chemical composition is achieved, the oxygen lance is pulled up from the furnace.

Slag resulting from the steelmaking process floats on top of the molten steel. The basic-oxygen furnace is tilted in one direction in order to tap the steel into ladles. The steel produced in the basic-oxygen furnace can either undergo further refining in a secondary refining unit or be sent directly to a continuous caster where semi-finished shapes (blooms, billets, or slabs) are solidified in integrated steel mills. After all the steel is removed from the basic-oxygen furnace, it is tilted again in the opposite direction to pour the liquid slag into ladles. The slag generated from a steelmaking cycle is later processed, and the final product after processing is referred to as basic-oxygen-furnace slag (BOF slag). The chemical reactions occurring during the removal of impurities determine the chemical composition of the basic-oxygen-furnace slag.

2.1.2 Electric-Arc-Furnace (EAF)

Process of Steelmaking and Slag Generation. Electric-arc furnaces (mini mills) use high-power electric arcs, instead of gaseous fuels, to produce the heat necessary to melt recycled steel scrap and to convert it into high quality steel. The electric-arc furnace steelmaking process is not dependent on the production from a blast furnace since the main feed for it is steel scrap with some pig iron. Electric-arc furnaces are equipped with graphite electrodes and resemble giant kettles with a spout or an eccentric notch on one side. The roof of the electric-arc furnaces can pivot and swing to facilitate the loading of raw materials. Steel scraps, either as heavy melt (large slabs and beams) or in shredded form are separated, graded, and sorted into different classes of steel in scrap yards. Scrap baskets are loaded carefully with different types of scrap according to their size and density to ensure that both the melting conditions in the furnace and the chemistry of the finished steel are within the targeted range.

The electric-arc furnace steelmaking process starts with the charging of various types of steel scrap to the furnace using steel scrap baskets. Next, graphite electrodes are lowered into the furnace. Then, an arc is struck, which causes electricity to travel through the electrodes and the metal itself. The electric arc and the resistance of the metal to this flow of electricity generate the heat. As the scrap melts, the electrodes are driven deeper through the layers of scrap. In some steel plants, during this process, oxygen is also injected through a lance to cut the scrap into smaller sizes. As the melting process progresses, a pool of liquid steel is generated at the bottom of the furnace. CaO, in the form of burnt lime or dolomite, is either introduced to the furnace together with the scrap or is blown into the furnace during melting. After several baskets of scraps have melted, the refining metallurgical operations (e.g., decarburization and dephosphorization) are performed. During the steel refining period, oxygen is injected into the molten steel through an oxygen lance. Some iron, together with other impurities in the hot metal, including aluminum, silicon, manganese, phosphorus, and carbon, are oxidized during the oxygen injections.

These oxidized components combine with lime (CaO) to form slag. As the steel is refined, carbon powder is also injected through the slag phase floating on the surface of the molten steel, leading to the formation of carbon monoxide. The carbon monoxide gas formed causes the slag to foam, thereby increasing the efficiency of the thermal energy transfer. Once the desired chemical composition of the steel is achieved, the electric-arc furnace is tilted, and the slag and steel are tapped out of the furnace into separate ladles. Steel is poured into a ladle and transferred to a secondary steelmaking station for further refining.

The molten slag is carried to a slag-processing unit with ladles or slag pot carriers. In electric-arc furnaces, up to 300 tons of steel can be manufactured per cycle (a cycle takes one to three hours to complete). Initially, the EAF steelmaking process was more expensive than the BOF process and, hence, it was only used for production of high quality steels. However, as the size of the electric-arc furnaces increased over the years, the EAF steelmaking process has become competitive in the production of different grades of steel and has started to dominate the US steel industry with a 55% share of the total steel output in 2006, according to USGS.

2.1.3 Ladle Furnace Refining and Slag Generation.

After completion of the primary steelmaking operations, steel produced by the BOF or EAF processes can be further refined to obtain the desired chemical composition. These refining processes are called secondary steelmaking operations. Refining processes are common in the production of high-grade steels. The most important functions of secondary refining processes are final desulfurization, degassing of oxygen, nitrogen, and hydrogen, removal of impurities, and final decarburization (done for ultralow carbon steels).

Depending on the quality of the desired steel, molten steel produced in the EAF and BOF process goes through some or all the above-mentioned refining processes. Most of the mini mills and integrated steel mills have ladle-furnace refining stations for secondary metallurgical processes. Figure 4 shows a schematic representation of an electric-arc-furnace and a ladle refining unit associated with it . Ladle furnaces, which look like smaller versions of EAF furnaces, also have three graphite electrodes connected to an arc transformer used to heat the steel. Typically, the bottom of the ladle furnace has a pipeline through which argon gas is injected for stirring and homogenization of the liquid steel in the furnace. By injecting desulfurizing agents (such as Ca, Mg, CaSi, CaC2) through a lance, the sulfur concentration in the steel can be lowered to 0.0002% . The addition of silicon and aluminum during deoxidation forms silica (SiO2) and alumina (Al2O3); these oxides are later absorbed by the slag generated by the refining process.

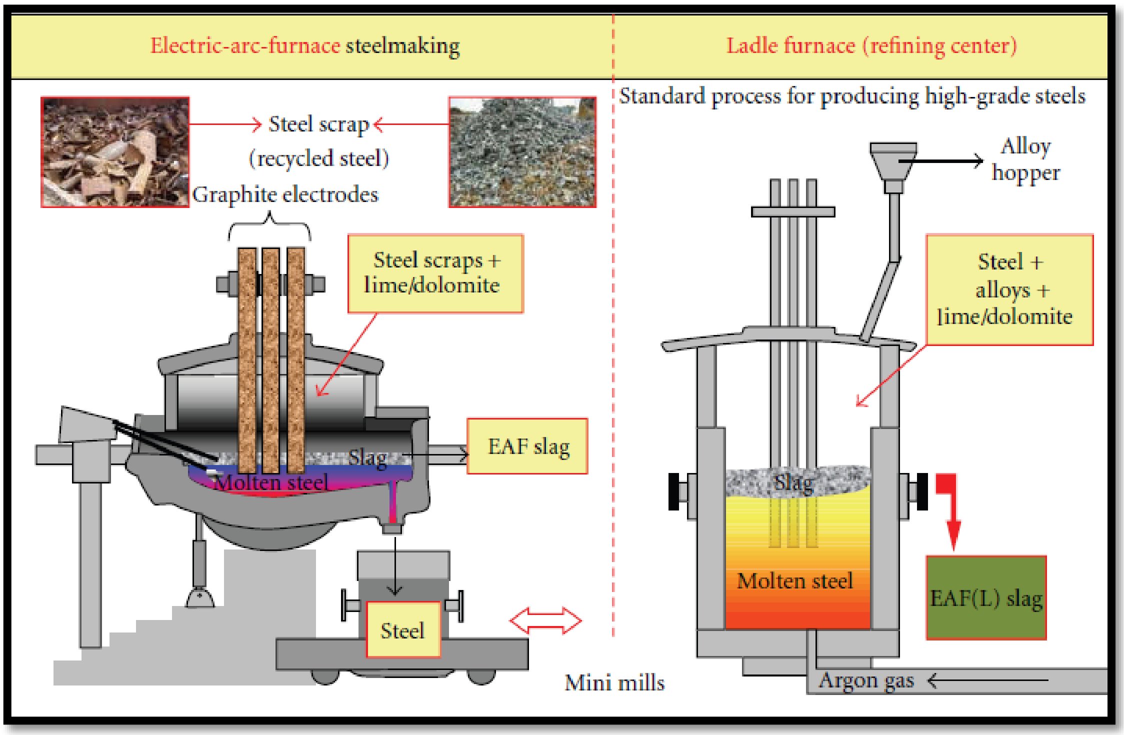

Figure 4: Schematic representation of the electric-arc-furnace steelmaking and ladle refining process

In addition, in order to adjust precisely the chemical composition of the steel to produce different grades of steel, the desired alloys are added to the molten steel through an alloy hopper that is connected to the ladle furnace.

Ladle furnaces also function as a storage unit for the steel before the initiation of casting operations. Therefore, ladle furnaces reduce the cost of high-grade steel production and allow flexibility in the steelmaking operations.

2.2 CONCRETE REPLACEMENT MATERIAL

Cement production is an energy intensive process which also has an important effect on the environment. Producing one ton of Portland cement releases about one ton of CO2 greenhouse gas into atmosphere and because of this production 1.6 billion tons of CO2 is released every year which is estimated at about 7% of the CO2 production worldwide (Mehta 2001; Malhotra 1999). The pressure of ecological constraints and environmental regulations are bound to increase in the coming years which will lead to greater use of supplementary cementitious materials such as fly ash or ground granulated blast furnace slag (GGBS) (Aitcin 2000).

There are two major reasons to use these by-products in concrete: decreasing cement consumption by replacing part of cement with these pozzolanic materials and improving fresh and hardened concrete properties. In recent years, the reduction of water/cement ratio by using superplasticizers and usage of ultrafine mineral admixtures lead to high performance concrete. Beside the advantages, pozzolanic materials have certain drawbacks. To overcome some of the disadvantages and to be able to use the pozzolan in higher amounts, quality of the pozzolan can be improved.

Chemical composition, particle-size distribution, fineness, and pozzolanic activity, and curing conditions of concrete are important factors affecting the properties of concretes with pozzolanic materials (ACI Committee 232 1996; ACI Committee 233 1995; ACI Committee 234 1996).

In recent years, it has been shown that the filler effect of mineral admixtures may be as important as their pozzolanic effects; according to some researchers, however, the filler effect can be more important than the pozzolanic effect (Goldman and Bentur 1993; Isaia et al. 2003). Particle-size distribution clearly plays a very important role in the rate of chemical reactivity and in the water demand. Pozzolanic reaction takes place on the surface of the particles and increasing surface area has an important effect on pozzolanic activity. Thus, the fineness of the pozzolan is very important for the improvement of cement paste-aggregate interfacial zone, which is the weakest link in concrete.

Development of new types of concrete with improved performance is a very important issue for the whole building industry. This development is based on the optimization of the concrete mix design, with an emphasis not only to the workability and mechanical properties but also to the durability and the reliability of the concrete structures in general. Appearance of the new types of concrete requires a revision and improvement of existing structural systems and actual building technologies. The economical aspect is of importance as well.

Cement replacement materials are special types of naturally occurring materials or industrial waste products that can be used in concrete mixes to partially replace some of the Portland cement. Cement replacement materials are frequently called fine minerals or pozzolans. Surprisingly, concrete with cement replacement materials can be stronger and more durable than concrete with ordinary Portland cement (OPC).

The three most-commonly used cement replacement materials are the following:

2.2.1 Fly ash

Is a fine, glass-like powder recovered from gases created by coal-fired electric power generation. U.S. power plants produce millions of tons of fly ash annually, which is usually dumped in landfills. Fly ash is an inexpensive replacement for Portland cement used in concrete, while it improves strength, segregation
and ease of pumping of the concrete. Fly ash is also used as an ingredient in brick, block, paving, and structural fills.

