UTILIZATION OF IRON SLAG, WASTE FOUNDRY SAND AND RICE HUSK ASH AS PARTIAL REPLACEMENT OF CEMENT AND FINE AGGREGATES IN PAVEMENT QUALITY CONCRETE

A Thesis submitted in partial fulfilment of the requirement
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CIVIL INFRASTRUCTURE ENGINEERING

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(A DEEMED TO BE UNIVERSITY)

PATIALA, PUNJAB

JUNE 2019

DECLARATION

I hereby declare that this work which is being presented in the thesis entitled "utilization of iron slag, waste foundry sand and rice husk ash as partial replacement of cement and fine aggregates in pavement quality concrete" in partial fulfilment of the requirement for the award of degree Master of Engineering in the field of civil engineering with specialization in Infrastructure Engineering submitted at Thapar Institute of Engineering and Technology (Patiala) is an authentic record of my own work carried out during the period from 27.7.2018 to 7.7.2019 under the guidance of Dr.Tanuj Chopra and Dr.Anush K Chandrappa.

The matter embodied in this thesis has not submitted by me for the award of any other degree or diploma.

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This is to certify that the above declaration made by the student concerned is correct according to the best of my knowledge and belief.

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ABSTRACT

The construction industry is one of the largest consumers of the natural resources. The main component in the construction industry being concrete consists of 75-85% of natural aggregates. The natural aggregates being non-renewable resource they may undergo extinction some day or even if exists, the form may not be used in the construction products. In order to reduce the consumption of natural aggregates, replacing them by materials possessing similar characteristics is one of the solutions. There are several industrial by-products, which possess characteristics similar / superior to natural aggregates. These industrial by-products can be used as partial replacement for natural aggregates in concrete, thus reducing the consumption of natural resources. Some of the most suitable industrial by-products include iron slag, waste foundry sand and rice husk ash. Rice husk ash (RHA) is a form of ash after burning the husk which is generated during rice milling process by rice milling industries. Further, iron and steel industries produce iron slag which is a by-product. In past studies usage iron slag shows good mechanical properties for concrete. The foundry industries produce large amount of sand by using it till the loss of all the properties for their industry this sand is a waste and generally known as waste foundry sand.

Pavement quality concrete (PQC) is a type of harsh concrete, which is mainly used in the construction of rigid pavements. With this increase in share of rigid pavements on Indian highways, the usage of concrete in the road construction has increased tremendously. As per IRC: 58, which is the guideline for design of rigid pavement, recommend 4.5 MPa flexural strength at 28 days for PQC. As above mentioned, industrial wastes can be a good replacement for natural aggregates in concrete, this study focused on replacing partially cement as rice husk ash and on the other hand sand is partially replaced by iron slag and waste foundry sand both in different proportions. The RHA is used as 10 %, 20 % and 30 % replacement by weight of cement. Further iron sag with 20 %, 40 % and 60 % replacement by weight of natural sand and WFS with 10 %, 20 % and 30 % replacement by weight of natural sand. The different proportions comprise to make different mixes using Taguchi method namely CM, M1, M2, M3, M4, M5, M6, M7, M8 and M9. These total of ten mixes have different mix design as per the IRC 44: 2017. Compressive strength test 7

days and 28 days and flexural strength test is done for 28 days of curing age. These tests done by casting 60 cubes (15 cm×15 cm×15 cm) and 30 beams (15 cm×15 cm×70 cm). These tests are done on M40 PQC concrete.

Results shows that mix M1 with (RHA-IS-WFS) as (10%-20%-10%) shows value that is ideal for M40 concrete but decreases as compared to control mix. The economic analysis shows results that the cost of Pavement Quality Concrete reduces by 4.23 % with the only optimum Mix-1. Also, according to the Minitab Analysis the optimum mix would be RHA 10%, IS 20% and WFS 20%.

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OBJECTIVE

Industrial wastes and its by-products are produced globally and these have either no cost or of very low cost. Also, these materials like RHA is a big threat to environment pollution if dumped openly. These materials required some proper dumping or proper usage. Secondly concrete is the second largest material used globally. If the concrete replacement of cement of fine aggregates gives the optimum strength than it can make an economical concrete as well as decrease in environment pollution.

The objective of this study is to provide a better usage to the industrial waste. Generally, the industrial wastes are dumped on the dumping sites openly of into river which ultimately convert into the environment pollution. Secondly these wastes are produced in globally and also are of no cost. Having strength using these wastes ultimately reduces the environment pollution and also the cost for concrete decreases as a result an economical process.

CHAPTER 1 INTRODUCTION

1.1. GENERAL

Concrete is a versatile construction material, adaptable to a wide variety of residential, pavement, agricultural and many other sectors. With proper techniques and materials, it can survive many acids, fertilizers, milk, silage, water, fire, abrasion and manure. Concrete, especially concrete with Portland cement, have the durability qualities, economy, strength and flexibility, and can also be moulded or be placed to almost any of the shape also and can reproduce any surface.

It is the construction material which is largely used in the world, second to water. Pavement is the basic need for any country to travel from one place to another. Connectivity of the different places with adequate road system effects the development of the country. Over to past few years PQC had become favourite type for the designers as it provides longer life to the pavement.

Large scale construction of Bridges & Highways is in process in India and all over the world. They are mainly made by using Pavement Quality Concrete (PQC) as rigid pavements. In the last few years, the production of various residues from different industries has been increased affectively. Most of these waste residues are dumped on the land fill sites with no proper dumping or treatment, which ultimately harms the environment. With no such proper dumping or any reuse facility, researchers are trying to find the proper reuse of these waste materials since past few decades.

1.2. PAVEMENTSTYPES

1.2.1. Flexible Pavement

Flexible pavements can be defined as the mixture of bituminous or bituminous materials and aggregates placed in a bed of compacted granular materials of adequate quality in different layers above the substrate. Macadam roads with stabilized ground with or without asphalt roofing are examples of flexible pavements, a flexible pavement is usually composed of several layers with low quality material in the lower or lower part and the upper layer is made of better quality material due to the development of tensions in the upper part during traffic loads.

Flexible pavements are analysed as a multilayer consisting of surface course, the fundamental courses and the subsoil. Each of these different layers has contribution to structural and drainage support to the pavement.

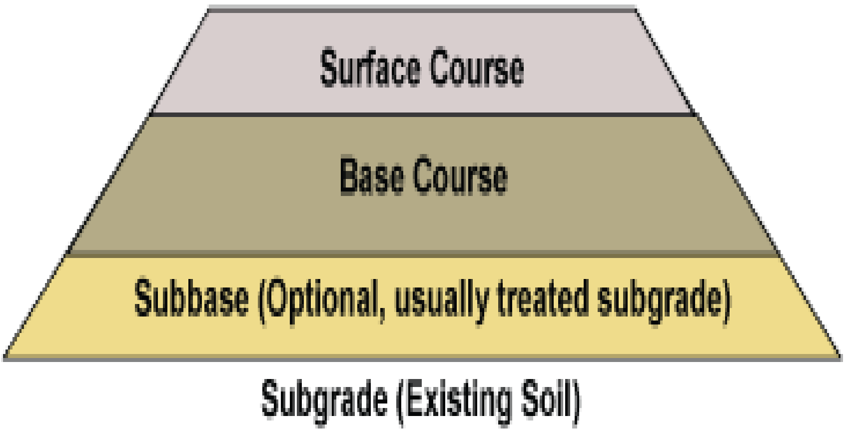


Figure 1-1Flexible Pavement Typical section

1.2.2. Rigid Pavement

Rigid pavements have very low deflections under load due to the high modulus of elasticity of the PCC material. Rigid pavements are those that contain a resistance of the radius sufficient to overcome the localized defects of the background and inadequate support areas. In hard pavements the stresses are reduced and these reduced stresses are distributed evenly under the slab area.