Fly ash concrete was first used in the U.S. in 1929 for the Hoover Dam, where engineers found that it allowed for less total cement. It is now used across the country. Consisting mostly of silica, alumina and iron, fly ash is a pozzolan a substance containing aluminous and siliceous material that forms cement in the presence of water. When mixed with lime and water it forms a compound like Portland cement. The spherical shape of the particles reduces internal friction thereby increasing the concrete's fluidity, permitting longer pumping distances. Improved workability means less water is needed, resulting in less segregation of the mixture. Although fly ash cement itself is less dense than Portland cement, the produced concrete is denser and results in a smoother surface with sharper detail.
sulfates that exist in fertilized soils and coastal areas get into PCC and attack the HCP. Usage of fly ash as a cement replacement material improves resistance to sulfate attack:

Class F fly ash, with particles covered in a kind of melted glass, greatly reduces the risk of expansion due to sulfate attack, is produced from Eastern coal.

Class C fly ash produced from western coal, is also resistant to expansion from chemical attack, and has a higher percentage of calcium oxide, and is more commonly used for structural concrete. Because fly ash comes from various operations in different regions, its mineral makeup may not be consistent; this may cause its properties to vary, depending on the quality control of the manufacturer. There are some concerns about freeze/thaw performance and a tendency to effloresce, especially when used as a complete replacement for Portland cement.

The Clean Air Act of 1990 requires power plants to cut nitric oxide emissions. To do so, plants restrict oxygen, resulting in high-carbon fly ash, which must be reprocessed for cement production. Thus, fly ash could be less available or costlier in the future. Researchers are studying why the unprocessed high-carbon ash doesn't work for cement, and other treatment options.

2.2.2 Ground granulated blast-furnace slag (GGBS)

Ground granulated blast-furnace slag is the granular material formed when molten iron blast furnace slag is quenched. It is a granular product with very limited crystal formation, is highly cementations in nature and, when ground to cement fineness, hydrates like Portland cement.

Blast furnace slag cement, which is made by intergrading the granulated slag with Portland cement clinker (blended cement), has been used for more than 60 years. The use of separately ground slag combined with Portland cement at the mixer as a mineral admixture did not start until the late 1970s.

ASTM C 989-82 and AASHTO M 302 were developed to cover ground granulated blast furnace slag for use in concrete and mortar. The three grades are 80, 100, and 120. The grade of a ground granulated blast furnace slag is based on its activity index, which is the ratio (in percent) of the compressive strength of a mortar cube made with a 50 percent GGBS, 50% OPC blend to that of a mortar cube made with 100% OPC.

The use of grade 80 ground granulated blast-furnace slag should be avoided unless warranted in special circumstances since it will have a lower compressive strength at all ages. The typical justification for using grade 80 GGBS is that it has a lower heat of hydration which is important in massive concrete pours.

Substitution of grade 100 ground granulated blast furnace slag will generally yield an equivalent or greater strength at 28 days.

For a given mix, the substitution of grade 120 ground granulated blast furnace slag for up to 50 percent of the cement will generally yield a compressive strength at 7 days and beyond equivalent to or greater than that of the same concrete made without ground granulated blast furnace slag.

2.2.3 Condensed Silica Fume (CSF)

Silica fume, also known as micro silica, is a byproduct of the reduction of high-purity quartz with coal in electric furnaces in the production of silicon and ferrosilicon alloys. Silica fume is also collected as a byproduct in the production of other silicon alloys such as ferrochromium, ferromanganese, ferromagnesian, and calcium silicon. Before the mid-1970s, nearly all silica fume was discharged into the atmosphere. After environmental concerns necessitated the collection and landfilling of silica fume, it became economically justified to use in various applications.

Silica fume consists of very fine vitreous particles approximately 100 times smaller than those of ordinary cement particles, and with a surface area on the order of 20,000 m2/kg Because of its extreme fineness and high silica content, CSF is a highly effective pozzolanic material. It has been found that CSF: improves compressive strength, bond strength, and abrasion resistance; reduces permeability; and therefore, helps in protecting reinforcing steel from corrosion.

CSF has been used at cement replacement rates of up to 15%, although the normal rate is 7-10% percent. With 15% replacement, the potential exists for very strong, brittle concrete.

Due to its extreme fineness, CSF reduces the fluidity (slump) of fresh concrete. It therefore increases the water demand in a concrete mix such that for each 1 kg of CSF used, the mass of water must be increased by 1 kg. Usage of CSF at rates of less than 5% will not typically require a water reducer. Higher replacement rates will require the use of a high range water reducer.

2.3 LADLE FURNACE SLAG APPLICATIONS

2.3.1 Ladle Furnace Slag in Asphalt Mixes

Road construction requires various materials; among these materials, bituminous mixes are mainly composed of aggregates, traditionally extracted from quarries and gravel pits. Along with the exploitation of limited natural resources, mining, crushing, sieving, washing and transporting natural aggregates expend significant amounts of energy. Global consumption of natural aggregates is estimated to exceed 30,000 million tons/year. Numerous lines of research have investigated substitution of the fine fraction and the filler of bituminous mixes by recycled materials: quarry by-products and mine tailings, foundry sand, coal fly ash, municipal solid waste incineration ash , cement bypass dust , waste glass , recycled concrete and mortar , waste ceramic materials (bricks, tiles. . .) , asphalt shingles, crushed steel slags , and nonferrous slags (copper, nickel, zinc). However, the existence of a line of investigation that introduces LFS into bituminous mixtures.

Porous Asphalt (PA) mixes, also known as Permeable Friction Courses (PFC) are special types of hot bituminous mixtures that have a coarse granular skeleton that develops stone-on-stone contact, and a high content of connected air voids, meaning that these mixtures have good drainage properties.

The main advantages of these kinds of mixtures are related to safety in wet-weather driving, owing to the reduction of splash and spray, the risk of hydroplaning and wet skidding; effective drainage also improves the visibility of pavement markings in wet weather.

Improvements to water quality after drainage have also been demonstrated. In addition to this, they also contribute to noise abatement, reportedly between 4 to 6 dB(A) when compared to a concrete pavement or dense-graded asphalt concrete.

The object is to demonstrate the suitability of Ladle Furnace Slag (LFS) for use in manufacturing porous bituminous mixtures.

The following observations were made in this research when using LFS, due to its volumetric instability:

- Its proportion in the total asphalt mixture was never in excess of 15%.
- The use of slag wrapped in a bituminous matrix is less problematic than its use as an unbound material, as its surrounding binder protects it from moisture and prevents hydration reactions. This protection is more noticeable in the case of fine materials, such as LFS.
- Its use in flexible and porous matrices, such as porous bituminous mixtures (with an approximate void ratio of 20%) means any eventual expansion will be absorbed into the mix voids.

First, the LFS was used as filler, to replace the cement that is usually employed as quality filler. Then, whole-particle-size LFS was used in substitution of the fine natural aggregate and the filler. All the bituminous mixtures were tested in terms of mechanical behavior, moisture susceptibility and durability, comparing their results with the standard mix. The final aim was to demonstrate that porous bituminous mixtures manufactured with ladle slag presented a strong, stable, durable and environmentally efficient behavior.

The use of the ladle furnace slag as asphalt mix are as following:

- Mix design and OBC in slag mixes can be assimilated to the control mixes. The void content of the mixtures with LFS sand was slightly higher, which may be due to the superior angularity of the slag. Mean permeability results were also very close to those of the control mixes.
- The binder drainage test demonstrated that the LFS works properly as filler, presenting good adhesion with the bitumen and forming good quality mastic. It was also noted that white slag had superior bitumen absorption than the conventional materials.
- The mechanical behavior of the mixes (abrasion, tensile strength) was excellent for every mixture designed, which enables these mixtures to be used even in the most demanding applications. Mixtures manufactured with slag sand showed a slightly worse performance, which could be attributed to the higher bitumen absorption of the slag.
- Aging produced similar effects on every mixture, far exceeding the regulatory recommendations.
- Thermal susceptibility of the mixtures improved with the incorporation of ladle slag.
- Moisture sensitivity in terms of TSR hardly met the regulatory requirements, although this may not be significant for the porous asphalt mixes. Water resistance evaluated by the Wet Abrasion Loss exceeded the prescriptions and showed a good cohesive performance that, in fact, increased with the incorporation of slag. The rougher texture of the slag and its better adhesion to the binder are favorable for the moisture susceptibility of the mixes.

2.3.2 Ladle Furnace Slag in Soil Stabilization

Natural clayey soils have often to be stabilized by mixing them with certain materials, such as cement, lime, or similar products, so that they acquire the necessary properties for civil works. Some industrial by-products can also be used for this purpose, among which steelmaking slags. By studying the properties of Ladle Furnace Slag (LFS) and the characteristics of several clayey soils susceptible to improvement with additions of this by-product. The behavior of the different soil and slag mixes was similar to the behavior of the soil and lime mixtures reported in the literature. The results of a series of test report improvements in various geotechnical properties, such as the plasticity index, expansiveness, bearing capacity and durability.

In the early 1990s , pioneering attempts to use ground steel slag from converter furnaces (LD) in soil stabilization for rural roads with low-traffic met with limited success and the milling process of the slags came at a high economic cost. Subsequent results obtained for the stabilization of soils in road bases using

LD slags were not encouraging; despite the use of activators, it was necessary to use excessively high proportions (15–20%) of finely milled slag and long curing periods, all of which were negative factors, in order to achieve acceptable performances. Similarly, the considering LD slag and Electric Arc Furnace Slag (EAFS) inappropriate for soil stabilization.

Nevertheless, high proportions of slag have recently been used for the stabilization of dredged marine clay embankments [31], and the use of EAF and LD slag mixed with fly ash has also provided successfully results. A promising type of slag for such applications is Ladle Furnace Slag (LFS), which is also known as basic slag, reducing slag, white slag and secondary refining slag. Its production in Spain stood at half-a-million tons in 2010; partially, it is reused in Portland cement manufacture (Oficemen – Unesid), being the rest allocated to new uses at sites close to the centres of production.

LFS is a dusty material with limited hydraulic reactivity, due to the majority presence of both calcium and magnesium oxides, silicates and aluminates. The foremost question hanging over the use of LFS in engineering concerns its volumetric instability as a result of weathering and consequent exposure to atmospheric agents, air and water. However, this short and medium- term expansiveness is irrelevant when used in low proportions (less than 10%) for flexible matrices, such as soil mixtures. LFS from any origin shares common chemical features, such as the presence of dicalcium silicate (in any of its crystalline varieties), calcium aluminates, free lime (lime, portlandite) and free magnesium oxide (periclase). These and other substances found in LFS are useful when considering their applications in the improvement of soils.

The replacement of quicklime by LFS is advantageous from the economic and environmental point of view; the results may be excellent for certain combinations of soil and LFS and poor in other cases, due to the great variety of clayey soils and the varied chemical and mineralogical composition of LFS .

The effects of the soil/slag mixtures with regard to improvements in resistance, bearing capacity, swelling properties and global plasticity may be attributed to the following facts:

- The expansion of LFS slag reported in long-term tests performed in water at 70 C is mainly due to the hydration of free lime and periclase present in LFS, and the appearance of various insoluble hydrated and carbonated products.
- The mixtures of clayey soils and LFS slag have resulted in improvements to their bearing capacity in relation to the natural ground soil, and the results are very close to those obtained for the stabilization of soils with lime. In each particular case, according to the characteristics of the soil and the slag that will be used, the most suitable percentages should be carefully studied.
- The soil and LFS slag mixtures and the soil and lime mixtures reduce the plasticity index (IP) and free swelling. They also significantly increase compressive strength and reduce the collapseslump.
- The monitoring of the pH solution, during the water-immersion curing process of mixtures, reveals that the presence of LFS slag leads to longer curing times.
- The durability index of the soil and LFS slag mixtures is higher than the durability index of the soil and lime mixtures.

2.3.3 Ladle Furnace Slag in the Construction of Embankments

Currently, several investigations into the use of LFS in the cement/concrete industry and slag/soil mixes are underway. In the cement/concrete industry, LFS can be used as a raw material in Portland cement. a cementing material with chemical activators under autoclave curing conditions, a supplementary cementing material in mortar and concrete, a filler in self-compacting concrete exposed to elevated temperatures, and mixed with electric arc furnace slag, for use in concrete . In the field of agriculture, LFS has been used to neutralize acidity, to supply plant nutrients, to construct rural pathways with blended soils, and to build road embankments. The hydraulic reactivity and volume stability of LFS must be studied to design effective soil mixes for the construction of embankments. It is important to establish the capacity of LFS to interact with mineral clays. Hydraulic reactivity is the property of a substance or material to react with water to produce solids of low solubility and, in most cases, high mechanical strength. The hydraulic reactivity of slag depends on its chemical composition, degree of mineralization, and particle size. This hydraulic reactivity often produces a binding effect; however, Shi (2002) considered these effects too weak for the use of LFS fines as a cementitious material in cement and concrete production. Nevertheless, the improvements associated with additions of LFS can be sufficient for low-strength applications, such as enhancing natural soils for embankment construction.

The most important property to take into account in the construction of embankments is volume stability the settlement and expansion of materials must be carefully studied to ensure stability. The presence of free lime and free magnesium oxide (periclase) in slag leads to potentially expansive behavior because of long-term hydration and carbonation reactions.

The advantages of using ladle furnace slag as a construction material for embankments follows:

- The use of ladle furnace basic slag as a material for the stabilization of soils in embankment construction is feasible and useful.
- All soils are not suitable for stabilization by mixing with LFS, in view of their mineralogical composition and the CEC of their clay fraction (the presence of montmorillonite and feldspars in the soil was revealed as positive in this paper, whereas those with traces of soluble salts may be considered negative).
- Elevated long-term potential expansion was registered in LFS (12–38%) because of the hydration of brucine, portlandite, and aluminates, in addition to hydro carbonation of magnesium.
- It is expected that the potential expansion of LFS mixed with soil in fieldwork will occur over very long periods, during which time the mineral products of the expansion may be accommodated within the soil-slag pore structure without causing catastrophic expansion

2.4 LADLE SLAG AS A POTENTIAL MATERIAL FOR BUILDING

An important step in secondary metallurgy of stainless steel is ladle metallurgy. Ladle slag is a by-product of ladle refining, typically specific for each steelmaking plant. Industrial secondary materials can be used for different applications, including construction and civil engineering. The use of industrial by-products requires the knowledge of the characteristics of the materials. Using metallurgical by-products that fulfil the relevant requirements can save natural resources, as well as helping to avoid impairment of the landscape through their excavation and, thus, minimizing the adverse landfilling of such materials.

Two types of slag are produced in the electric arc furnace steelmaking process: EAF slag and Ladle Furnace (LF) slag. This latter is known as basic slag, reducing slag or white slag. LF slag is produced in the secondary metallurgy or refining process, which generates high-grade steels. In this process, liquid steel first undergoes an acid dephosphorylating process in the EAF (oxygen blowing). Then, the steel is discharged into a ladle furnace, where it is deoxidized, alloyed under the protection of a basic slag.

Steel is an inherently never-ending product in terms of recycling and reuse. Over 1,400 million tons (MT) of steel is produced around the world per annum (Brooks et al. 2011). Slag is considered a byproduct of the production of iron and steelmaking process. The World Steel Association (2014) reported more than 400 MT of slag is generated annually in many metallurgical operations throughout the world.

The annual production of steel slag is reported to be 15 MT in the United States of America (Pasetto and Baldo 2012) and 12 MT in Europe (Ducman and Mladenovič 2011). Caster ladle furnace slag (LFS) is one of the by-products of manufacturing the iron and steel.

The Australian Slag Association reported the production of slag is approximately 2.88 MT in Australia. In the same year, 86% or 2.5 MT was effectively utilized within civil and construction material applications such as cementitious and no cementitious applications, general civil, and fill applications in Australia. Almost 60% of the utilized slag in 2013 was granulated blast furnace slag, which is highly demanded by the cement and concrete sector. There are currently limited or even no engineering reuse applications for other types of slags, including LFS. Steelmaking operations in Australia are specifically concerned by this problem because of the huge production of LFS by-products. Currently in Australia, large stockpiles of nonutilized LFS slag are rapidly accumulating at steel company sites, while future reuse options are being investigated (ASA 2002).

LFS is generated during the secondary steelmaking process in the ladle furnace. Decarburization, deoxidation, vacuum treatment to remove hydrogen, and trimming of Ferro alloys are all the steps taking place in ladle refining to allow steelmakers more control of the final steel product (Dippenaar 2005).
As the melted refined steel is poured out of the furnace, the resulting product on the bottom of the ladle is known as LFS. The LFS generated in the ladle furnace process is equal to 30 kg/t of steel produced (Heidrich and Woodhead 2010).

The chemical composition of LFS varies depending on furnace processing conditions and the type of steel grade being produced. The qualities of slags are varied and LFS is ranked as a low-quality by-product due to its fine grain size, adverse leaching potential, and expansive behavior (Serjun et al. 2013). Limited studies on engineering characteristics of LFS have been reported to date. Manso et al. (2005) stated LFS is a useful byproduct after it has been turned into a dusty product through weathering, and its expansive characteristics can be reduced in this form. This approach also suggested two potential uses for LFS: in masonry mortars and as a soil-cement mixture in pavement of rural roads with low traffic.

The behavior of several soils stabilized with LFS was studied and found to be similar to the behavior of the same soils after mixing with lime (Manso et al. 2013). The plasticity index and free swelling behavior of soils were reduced and unconfined compressive strength (UCS) significantly increased in the soils blended with LFS powder. Due to its cementitious hydraulic properties, LFS has the potential to be used as a supplementary cementing material in building and civil engineering applications (Serjun et al. 2013). Pasetto and Baldo (2013) designed and studied the mechanical characterization of various cement bound mixtures with electric arc furnace slag (EAFS), foundry sand, and LFS for road construction. This study suggested a mix with a high proportion of EAFS and small amount of foundry sand and 10% of LFS in roadwork construction.

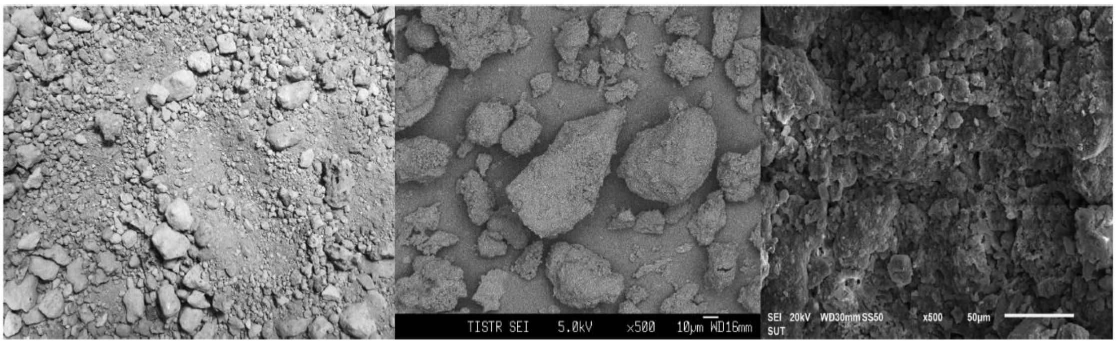

Figure 5: (a) actual sample; (b) SEM image 5.0 kV; (c) SEM image 20 kV

As a preliminary research, ladle slag has been investigated using SEM/EDS. The commonly known hydraulic minerals, such as calcium aluminate, magenta, calcium silicate and calcium silicate, were detected in this analysis. Since a large proportion of the mineral phases of ladle slag exhibit hydraulic properties, ladle slag could also have a potential use in the bonded composites in construction.

The component of a slag are:

Number	Chemical composition (%)	LFS (%)
1	MgO	8.633
2	Al_2O_3	N.D.
3	SiO_2	22.934
4	P_2O_5	0.466
5	SO_3	0.498
6	K_2O	0.059
7	CaO	24.899
8	TiO_2	0.498
9	Cr_2O_3	0.954
10	MnO_2	5.827
11	Fe_2O_3	35.233

Note: N.D. = none detected.

Table 3: Chemical Composition of LFS

The elements of each component are:

CaO
- Lime (98 % CaO)
- Dolomite (≈58 % CaO & 39 % MgO)
- Ca-Aluminate (≈45% CaO & 53% Al_2O_3)
- Refractories (dolomite)

MgO
- Dolomite (≈58 % CaO & 39 % MgO)
- Magnesia (> 92% MgO)
- Refractories (Mag-C & Dolomite)

SiO_2
- Oxidation of the Si in the scrap ($\underline{Si} + O_2 = SiO_2$)
- Steel deoxidation ($2\underline{O} + \underline{Si} = SiO_2$)
- Sand and dirt
- Refractories (High Alumina)

Al_2O_3
- Oxidation of the Al in the scrap ($2\underline{Al} + 3/2O_2 = Al_2O_3$)
- Steel deoxidation ($3\underline{O} + 2\underline{Al} = Al_2O_3$)
- Ca-Aluminate (≈45% CaO & 53% Al_2O_3)
- Bauxite (>80% Al_2O_3)
- Refractories (High Al_2O_3 sidewalls & bottoms)

FeO
- Scrap ($2\underline{Fe} + O_2 = 2FeO$)

MnO
- Scrap ($2\underline{Mn} + O_2 = 2MnO$)
- Steel deoxidation ($\underline{O} + \underline{Mn} = MnO$)

CaF_2
- Fluorspar (≈90% CaF_2)

As it is shows the chemical components of the slag, at the present, most industrial slags are being used without taking full advantage of their properties or disposed rather than used. The main kinds of metallurgical slags are properly fast cooled iron blast furnace slag (GGBS), steel slag, phosphorus slag, copper slag and lead slag. Due to their chemical and mineral composition, these slags have cementations and/or pozzolanic properties and can be potentially used as cement main constituents. Today, most metallurgical slags are used as aggregates for different applications, and only the ground granulated blast furnace slag is used for a partial Portland cement replacement.