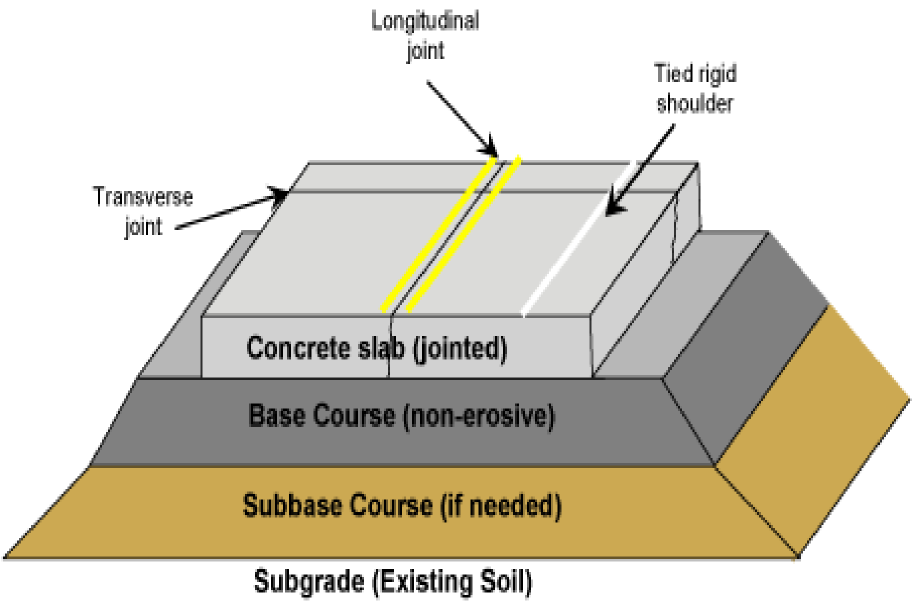


Figure 1-2Rigid Pavement cross-section

1.3 COMPONENTS OF CONCRETE PAVEMENT

The main components of pavement of concrete are discussed as below:

a) Sub-grade
b) drainage layer
c) capping layer

1.3.1 Sub-grade

Formally sub-grade is not a pavement layer. In order to construct and design a suitable pavement over it, its function and properties must be fully understand by the designer. Sub-grade is the normal soil (natural soil) or made-up ground on which the pavement is built. The load of the whole pavement finally transfers to the sub-grade.

The sub-grade and sub-base for lying of paving concrete slab shall comply with the following requirements given in (IRC: 15-1991)

a) In the sub-grade or sub-base there should be no presence of soft spots.

b) Sub-grade should be properly drained.

c) The uniformly compacted sub-grade or sub-base extends at least 300 mm on either of width to be connected.

d) The maximum modulus of sub-grade reaction obtained with a plate bearing test shall be 5.5 kg/cm^3.

1.3.2 Drainage layer

Drainage layer is a sand or graded gravel layer. It is a layer on a subtext for better drainage of the floor. Drainage in geographic composite has advantages with respect to natural drainage maintaining its compressive rigidity and flow capacity in services and construction, in addition to irregular support. The drainage layer of geo-composite material is provided on a substrate layer to improve the drainage of the pavement.

1.3.3 Capping layer

To improve sub-grade loading capacity capping layer is provided over it and also it prevents the deterioration of sub-grade. In some cases, lime or cement are also used in upper portion of the sub-grade so as to increase its bearing and strength capacity.

Cheaper and lower quality of material which is easily locally available is used in the construction of capping layer.

1.3.4 Dry lean concrete (DLC)

DLC is a vital part of rigid pavement and that of modern era. It has a large ratio for aggregate to cement and is a plain concrete as compare to normal concrete. It is usually use as a sub-base of pavement of concrete, also some IRC specifications of Dry Lean Concrete are discussed as below (MORTH section 600):

- Dry lean concrete is a concrete with low workability and compacted by roller.
- Dry lean concrete is defined as a lean concrete with low w/c ratio. It is also commonly known as roller compact concrete layer. It should be laid in such a manner that it should be able to support a roller while being compacted.

1.4COMPOSITION OF RIGID PAVEMENT

In general, the primary structural element used for rigid pavement is Portland cement concrete. Depending upon the loading conditions and soil strength, reinforcement is provided in the slab and also the concrete slab lies on a treated or compacted granular sub-base, this sub-base is supported by a compacted sub-grade.

The strength to rigid pavement mostly depending upon its concrete slab, that is why, it should be laid properly with no errors and making it a strongest layer while other layers should be constructed using low cost material making the pavement economical.

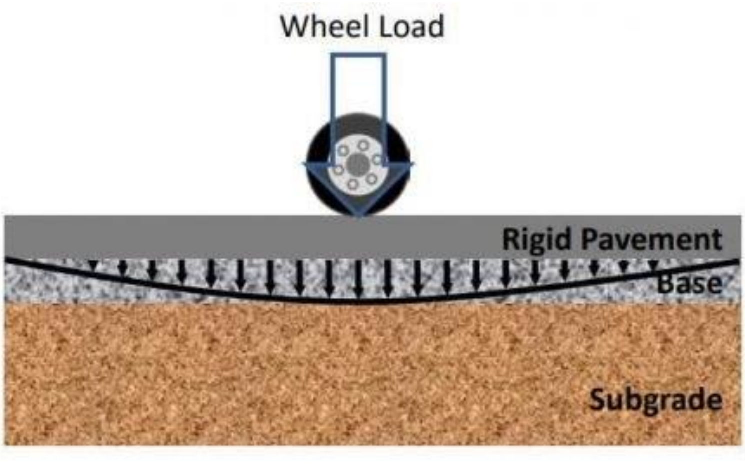


Figure 1-3Transfer of Load of wheel to Rigid Pavement in Subgrade.

1.5.1 Rigid Pavement Structure

Following are the layers of rigid pavement

1. Surface course
2. Stabilized Granular base
3. Stabilized Granular sub-base
4. Frost protection layer
5. Sub-grade soil

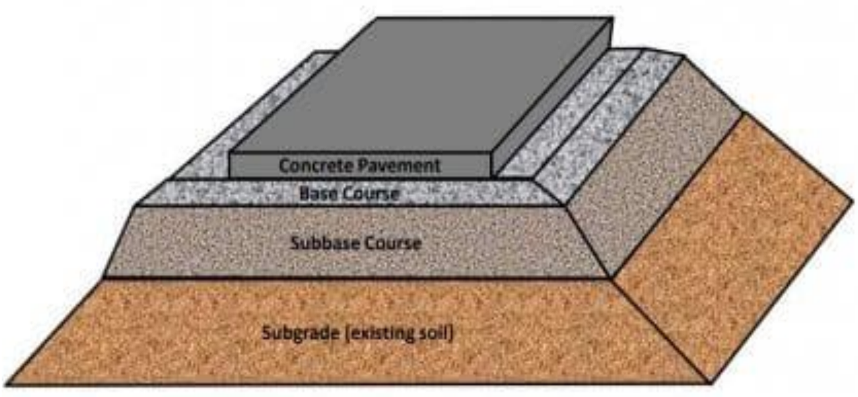


Figure 1-4Typical Rigid Pavement Structure

Concrete slab

The top most deposit to rigid pavement which in direct contact to traffic loads is known as concrete slab. Surface course is another name for concrete slab. To give skid resistance it offers friction to the vehicles. Concrete slab also prevents water infiltration into the base course and acts like a water resistant. General thickness provided to concrete slab is between 150mm to 300mm.

Figure 1-5Concrete Slab Laying

Granular base

Second layer from the top is base course or stabilized base or granular base is generally constructed using crushed aggregates. This layer provides a stabilized stage to construct rigid pavement and also it supports additional loads to the surface course. It helps in control the swelling of sub-grade soil and also to provide sub surface drainage system which is very useful. In frost areas, this layer also controls the frost action.

Figure 1-6Providing base course

Stabilized Granular sub-base

Granular sub-base is the third layer from the top and is sandwiched between base course and sub-grade, generally when traffic loading is light this layer is not required. Primary function of this layer is to provide support to the top layers and also acts as a controller in frost action. It also prevents the entry or intrusion of the fines from sub-grade to top layers. Also, the drainage efficiency improves when the sub-base course is provided.

Figure 1-7 Laying of sub-base course.

Frost protection layer

Frost action on the pavements is the biggest problem in the low temperature regions. Where ground water table is high, the water generally freezes during the low temperature and formation of frost heave under the sub-grade will results in pavement to rise. Similarly, during the high or normal temperature, ice tends to melts and the pavement penetrates into the sub-grade whenever the load comes on it.

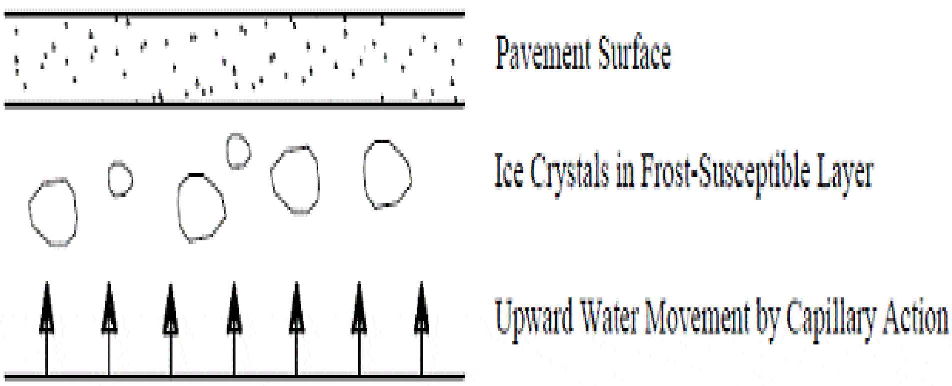


Figure 1-8 Formation of ice crystals in frost-susceptible soil.

Sub-grade soil

The sub-grade layer is the existing soil layer which is compacted to provide support to the other layers of the rigid pavement. Stresses tends to reduce with depth due to which sub-grade have lower stresses as compared to top layers.

Figure 1-9 Preparing of sub-grade soil.

1.5 PAVEMENT QUALITY CONCRETE (PQC)

The IRC specifications of materials used for pavement quality concrete (PQC) are mentioned in (M.O.R.T&H. section 600).

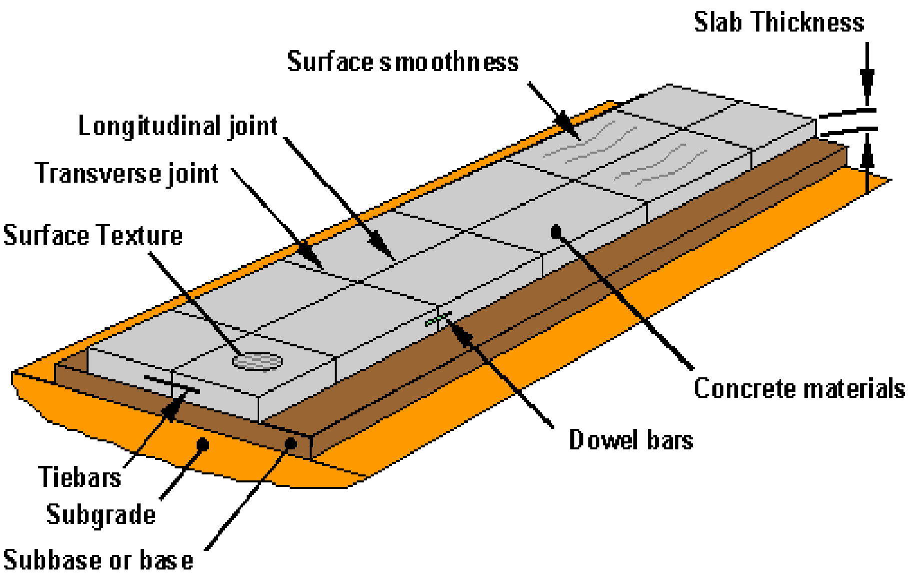


Figure 1-10 Typical section or Pavement Quality Concrete.

Cement

Technical specifications provided to M.O.R.T.H with section 601.2.1, OPC to43 grade confirming of IS: 8112.

1) Fly ash up to 20 percent by weight of cement may be used in ordinary Portland cement 53 Grade. No fly ash shall be used in any additional grade of cement other than 53 Grade. The fly ash shall conform to IS: 3812 (part I).

2) Following to IS: 12089by grinding granulated slag shall be use to obtain GGBFS. Limit the content of GGBFS to 50% by the mass of 53 grade of Ordinary Portland Cement. GGBFS shall not be used in any other grade of cement, except 53 Grade.

3) According to IS 44: 2017 mix design of PQC to be done. In of case of site mixing the content for OPC shall be atleast 310kg/m^3. The maximum percentage for the elongation as well as for to flakiness should be as 35%.

Table 1-1Type of cements

S. No.	Type	IS: Codes
1	OPC 43	IS:8112
2	OPC 53	IS:12269
3	PPC	IS:1489 (Part – 1)
4	Portland Slag cement	IS: 455

Coarse aggregates

The maximum size of coarse aggregate to concrete pavement be 31.5 mm. The aggregate with water absorption of more than 2 percent shall not be used in mix design of concrete and soundness test for aggregate can be done as per IS standards. If the solution of magnesium sulphate to be use than the loss shall not be above 18 % and for solution of sodium sulphate not more than be 12 % and all this after 5 cycles to testing. The maximum percentage for the elongation as well as for flakiness should be as 35 %.

Cement content

Atleast 360 kg/m^3 of Cement use when OPC being used. In case fly ash Grade-I (as per IS: 3812) is blended at site as part replacement of cement, the quantity of fly ash shall be up to 20 percent by weight of cement. Also, in such a mixture the quantity of OPC should not to be below 310 kg/m^3.

Fine aggregates

Crushed stone or natural sand or combination makes a fine aggregates which should conform as according to IS: 383 (Table 1-2) mica or particles which are soft in nature, even clay and shale and organic matters these kind of materials shall be taken care of not to be mixed in fine aggregates.