Iron blast furnace slag is formed in the process of pig iron manufacture from iron ore. GGBS results from the fast cooling of the molten slag and is a pozzolanic as well as a latent hydraulic material. GGBS has been extensively studied as a cement or concrete constituent and as an alkali activated cementations material.

Steel slag is the industrial waste resulting from the steel-refining process in a conversion furnace. Fifty million tons per year of steel slag is produced worldwide, while nearly 12 million tons of steel slag is the annual production in Europe. Owing to the intensive research work during the last 30 years, about 65% of the produced steel slag is used today on qualified fields of applications. But the remaining 35% of this slag is still dumped. Further intensive research work is needed to decrease this rate as far as possible.

Two different approaches exist for the incorporation of steel slag in cement production. The first one involves the use of slag, mixed with limestone and clay, as raw material feed to the cement kiln. This may be a solution to the disposal problem but there is not any energy benefit (the slag must be clinkered) or economic benefit (one inexpensive material is substituted for another). A more attractive approach is the incorporation of steel slag in cement.

CHAPTER 3

RESEARCH METHODOLOGY

This chapter will discuss how the work will carry out to meet the study's aims and objectives and discuss the choices of methodology. The discussion of these aspects provides a better understanding of the appropriateness of the research.

3.1 INTRODUCTION

The main target of this research is to add a cement replacement material to the concrete to incorporate their outstanding intrinsic properties to the concrete. However, smaller particles of the LFS are dominated by greater surface effects and force interactions that increase manual attraction and their tendency to agglomerate that expected to improve the concrete strength. There are no specific guidelines given for the mix proportions of the LFS as a cement replacement material, thus making laboratory test by using trial and error method is the best solution around to confirm on the desired requirements. For the purpose of identifying optimized and effective design of LFS concrete proportions Firstly the testing process will start with mortar cubes to identify the optimum mix then start the concrete mixing. The mortar and the concrete will be mixed with different proportions of LFS percentage as cement replacement material (5%, 10%, 15%, 20%, 25%, and 30%) for mortar and (5%, 10%, 15%, and 20%) for concrete which will be adjusted per the desired objective.

Also comparing between the Fly Ash as a cement replacement material and LFS by(5%, 10%, 15%, and 20%) . Then it will undergo for the compressive testing for further confirm the compressive strength performance of LFS to choose the best mixing design. Therefore, major challenges need to be resolved by increasing the LFS percentage in the mix design without adversely affecting the workability of the concrete mix. As samples, here. The estimated LFS mixture proportions of the mortar and concrete which will be used in this paper.

Experiments Details

Experiment:	Compressive strength	Tensile strength	Slump Test
Number of Mix	Mortar:M1-M7 Concrete: M1-M5	M1-M13	------
Sample Size	Mortar :50×50×50 cube Concrete :100×100×100 cube	966 cm^3	------
Number of sample	Mortar: 3 per age Concrete :3 per age	1 per age	Concrete :1per mix
Age of sample	Mortar :3,7,28 days Concrete :7,28 days	28 days	------
Measure	Compressive strength	Tensile strength	Workability
Machine	ELE ADR 3000	UNIVERSAL 100kN	Manual

Table 4: Experiments Details

Mix	Cement	LFS	Sand	Water	W/C
M1 (0%)	533.33 Kg/m^3	0	1066.66 Kg/m^3	300ml	0.5
M2 (5%)	506.66 Kg/m^3	26.66 Kg/m^3	1066.66 Kg/m^3	300ml	0.5
M3 (10%)	480 Kg/m^3	53.33 Kg/m^3	1066.66 Kg/m^3	300ml	0.5
M4 (15%)	453.33 Kg/m^3	80 Kg/m^3	1066.66 Kg/m^3	300ml	0.5
M5 (20%)	426.66 Kg/m^3	106.66 Kg/m^3	1066.66 Kg/m^3	300ml	0.5
M6 (25%)	400 Kg/m^3	133.33Kg/m^3	1066.66 Kg/m^3	300ml	0.5
M7 (30%)	373.33 Kg/m^3	160 Kg/m^3	1066.66 Kg/m^3	300ml	0.5

Table 5: Mortal mix proportions

Mix	Cement	LFS	Coarse aggregate	Sand	Water	W/C
M1 (0%)	528 Kg/m^3	0 Kg/m^3	1586.33 Kg/m^3	1056 Kg/m^3	1.9 L	0.6
M2 (5%)	501.5 Kg/m^3	26.4 Kg/m^3	1586.33 Kg/m^3	1056 Kg/m^3	1.9 L	0.6
M3 (10%)	475.2 Kg/m^3	52.8 Kg/m^3	1586.33 Kg/m^3	1056 Kg/m^3	1.9 L	0.6
M4 (15%)	448.7Kg/m^3	79.16 Kg/m^3	1586.33 Kg/m^3	1056 Kg/m^3	1.9 L	0.6
M5 (20%)	422.5 Kg/m^3	105.5 Kg/m^3	1586.33 Kg/m^3	1056 Kg/m^3	1.9 L	0.6

Table 6: Concrete mix proportions

Mix	Cement	LFS	Sand	Water	W/C
M1 (0%)	724.6 Kg/m^3	0	1449.27 Kg/m^3	350ml	0.5
M2 (5%)	688.4 Kg/m^3	36.23 Kg/m^3	1449.27 Kg/m^3	350ml	0.5
M3 (10%)	652.2 Kg/m^3	72.4 Kg/m^3	1449.27 Kg/m^3	350ml	0.5
M4 (15%)	615.94 Kg/m^3	108.69 Kg/m^3	1449.27 Kg/m^3	350ml	0.5
M5 (20%)	579.71 Kg/m^3	144.92 Kg/m^3	1449.27 Kg/m^3	350ml	0.5

Table 7: Tensile specimen mix proportions

3.2 EXPERIMENT SET UP

3.2.1 Experiment Materials

3.2.1.1 Cement

The cement will be used in this LFS Based concrete experiment is the normal OPC used in UTP laboratory as the most common cement used in general concrete construction. OPC is a gray colored powder. It is capable of bonding mineral fragments into a compact whole when mixed with water. This hydration process results in a progressive stiffening, hardening and strength development.

3.2.1.2 Ladle furnace slag (LFS)

The LFS will be used in this experiment of concrete design mix is the slag that produced in the final stages of steelmaking Company in Penang, Malaysia. Ladle furnace slag is one of the most beneficial cement replacement material in concrete. Because of its chemical and physical properties. Concrete containing LFS can have very high strength and can be very durable. LFS is available from suppliers of concrete admixtures and, when specified, is simply added during concrete production. Placing, finishing, and curing LFS based concrete is very easy, simple and does not required any special attention on the part of the concrete contractor.

3.2.1.3 River Sand

In this slag based concrete design mix experiment, local river sand sourced from Tronoh, Perak will be used with approximately particle size range from 0.3mm to 0.8 mm. This specific aggregate will replace the coarse aggregate in the mortar concrete. The sand will be washed to remove any dirt associated with it and it will be used in in saturated surface dry condition.

3.2.2 Experiment Mixing & Casting

The process of casting influences the quality of the concrete physically and mechanically. The strength of a concrete is depending on the bond between particles and full coating of the cement binder to the aggregate. The mixing concrete batches will be carried out with a 60-liter electrical pan mixing. The pan mixer selected to ensure full and uniform mixing of the solid materials. All mixing will be performed at the civil engineering laboratory block 13 in UTP. Since amalgamating the constituent's plays a vital role in production, the procedures must be strictly obeyed. The slag based mixing procedures will be involving the following steps according to EN-1992-1-1:

1. Design specification
2. Testing of materials
3. Selecting water/cement ratio
4. Calculating water content
5. Calculating cement content
6. Finding out volume proportions for Coarse aggregate & fine aggregate
7. Mix calculations

Figure 6: UTP concrete mixer

Figure 7: Mortal Cubes molds

3.3 EXPERIMENTATION TESTING

LFS based concrete have great potential to improve the strength and toughness of traditional concrete-based building materials. Some tests will be conducted to get the mechanical properties of this mixing which are as following:

3.3.1 Compressive Test

In accordance with ASTM C109 and C109M, compression tests will be performed on cubic specimens with an edge length of 50 mm (mortar) and 100 mm (concrete). Before testing, the cubes had to be placed in the sun to make them dry and the two loading surfaces where be placed in the machine. Three specimens per mix were tested, and their average strength will be computed. This concrete is poured in the mold and tempered properly so as not to have any voids. After 24 hours, these molds are removed and test specimens are put in water for curing. The top surface of these specimen should be made even and smooth. These specimens are tested by compression testing machine after 7 days curing or 28

days curing. Load should be applied gradually at the rate of 140 kg/cm2 per minute till the Specimens fails. Load at the failure divided by area of specimen gives the compressive strength of concrete.

Figure 8: Compressive Strength Test Machine

3.3.2 Tensile Strength Test

In accordance with ASTM D638 Tensile Specimens. Consider the typical tensile specimen shown in the Figure. It has enlarged ends or shoulders for gripping. The important part of the specimen is the gage section. The cross-sectional area of the gage section is reduced relative to that of the remainder of the specimen so that deformation and failure will be localized in this region. The gage length is the region over which measurements are made and is centered within the reduced section.

The distances between the ends of the gage section and the shoulders should be great enough so that the blarger ends do not constrain deformation within the gage section, and the gage length should be great relative to its diameter. Otherwise, the stress state will be more complex than simple tension.

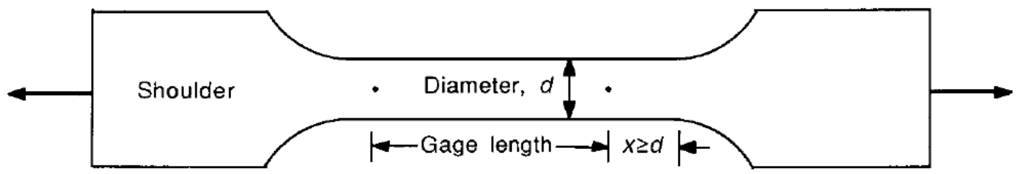

Figure 9: Typical tensile specimen

Tensile tests will be performed on specimens with a volume of 966 m^3 (mortar). Before testing, the samples had to be placed in the sun to make them dry and the loading surfaces where be placed in the machine. one specimens per mix were tested and for every mix different particle size of LFS.

This sample is poured in the mold and tempered properly so as not to have any voids. After 24 hours, these molds are removed and test specimens are put in water for curing. The top surface of these specimen should be made even and smooth. These specimens are tested by compression testing machine 28 days curing. Load should be applied gradually till the Specimens fails. Load at the failure divided by area of specimen gives the Tensile e strength of sample.