Table1-2 Percentage passing as per IS 383:2016

IS Sieve Designation	Passing Percentage			
	Zone of Grading I	Zone of Grading II	Zone of Grading III	Zone of Grading IV
10 mm	100	100	100	100
4.15 mm	90-100	90-100	90-100	95-100
2.36 mm	60-95	75-100	85-100	90-100
1.18 mm	30-70	55-90	75-100	90-100
600 micron	15-34	35-59	60-79	80-100
300 micron	5-20	8-30	12-40	15-50
150 micron	0-10	0-10	0-10	0-15

Table 1-3 Aggregate Gradation as per MORTH

Sieves Designation	Percentage by weight passing by sieve
31.5 mm	100
26.5 mm	90-95
19 mm	80-90
9.5 mm	55-75
4.75 mm	35-60
600 micron	10-35
75 micron	0-8

Concrete strength

The minimum of 4.5 MPa that is characteristic flexural strength of concrete of M40 Grade. Adding up, at 7 curing day's atleast 7.5 MPa should be the compressive strength of a single cube.

Separation Membrane

Water stopping or resistant membrane usually calls as separation membrane and this sheet has a thickness of 125 micron. Any irrespective material found shall be swept of the layer known to be DLC. Damaged sheet if any should change with immediate effect.

Joints

After initial set of 6 to 8 hours a depth to longitudinal or transverse direction, with 100 mm size shall be provided and 3 mm shall be provided first saw cut. After 14 curing days of concrete there shall be provision of 20 to 25 mm depth to joint sealent and final cutting of saw takes place with 10 to 12 mm wider. Atleast 0.3 m of staggering shall be provisioned to base of transverse joint.

Figure 1-11 Pavement showing Longitudinal and Transverse joint

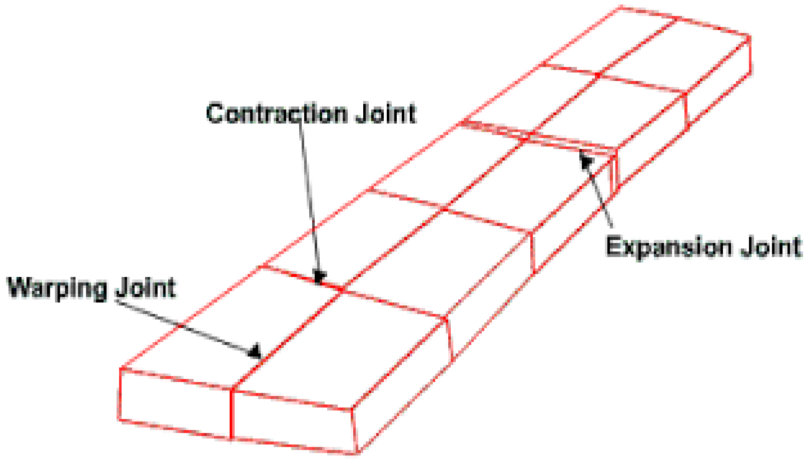


Figure 1-12 section showing pavement joints

Figure 1-13 Concrete Pavement showing joint

Dowel Bars

Dowel bars shall be checked for durability as well for toughness and it shall confirm to IS: 432, IS: 1786 and IS: 1139. The dowel bar helps to transfer the load efficiently between two concrete slabs. It also keeps the two slabs on equal height. These bars are provided in longitudinal direction of the road along the direction of traffic.

Figure 1-14 Arrangement of Dowel bars

Figure 1-15 Dowel bars

Tie Bars

Joints with tie bars in longitudinal direction should be of deformed steel with strength complying to IS: 1786.Oil, loose rust, dirt and scale to be taken care of to which tie bars be free from. Application of bituminous paint should be done to protect it from corrosion on every side of joint. It shall be 90 degrees of joint line.

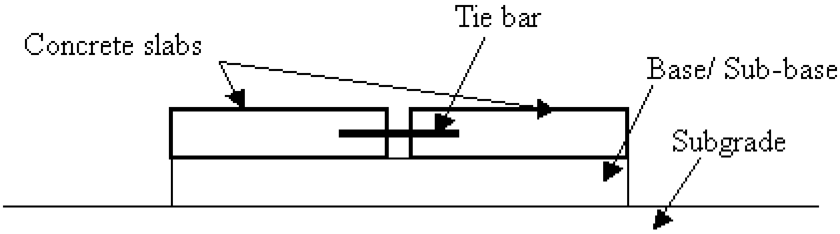


Figure 1-16 Section showing Tie Bar placement

Figure 1-17 Tie Bars in Pavement

1.6 RICE HUSK ASH

Husk is generated as of by-product by Rice milling industries. During this process 78 percentage of rice is generated, that also of different types of rice and the rest of the 22% generated is a by-product known to be Husk or as rice husk. Husk itself contains 75% of organic matter and when the husk is burnt its weight remains 25% of the husk as ash known as Rice Husk Ash. Generally, RHA is in grey black colour. This rice husk ash have been studied by many researchers in past which says that it can enhances the properties of concrete. Partially adding RHA to concrete increases its mechanical as well as durability properties.

Figure 1-18 Picture representing rice husk ash

As a by-product material it also decreases the cost of concrete and making it an economical construction method. RHA as a waste utilization decreases the environmental pollution and also the carbon dioxide emission.

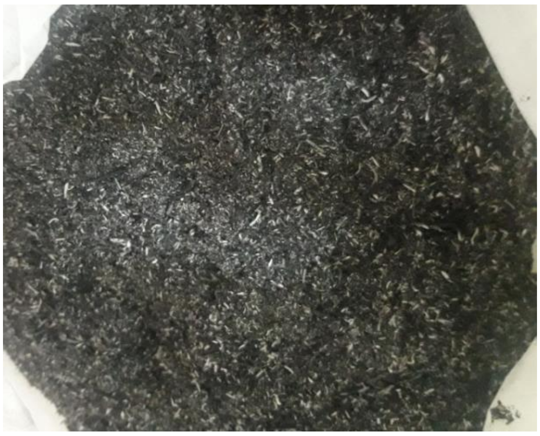


Figure 1-19 Actual picture of Rice Husk Ash used in study

1.7IRON SLAG

Iron and steel slag refer to the type of metal production slag that is generated during the manufacturing process of steel products. The term "slag" originally referring to the slag produced by metal manufacturing processes, however, is now also used to describe the slag that comes from molten waste material when waste and other substances are disposed of in an incineration plant. Iron Slag is generally in black colour. Recent studies states that usage of Iron Slag in concrete enhances its mechanical properties.

Figure 1-20 Iron Slag

Figure 1-21 Original picture of Iron Slag

1.8WASTE FOUNDRY SAND

Industries of Non-ferrous and ferrous metals generate a by- product to be named as to be waste sand foundry. It is one of those promising materials to which one can used as an alternative to the aggregates in concrete, as the presence of natural sand is coming to extinction stage in coming future. As sand to residual casting it been in recent studies to be evaluate its properties by adding to concrete as a replacement. This sand is threat to the environment if not dumped properly with proper treatment.

Studies shows, that WFS inclusion of increases to the concrete mechanical properties, due to the presence of finer particles in the WFS. These finer particles make the bond strong if used in proper proportion. As a waste material it also decreases the cost of concrete and making it an economical construction method.