Figure 10: Tensile Specimen Sample

3.3.3 Slump test

The slump test is the simplest workability test for concrete, involves low cost and provides immediate results. Due to this fact, it has been widely used for workability tests since 1922. The slump is carried out as per procedures mentioned in **ASTM C143.**

Procedure for concrete slump test:

1. Clean the internal surface of the mold and apply oil.
2. Place the mold on a smooth horizontal non- porous base plate.
3. Fill the mold with the prepared concrete mix in 4 approximately equal layers.
4. Tamp each layer with 25 strokes of the rounded end of the tamping rod in a uniform manner over the cross section of the mold. For the subsequent layers, the tamping should penetrate into the underlying layer.
5. Remove the excess concrete and level the surface with a trowel.
6. Clean away the mortar or water leaked out between the mold and the base plate.
7. Raise the mold from the concrete immediately and slowly in vertical direction.
8. Measure the slump as the difference between the height of the mold and that of height point of the specimen being tested.

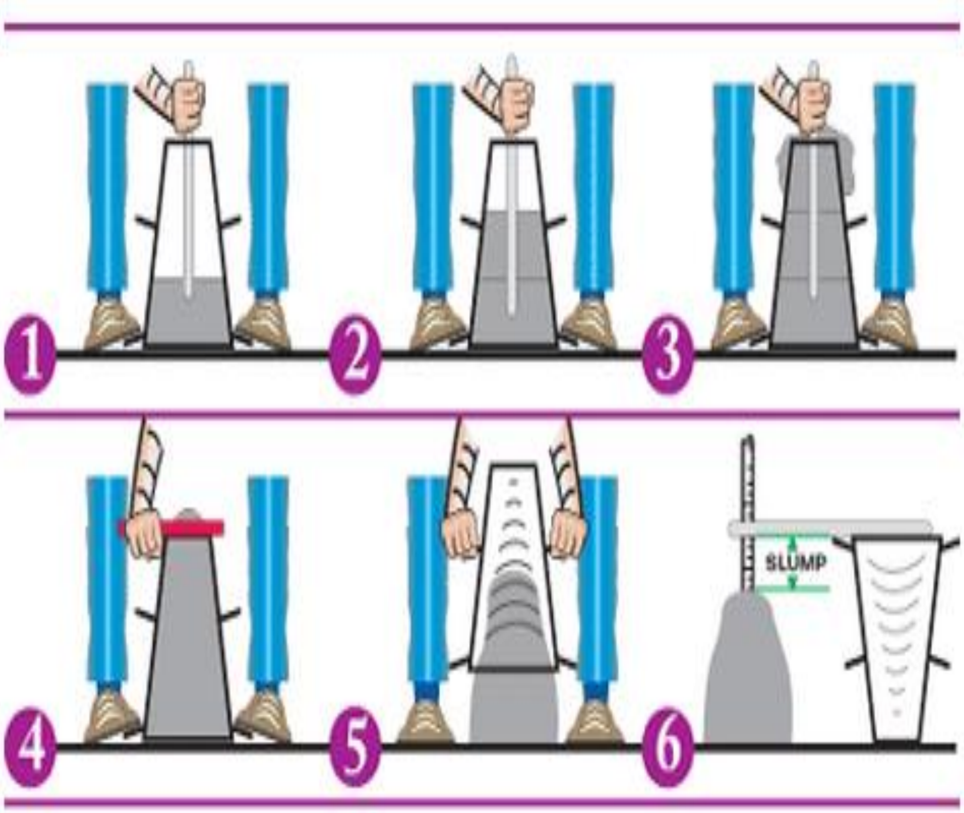

Figure 11: Slump test

CHAPTER 4

RESULTS AND DISCUSSION

4. 1 COMPRESSIVE TEST

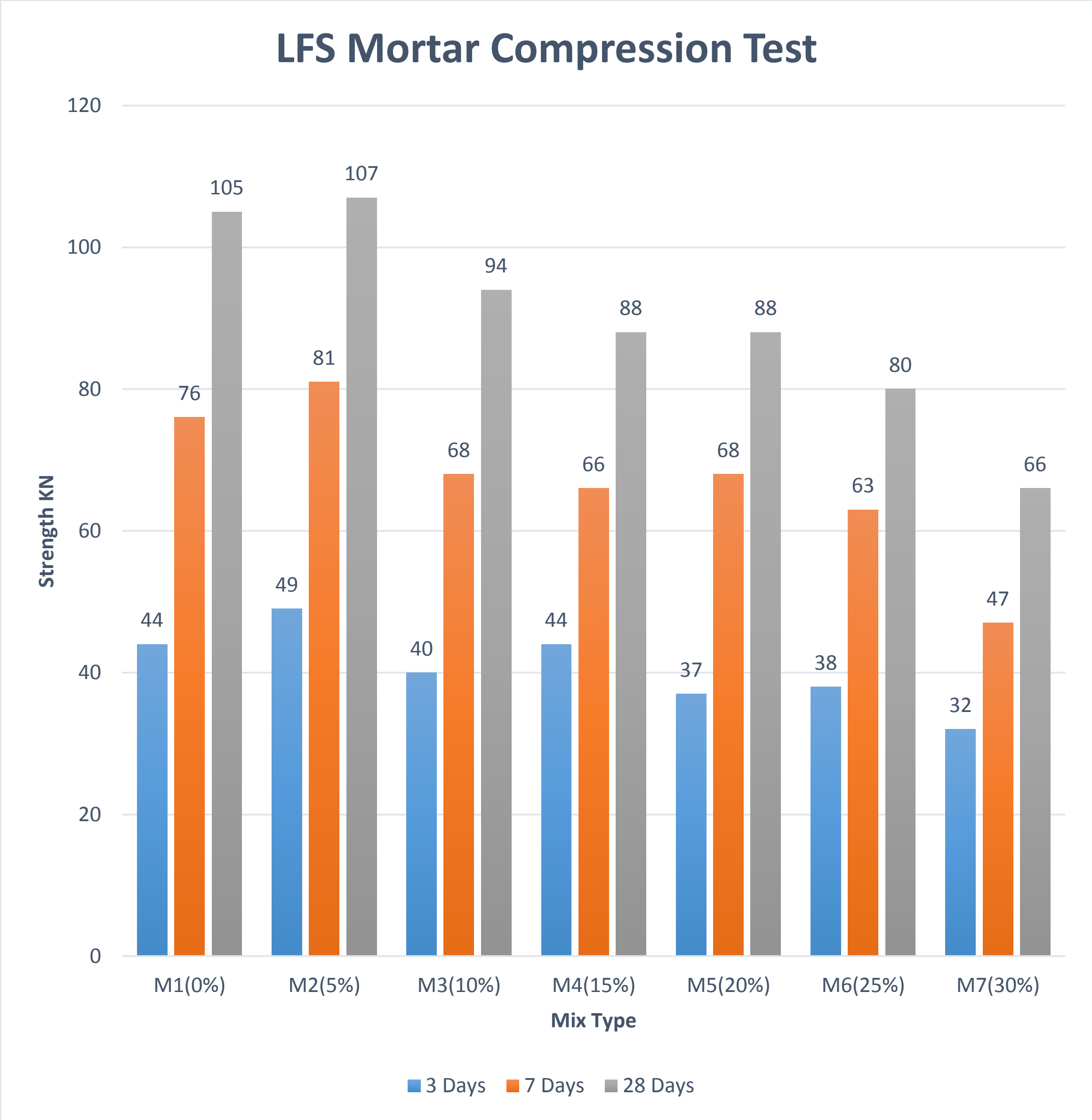

Chart 1: Different Compressive strength test between 3 Days, 7 Days and 28 Days of mortar

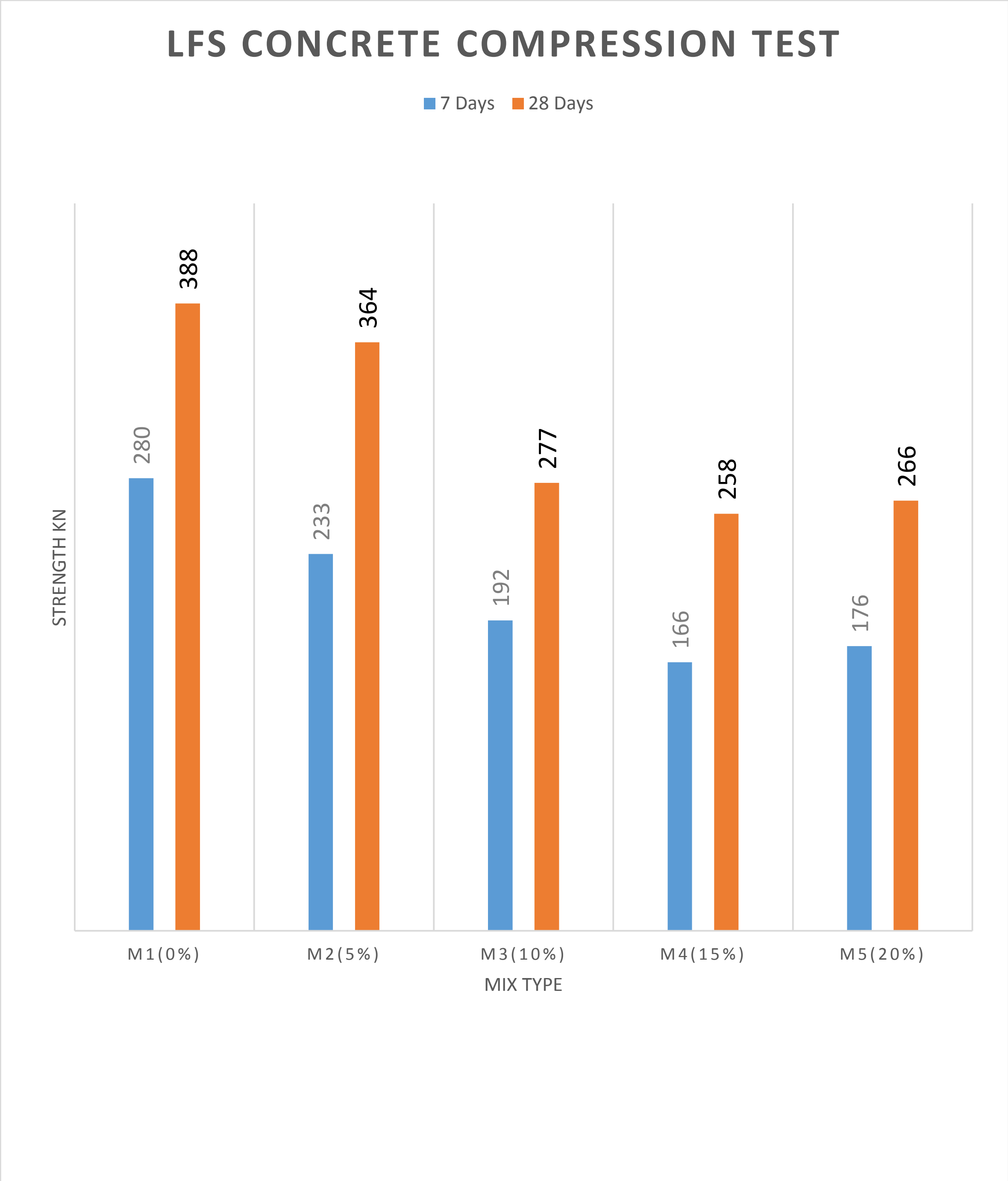

Chart 2: Different Compressive strength test between 7 Days and 28 Days of LFS Concrete