Figure 1-22 Waste Foundry Sand

Figure 1-23 Original picture of Waste Foundry Sand

CHAPTER 2 LITERATURE REVIEW

2.1. GENERAL

Researchers have investigated various waste by-products of different industries as a partial replacement for concrete as well as for pavement quality concrete, whether it is a replacement for cement or for aggregates. In this chapter study is done on some literature of the past studies done on Rice Husk Ash, Iron Slag and Waste Foundry Sand.

2.2. RICE HUSK ASH

2.2.1 Properties of Fresh Concrete:

V. Sata et al. (2007) in research paper "**Influence of Pozzolan from various by-product materials on mechanical properties of high-strength concrete**" tries to replace cement with different materials for production of high strength concrete. Rice husk bark ash (RHBA), Ground coal pulverized combustion fly ash (FA), oil ground to palm fuel ash (POFA) and fluidized ground combustion fly ashbed (FB) were used as by-product materials to replace partially Portland type cement to type-1for the casting of high strength concrete. W/c ratio was kept constant as 0.28 and usage of different materials as cement replacement decreases the use of superplasticizer and therefore decreases cost of high-strength concrete.

Ganesan et al. (2008) in his paper **" Rice husk ash blended cement: assessment of optimum level of replacement for strength and permeability properties of concrete**" reported the affect of replacement cement to RHA for cement setting times and consistency. Cement was replaced to 0, 5, 10, 15, 20, 20, 25, 30, and 35 Percentages. Approximate 32%, consistency to be observed of conventional mix, however, increase to RHA also increase requirement of water for standard consistency that to linearly. The35% replacement to standard consistency of 44%.More water needed because of RHA area of specific surface due to its nature hygroscopic. The initial setting time increases to the level of 15% RHA. Whereas for 20, 25, 30 and 35% it decreases and for final setting time it increases upto 35% replacement.

H. Chao-Lung et al (2011) in their paper "**Effect of rice husk ash on the strength and durability characteristics of concrete**" tries to find out the properties of the concrete such as strength properties on durability by replacing cement with the RHA. Due to specific area and also due to higher level of carbon content of RHA the desired slump needs more water content as compared to CM.

C. Fapohunda et al. (2016) in research **"Structure and properties of mortar and concrete with rice husk ash as partial replacement of ordinary Portland cement – A review"** review of different past research on to the usage of RHA as a replacement to natural sand. The fresh property, consistency was concluded that with increase to RHA concrete, the amount of water required to achieve the consistency increased as compared to CM. Further, the workability of concrete to decrease as increase in RHA content. Researcher investigated the setting time of concrete but some of them which had done the research have shown increase of RHA increases the setting time whereas some shows decrease in setting time.

Ahsan et al. (2018) in research "**Supplemental use of rice husk ash (RHA) as a cementitious material in concrete industry**" an alternative to SCMRHA is used. This research deals in three different sizes of RHA (600 mm, 150 mm, and 44 mm) with the two of the different percentages (10% and 20%). Though, type-1 and type-2 both have a potential to use a controlled low strength material. RHA-2 and RHA-3 to show the values of slump of fresh concrete as less than75 mm. Finer RHA content shows stiffness and also the workability was low.

2.2.2 Properties of Hardened Concrete:

V. Sata et al. (2007) in research paper **"Influence of Pozzolan from various by-product materials on mechanical properties of high-strength concrete"** tries to replace cement with different materials for production of high strength concrete. Rice husk bark ash (RHBA), Ground coal pulverized combustion fly ash (FA), oil ground to palm fuel ash (POFA) and fluidized ground combustion fly ash bed (FB) were used as by-product materials to replace partially Portland type cement to type-1for the casting of high strength concrete. Results shows, that after the 7 days of curing concrete with 10-40% of FA and 10-30% of RHBA or POFA to have higher strength that control mix. Concrete with FA, FB, RHBA and POFA with pozzolanic materials can be used in casting high strength concrete having 28-day strength higher to than 80 MPa.

H. Chao-Lung et al (2011) in their paper "**Effect of rice husk ash on the strength and durability characteristics of concrete**" tries to find out the properties of the concrete such as strength properties on durability by replacing cement with the RHA. The concrete compressive strength with 20% replacement shows the same properties as of CM. Also after 91 days electrical resistance and UPV increases with increase in RHA.

C. Fapohunda et al. (2016) in research **"Structure and properties of mortar and concrete with rice husk ash as partial replacement of ordinary Portland cement – A review"** review of different past research on to the usage of RHA as a replacement to natural sand. Researcher concluded that concrete compressive strength with RHA as replacement depends upon the water/cement ratio. With atleast 10%replacement they concluded that the strength to increases as compared to CM.

Ahsan et al. (2018) in research "**Supplemental use of rice husk ash (RHA) as a cementitious material in concrete industry**" an alternative to SCMRHA is used. This research deals in three different sizes of RHA (600 mm, 150 mm, and 44 mm) with the two of the different percentages (10% and 20%). Though, type-1 and type-2 both have a potential to use a controlled low strength material. Finer of RHA (RHA-3) to showed the properties of improved strength as comparable to that of the Control sample. RHA-3 can be use as SCMs in preparing the durable type concrete which may perform well.

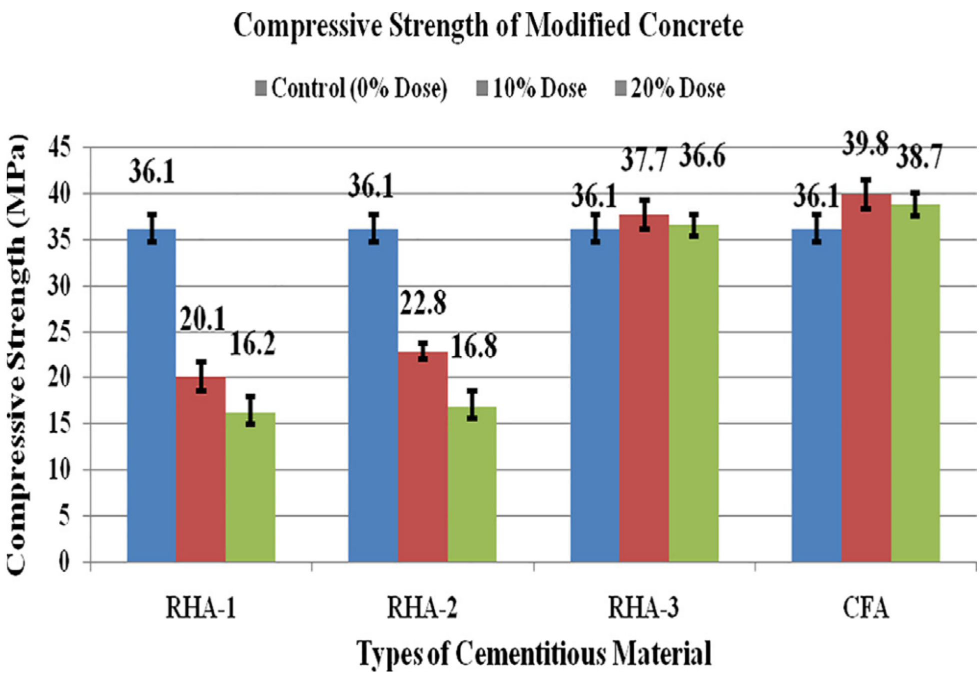


Figure 2-1 compressive strength due to Effect of RHA

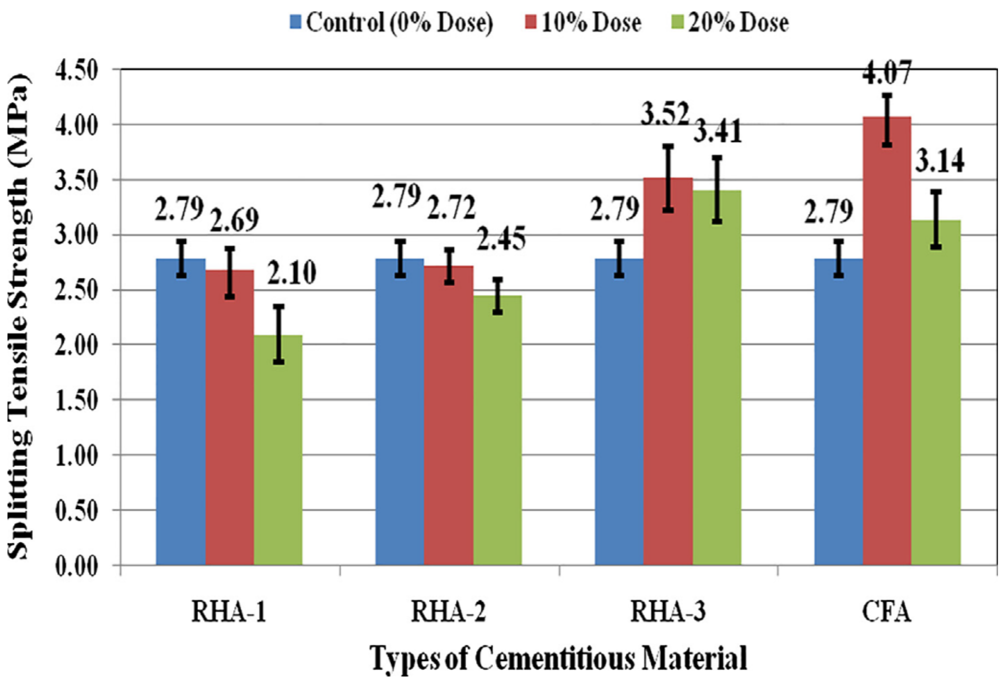


Figure 2-2 splittensile strength due to Effect of RHA

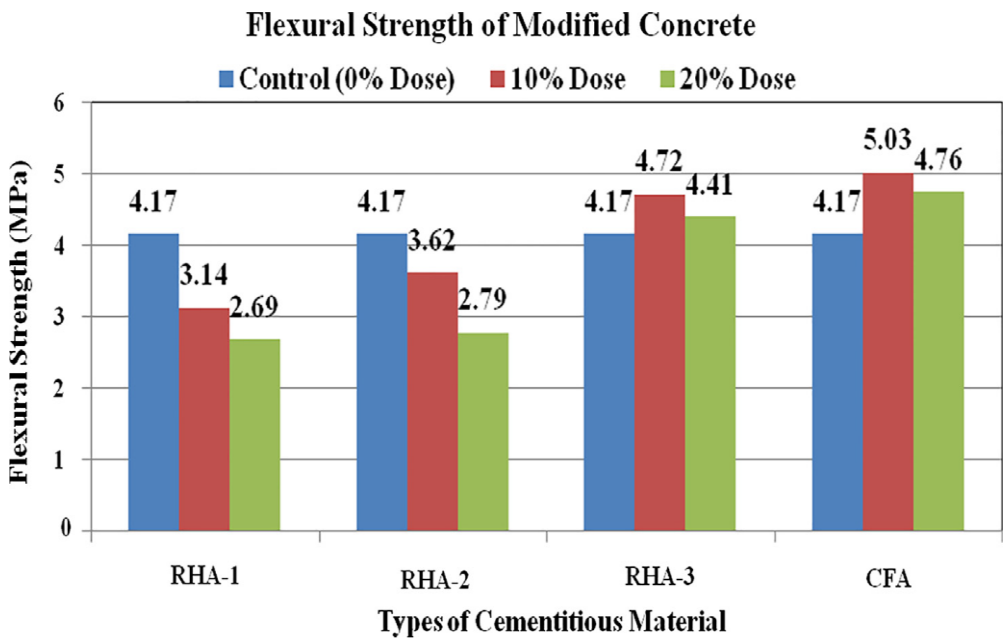


Figure 2-3 flexural strength due to Effect of RHA

2.3 IRON SLAG

2.3.1 Properties of Fresh Concrete:

Raza et al. (2014) in research "**Strength Analysis of Concrete by Using Iron Slag as a Partial Replacement of Normal Aggregate (Coarse) in Concrete**" replaces the coarse aggregate with different proportions of iron slag by 0, 10, 20, 30, 40 and 50%. The ratio of water cement for M-40 concrete was kept 0.45. Workability of concrete increases from 30 to 50% replacement, further it decreases by 8% at 100% replacement. Due to the availability of finer particles in higher grade M-40 workability increases.

Quadir et al. (2018) in research **"Flexural Strength of Concrete by Partial Replacement of Sand with Basic Oxygen Furnace Slag"** partially replaced sand with basic oxygen furnace slag. Sand was replaced with different proportions with 0%, 15%, 25%, and 35% of BOFS. There were four mixes namely A Mix, B Mix, C Mix and D Mix. Slump test and density tests were performed. Results show that the addition of BOFS increases slump. Slump value increased to 72 mm at replacement of 35% of BOFS as compared to CM where slump value was 58mm.

Table 2-1 For different mixes different slump values

Mix	% Fine Aggregates Replacement	Slump (mm)
A- Mix	0	58
B - Mix	15	63
C - Mix	25	68
D - Mix	35	72

2.3.2 Properties of Hardened Concrete:

Raza et al. (2014) in research "**Strength Analysis of Concrete by Using Iron Slag as a Partial Replacement of Normal Aggregate (Coarse) in Concrete**" replaces the coarse aggregate with different proportions of iron slag by 0, 10, 20, 30, 40 and 50%. The ratio of water cement for M-40 concrete was kept 0.45.The concrete compressive strength increases by 30% replacement to iron slag as compared to CM. Further, flexural strength increases to 20% of replacement of iron slag. The maximum of flexural strength at 28 days is7.63 MPa at 20% replacement.