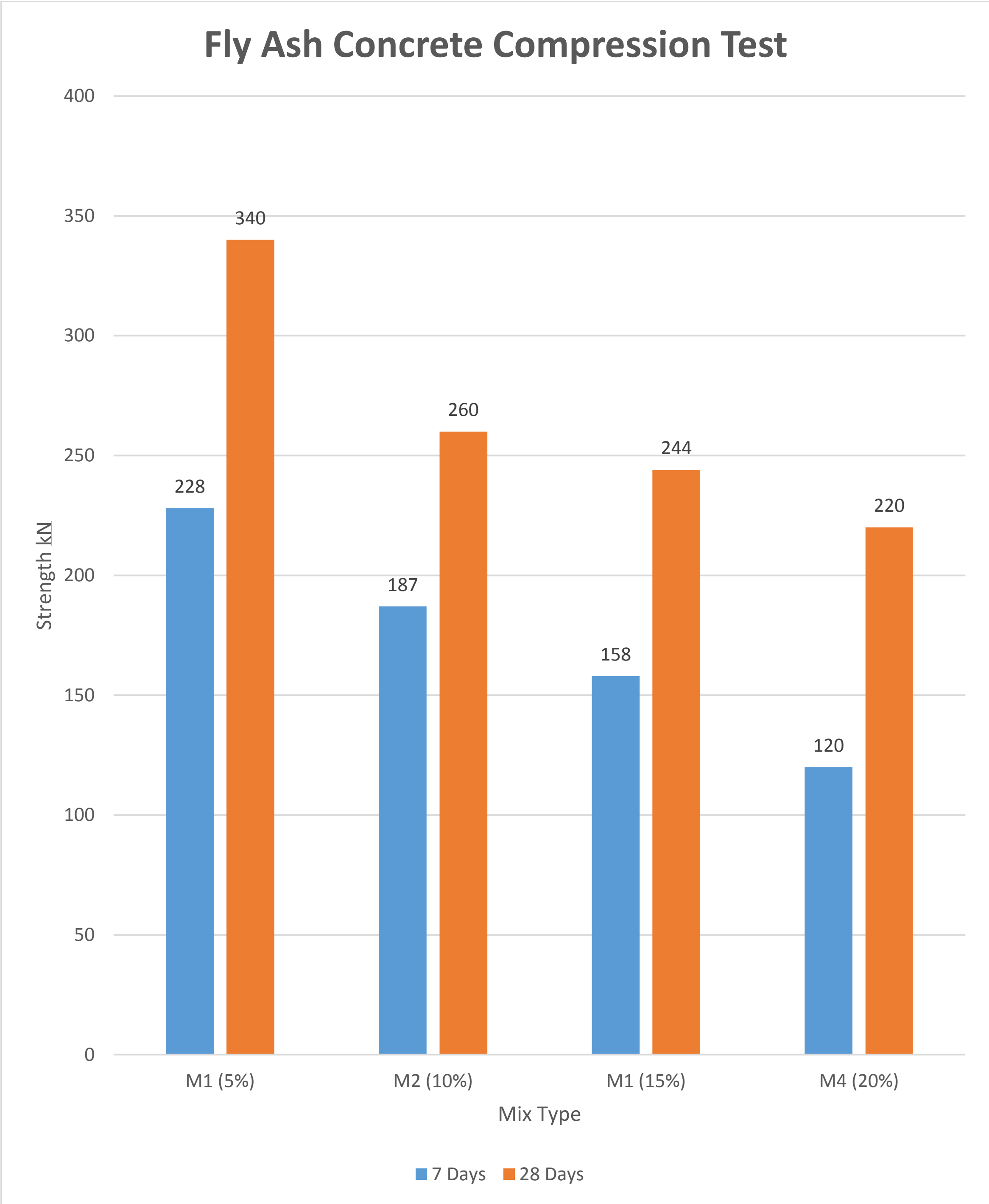

Chart 3: Different Compressive strength test between 7 Days and 28 Days of Fly Ash Concrete

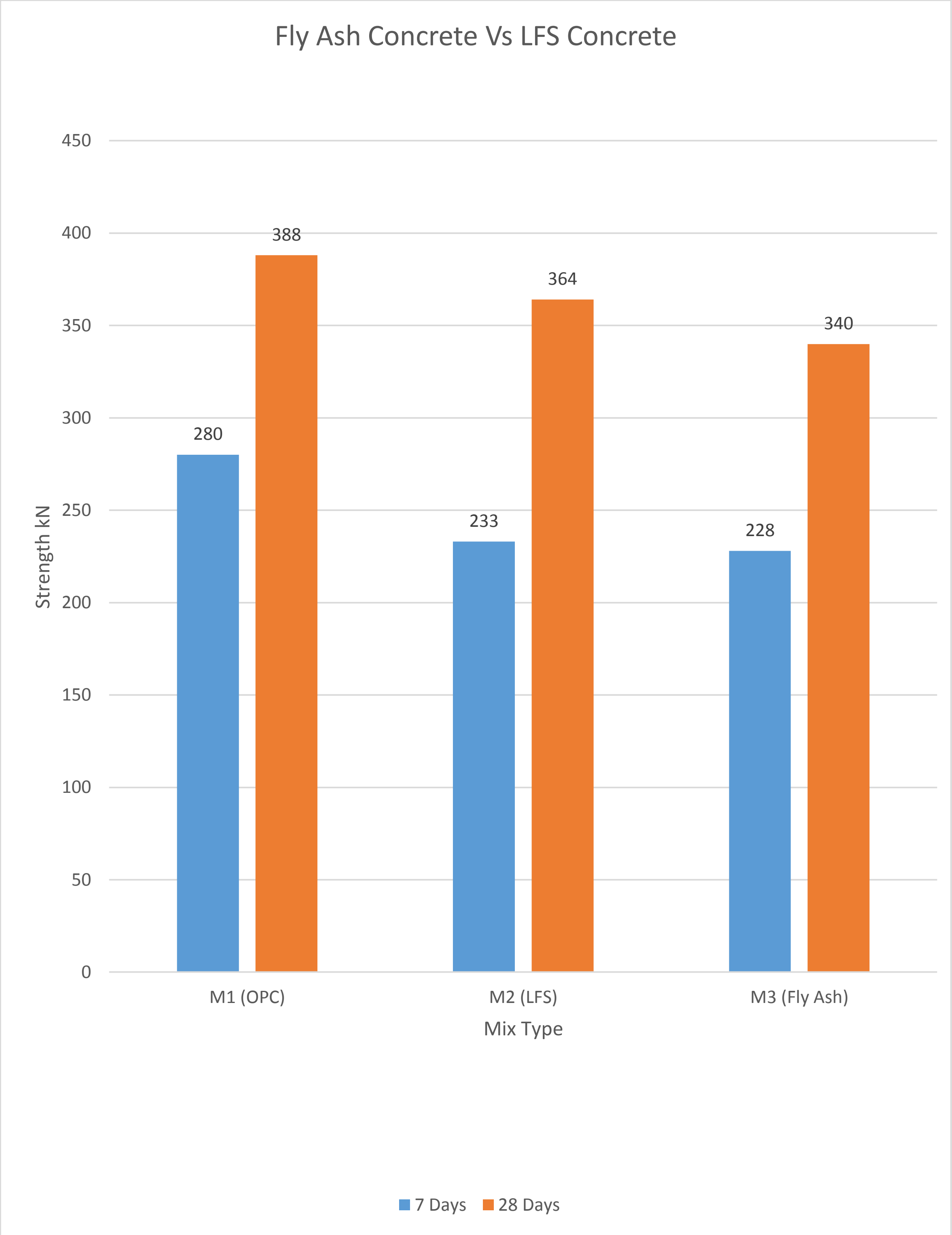

Chart 4: Comparison between Compressive strength between 7 Days and 28 Days of Fly Ash and LFS

Chart 1 shows the compressive strength test results of LFS mortar and it indicate that the optimum mix percentage is (5% of LFS) as a cement replacement material that increase with time until it exceeds normal OPC mix in 28 days. From chart 2 shows Compressive strength test between 7 Days and 28 Days of LFS Concrete that reveal 5% of LFS is the closest one to the normal OPC concrete in the compressive strength on the other hand the other percentages dramatically decrease the compressive strength if the percentage of the LFS increased. From Chart 3 Different Compressive strength test between 7 Days and 28 Days of Fly Ash Concrete that also indicate the optimum percentage of Fly Ash is 5 % then the strength drops. From Chart 4 it is a comparison between the two-optimum percentage of Fly Ash and LFS (5%) as a cement replacement material with the normal concrete (100% OPC) as a datum of compression that shows that the LFS have more compressive strength compared to the Fly Ash as better replacement material.