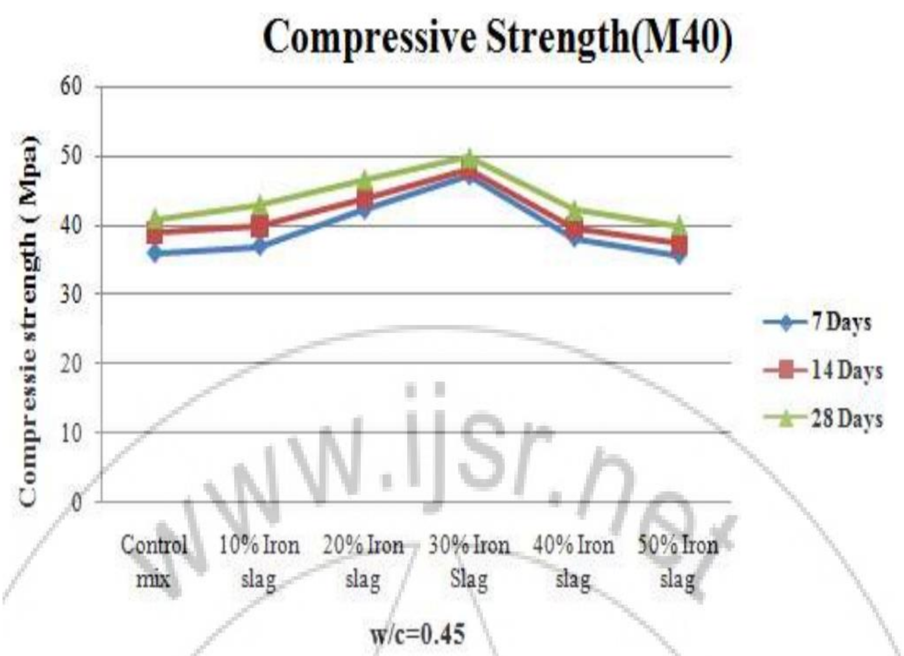


Figure 2-4 For different iron slag proportions at different ages compressive strength

Table 2-2 Flexural strength for different ages (Raza. 2014).

Sr.No.	Iron Slag%	Flexural Strength (MPa) at 7 days	Flexural Strength (MPa) at 14 days	Flexural Strength (MPa) at 28 days
1	0%	5.18	5.63	6.37
2	10%	5.54	5.85	6.94
3	20%	5.94	6.74	7.63
4	30%	5.03	5.48	5.63
5	40%	4.96	5.18	5.04
6	50%	4.05	4.74	4.40

Table 2-3 Different ages compressive strength (Raza. 2014)

Sr. No.	*% of slag*	*Compressive strength in (N/mm^2) at 7 Days*	*Compressive strength in (N/mm^2) at 14 Days*	*Compressive strength in (N/mm^2) at 28 Days*
1	0%	36	39	41
2	10%	37	40	43
3	20%	42.22	44	46.63
4	30%	47.13	48.22	49.76
5	40%	38.22	39.73	42.22
6	50%	35.75	37.43	40

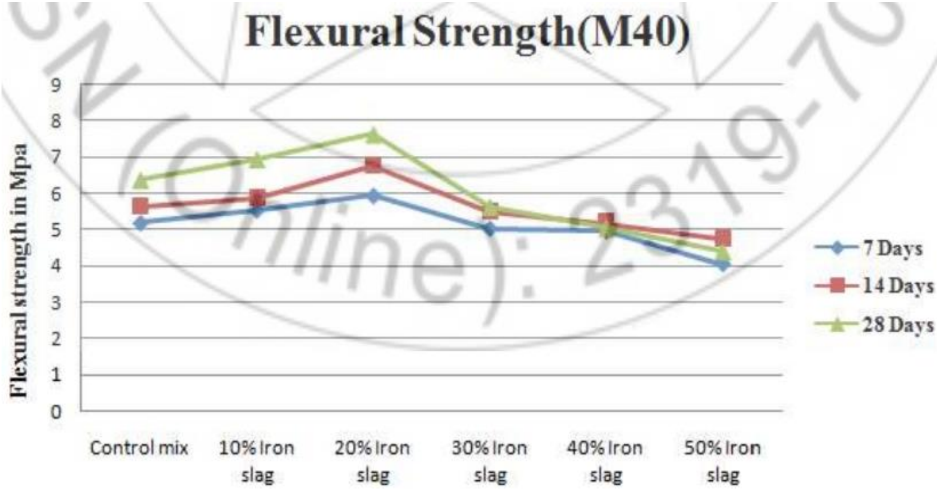


Figure 2-5 flexural strength to for different ages (Raza. 2014)

Quadir et al. (2018) in research **"Flexural Strength of Concrete by Partial Replacement of Sand with Basic Oxygen Furnace Slag"** partially replaced sand with basic oxygen furnace slag. Sand was replaced with different proportions with 0%, 15%, 25%, and 35% of BOFS. There were four mixes namely A Mix, B Mix, C Mix and D Mix. Density increases with the increase of BOFS. The average weight of Mix-A i.e. control Mix is 8.15 kg and it increases with the increase of BOFS to 8.858 kg in mix-D.

Also results show that Flexural strength increases with the increase in BOFS but till 25% replacement after that in 35 % replacement it decreases. After 7 days at 15% and 25% replacement flexural strength increased by 17.67% and 28.37% respectively, whereas after 28 days strength increased by 17.26% and 23.31% respectively.

Table 2-4 density of concrete for different mixes (Quadir. 2018)

Mix	Age of Cubes (days)	% Replacement of Fine Aggregates	Average Weight (kg)	Volume of Cubes (m^3)	Mass Density of Concrete (kg/m^3)
A Mix	28	0%	7.84	0.3375	2323.00
B Mix	28	15%	8.21	0.3375	2432.60
C Mix	28	25%	8.42	0.3375	2497.20
D Mix	28	35%	8.85	0.3375	2624.59

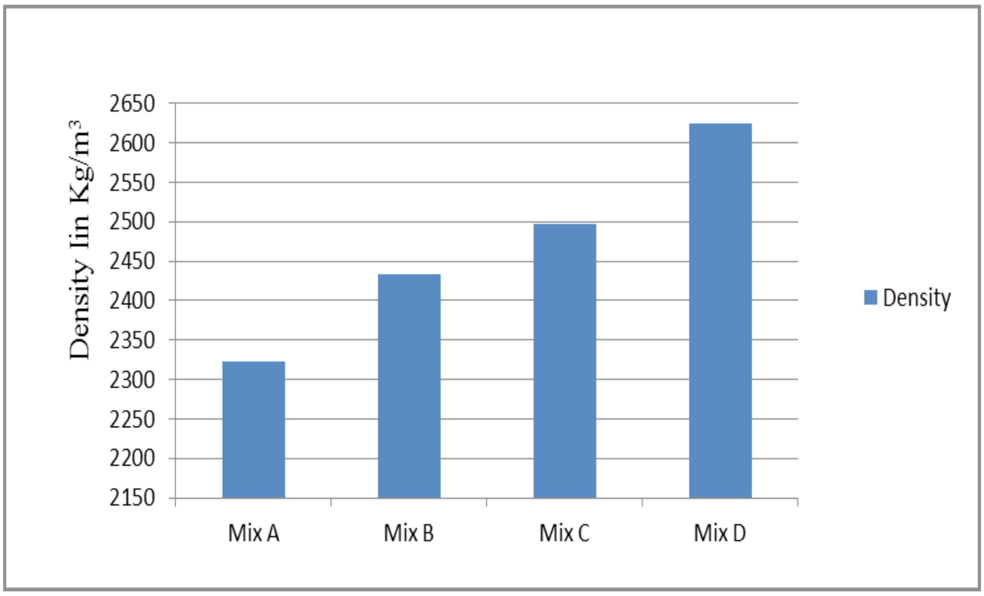


Figure 2-6 Density of concrete for different mixes (Quadir. 2018)

Table 2-5For different mixes concrete flexural strength (Quadir. 2018)