4.2 TENSILE STRENGTH TEST

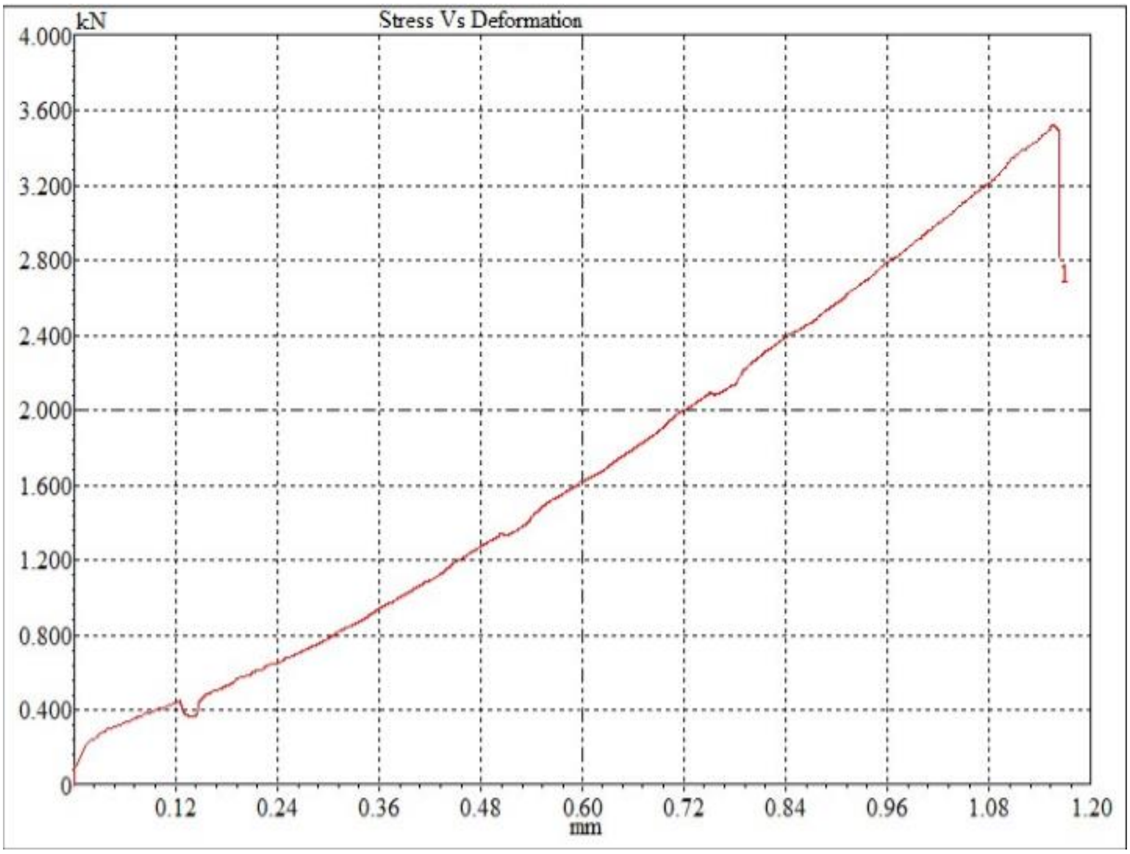

Chart 5: Tensile strength of 5% LFS specimen

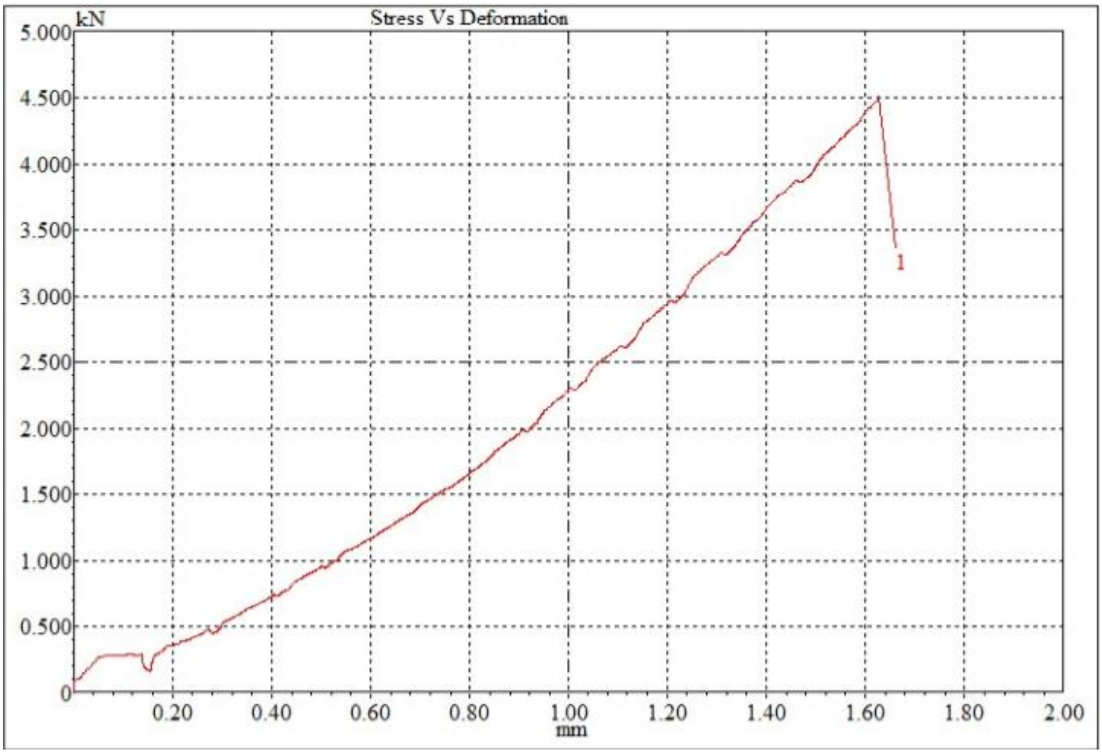

Chart 6: Tensile strength of 10% LFS specimen

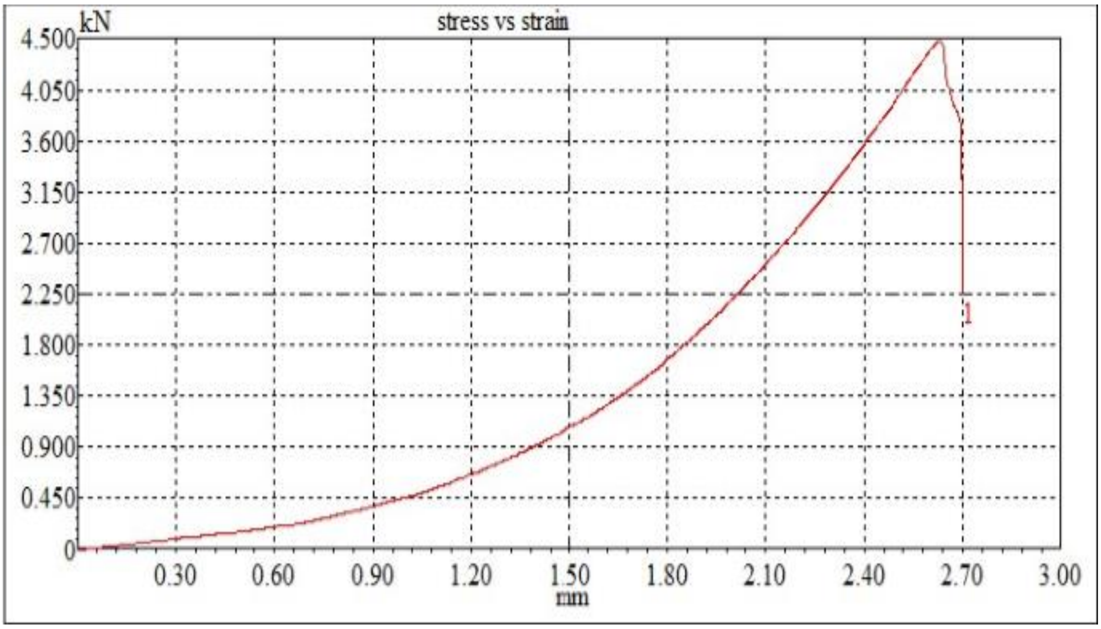

Chart 7: Tensile strength of 15% LFS specimen

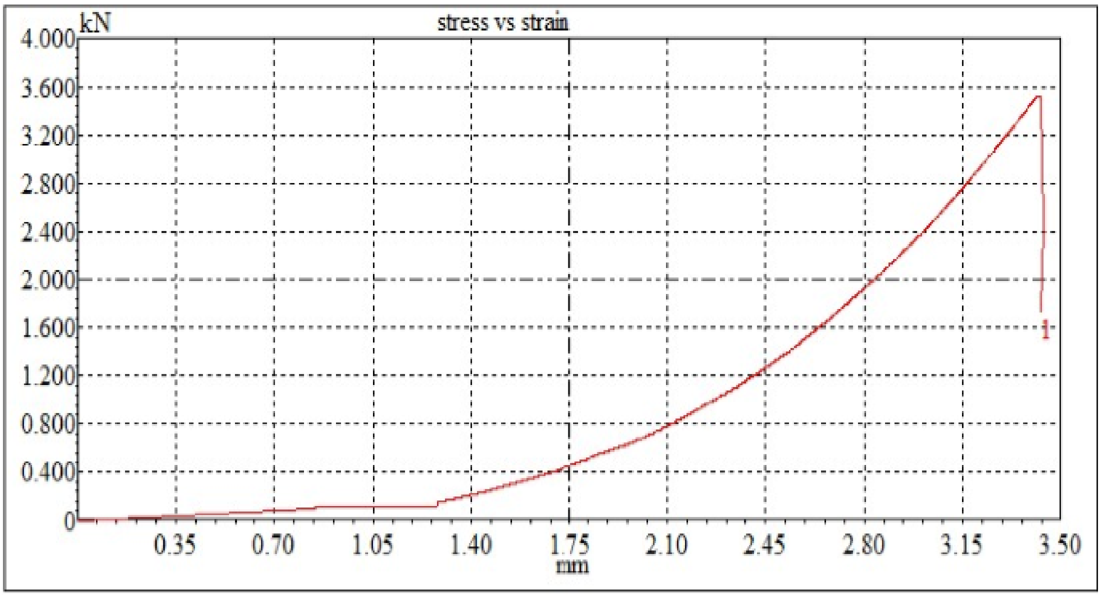

Chart 8: Tensile strength of 20% LFS specimen

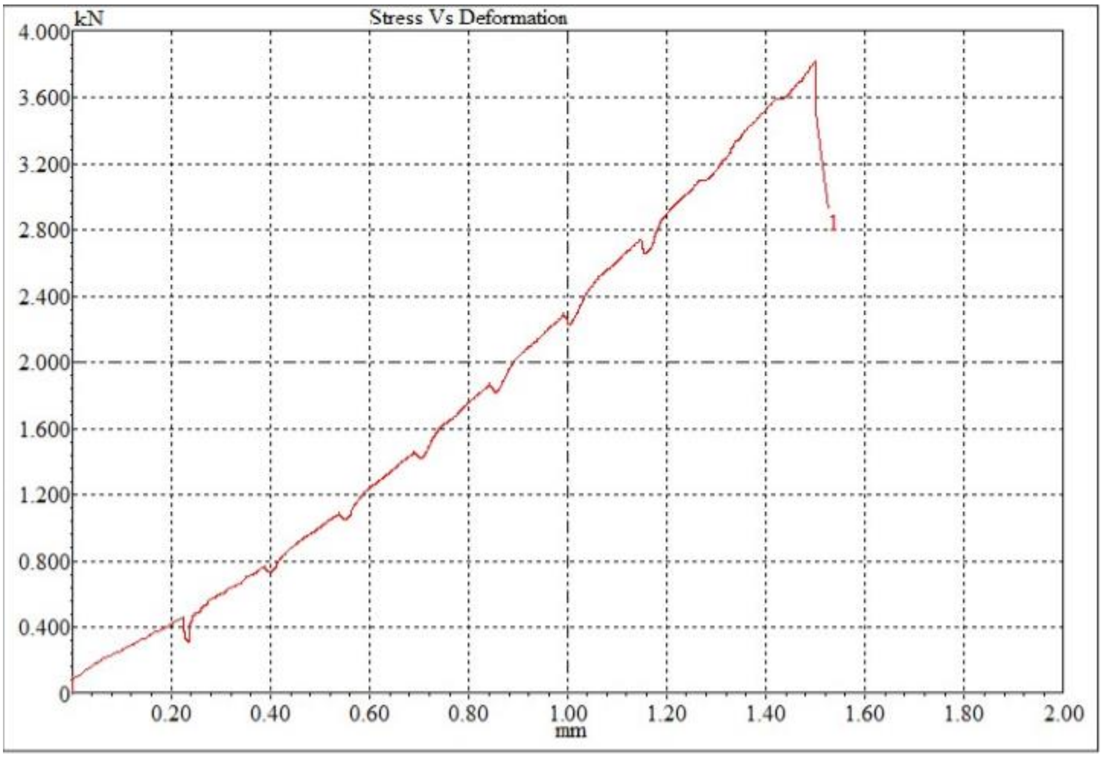

Chart 9: Tensile strength of control specimen

The previous charts shows the following results:

Specimen	Weight	Maximum Load kN
Control 100%OPC	2.20 Kg	3.820
5%LFS	2.22Kg	3.519
10%LFS	2.20Kg	4.512
15%LFS	2.26Kg	4.478
20%LFS	2.12Kg	3.525

Table 8: Tensile Strength

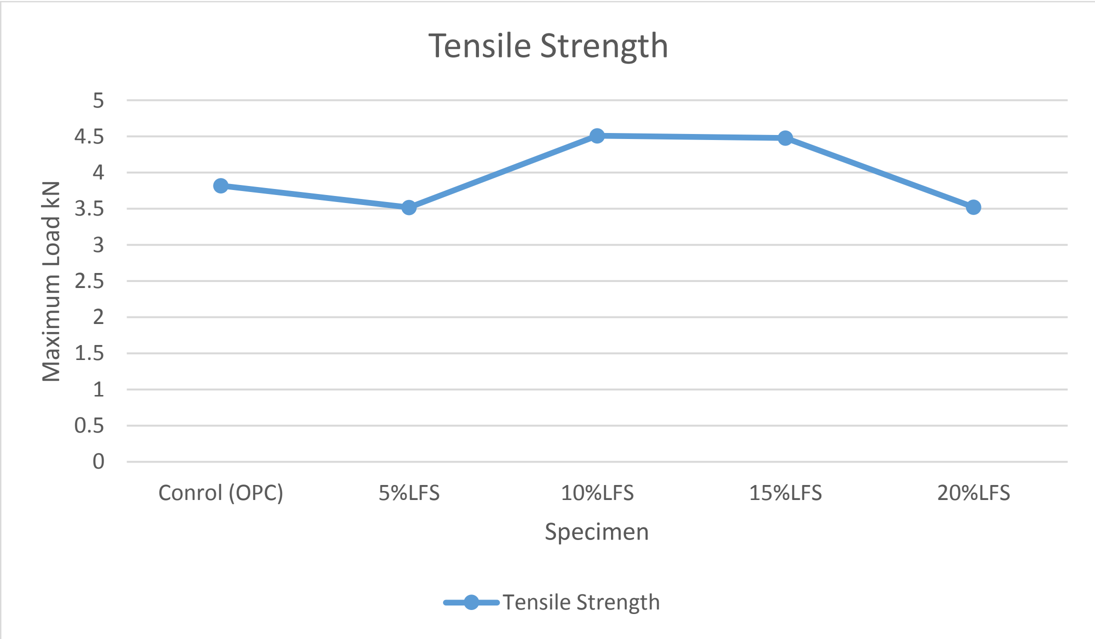

Chart 10: Tensile strength of specimen

As it shown in the graph the tensile strength increase dramatically when the percentage of the LFS increases until it reaches 15% then it starts to decrease even lower than the control specimen.

4.3 SLUMP TEST

Sample	LFS %	Slump cm
Control M1	**0**	**115**
M2	**5**	**118**
M3	**10**	**114**
M4	**15**	**116**
M5	**20**	**117**

Table 9: Slump Test

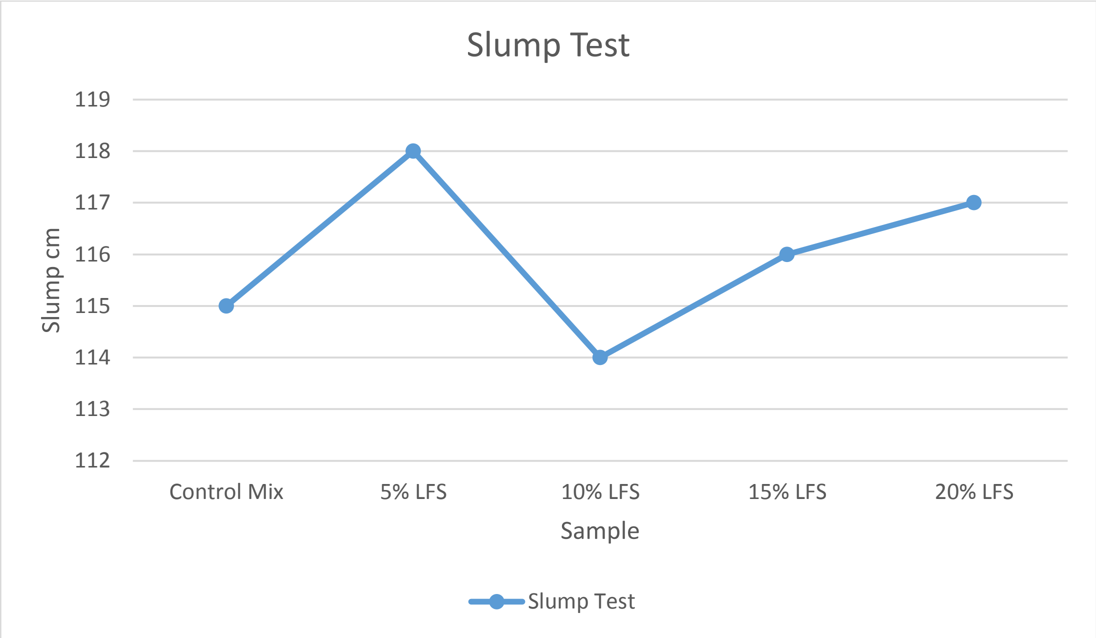

Chart 11: Slump test

From the Slump test values that shown in the chart the workability of the concrete does not get effected by the LFS as a cement replacement material as the slump change in the range of ±3cm from the control mix.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

This research is to create the optimum mix design of LFS based concrete using trial and error method that can assemble all the mixing proportions.by making sure that the LFS have the chemical composition required for the pozzolanic reactions (CaO,MgO,SiO2,Al2O3,FeO,MnO,CaF2) As it is shows the chemical components of the slag, at the present, most industrial slags are being used without taking full advantage of their properties or disposed rather than used ,But as cement replacement material there are some mechanical properties have to be tested as for this research paper those tests are : Compressive strength and Tensile strength .

From the compressive strength test the optimum mix proportion of LFS concrete is 5% as it is exceeding the strength of the normal concrete in 28 days mortal and for the concrete it closer to the normal concrete compared to the optimum Fly Ash mix proportions. As for the Tensile strength test the optimum mix is 10% of LFS as the strength is the highest.

5.2 Recommendation:

1- Furthered research tests must conduct to increase the strength as well as the percentage of the LFS as a cement replacement material.

2- Research further if the particle size of the LFS effect the properties of the concrete as the compressive strength or the tensile strength will be effected or not.

3- Compare the LFS concrete with other cement replacement material by taking the normal concrete as a datum of comparison to get accurate data as much as possible.

4- Conduct a 56 day of curing concrete process of LFS to get more accurate data.

CHAPTER 6

REFERENCES

1. G. Stolte, Secondary Metallurgy, Stahleisen GmbH, Düsseldorf, Germany, 2002.
2. J. Setién, D. Hernández, and J. J. González, "Characterization of ladle furnace basic slag for use as a construction material," Construction and Building Materials, vol. 23, no. 5, pp. 1788–1794, 2009.
3. I. Z. Yildirim and M. Prezzi, "Chemical, mineralogical, and morphological properties of steel slag,"Advances in Civil Engineering, vol. 2011, Article ID 463638, 13 pages, 2011.
4. J. Geiseler, "Use of steelworks slag in Europe," Waste Management, vol. 16, no. 1–3, pp. 59–63, 1996.
5. P. J. Koros, "Dusts, scale, slags, sludges. . .not wastes, but sources of profits," Metallurgical and Materials Transactions B, vol. 34, no. 6, pp. 769–779, 2003.
6. H. Yi, G. Xu, H. Cheng, J. Wang, Y. Wan, and H. Chen, "An overview of utilization of steel slag," Procedia Environmental Sciences, vol. 16, pp. 791–801, 2012.
7. R. Dippenaar, "Industrial uses of slag (the use and re-use of iron and steelmaking slags)," Ironmaking and Steelmaking, vol. 32, no. 1, pp. 35–46, 2005.
8. Anastasiou, E. K. (July 2014). Materials & Design. Behavior of self-compacting concrete containing ladle furnace slag and steel fiber reinforcement, 59, 454–460.
9. T. Sofilić, A. Mladenoviè, and U. Sofilić, "Defining of EAF steel slag application possibilities in asphalt mixture production," Journal of Environmental Engineering and Landscape Management, vol. 19, no. 2, pp. 148–157, 2011.

10. C. Shi, “Steel slag—its production, processing, characteristics, and cementitious properties,” Journal of Materials in Civil Engineering, vol. 16, no. 3, pp. 230–236, 2004.

11. V. A. Rovnushkin, E. A. Visloguzova, S. A. Spirin, E. V. Shekhovtsov, V. V. Kromm, and A. A. Metelkin, “Composition of ladle slag and refractory materials and its effect on the wear resistance of the lining of an RH vacuum degasser,” Refractories and Industrial Ceramics, vol. 46, no. 3, pp. 193–196, 2005.

12. D. Janke, L.S., H.J Weddige, E Schilz Scrap based steel production and recycling of steel. 2000.

13. Rodriguez, J. M. Manso, A. Aragon, J. J. Gonzalez, Resources, Conservation and recycling, 53 (2009), 645–651

14. F.M. Lea, the Chemistry of Cement and Concrete, 3rd ed., Chemical Publishing, New York, 1971.

15. J. M. Manso, A. Rodriguez, A. Aragon, J. J. Gonzalez, Construction and Building Materials, (2011), 3508–3519

16. ACI Committee 232. (1996). “Use of fly ash in concrete.” ACI 232.2R-96, American Concrete Institute, Farmington Hills, Mich.

17. Aitcin, P. C. (2000). “Cement and concrete development from an environmental perspective.” Concrete technology for a sustainable development in the 21st century, O. E. Gjorv and K. Sakai, eds., E & FN Spon, Lofoten, Norway, 206–217.

18. Arulrajah, A., Piratheepan, J., Disfani, M. M., and Bo, M. W. (2013b). “Resilient moduli response of recycled construction and demolition materials in pavement subbase applications.” J. Mater. Civ. Eng., 10.1061/(ASCE)MT.1943-5533.0000766, 1920–1928.

19. Serjun, V. Z., Mirti, B., and Mladenovi, A. (2013). “Evaluation of ladle slag as a potential material for building and civil engineering.” Mater. Technol., 47(5), 543–550.

20. Rahman, M. A., Arulrajah, A., Piratheepan, J., Bo, M. W., ASCE, M., and Imteaz, M. A. (2014). "Resilient modulus and permanent deformation responses of geogrid-reinforced construction and demolition materials." J. Mater. Civ. Eng., 10.1061/(ASCE)MT.1943-5533.0000824, 512–519.

21. Bergado D, Anderson L, Miura N, Balasubramaniam A. Soft ground improvement: in lawland and other environment. New York: American Society of Civil Engineers; 1996.

22. Anagnostopoulos, N., Sideres, K. K., and Georgiadis, A. (2009). "Mechanical characteristics of self-compacting concrete with filler materials, exposed to elevated temperatures." Mater. Struct., 42(10), 1393–1405.