MIX	Basic Oxygen Furnace Slag			
	Flexural strength (kg/cm²)		Average flexural strength (kg/cm²)	
	7 Days	28 Days	7 Days	28 Days
A	58.30	70.23	54.94	65.57
	56.37	65.54		
	50.15	60.96		
B	64.42	77.78	64.65	76.89
	68.60	76.25		
	60.95	76.66		
C	70.13	80.42	70.53	80.86
	70.54	80.83		
	70.94	81.34		
D	54.23	57.28	53.20	54.80
	54.12	56.27		
	51.27	50.86		

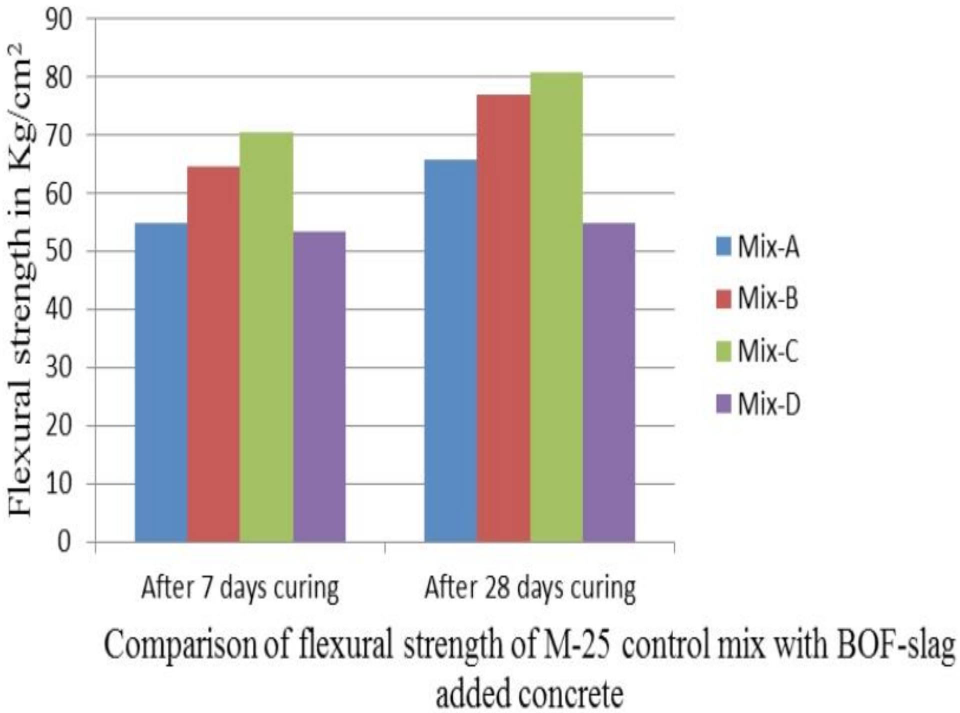


Figure 2-7For different mixes at different ages concrete Flexural strength (Quadir. 2018)

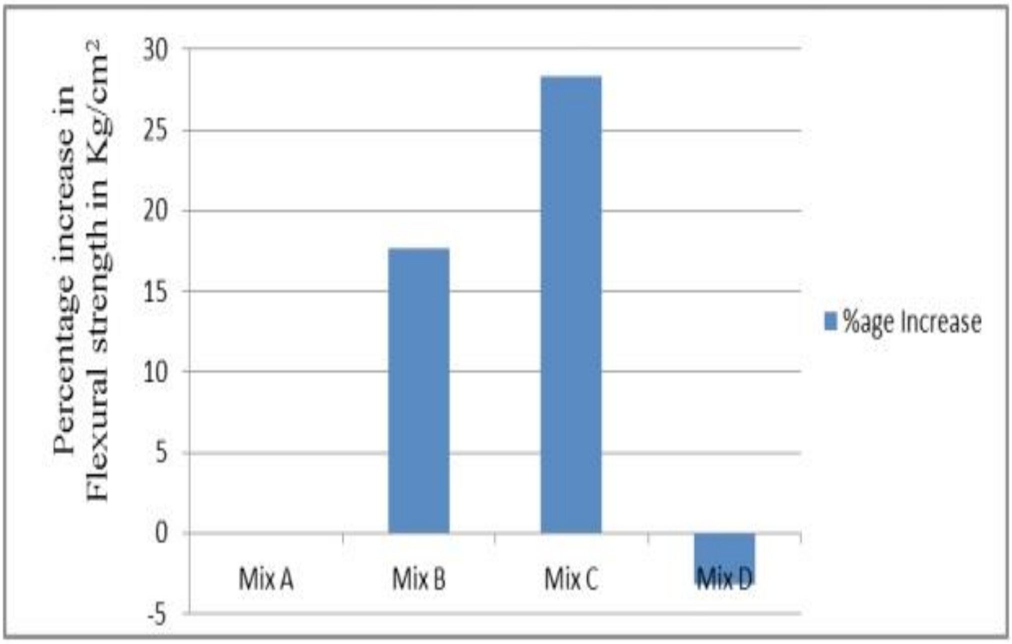


Figure 2-8 percentage increase in flexural strength to of different mixes at 7 days (Quadir. 2018)

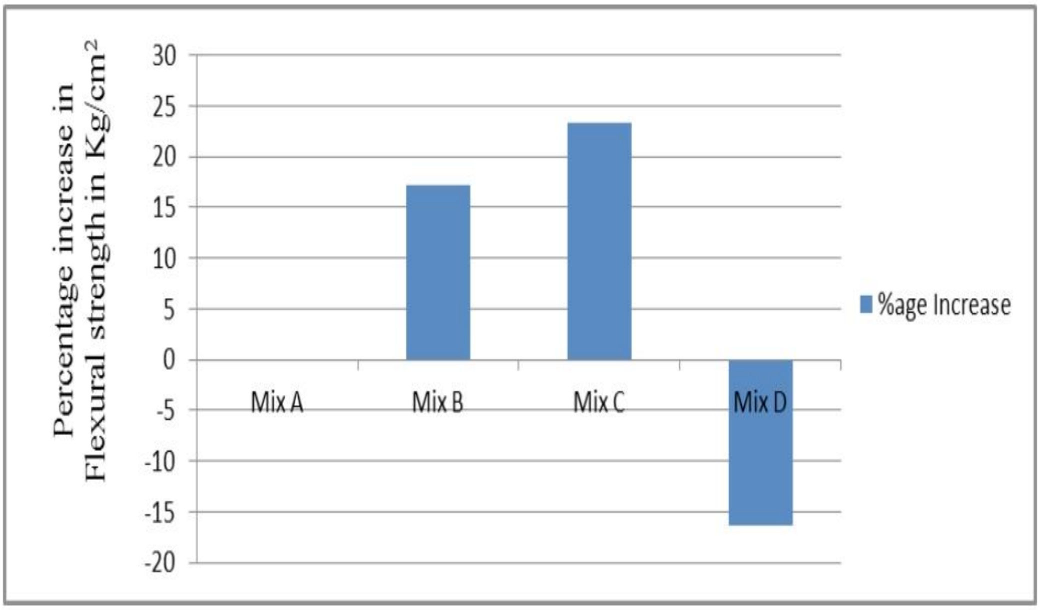


Figure 2-9 flexural strength increase Percentage of 28 days (Quadir. 2018)

2.4 WASTE FOUNDRY SAND

2.4.1 Properties of Fresh Concrete

Basar et al. (2012) had done the study "**The effect of waste foundry sand (WFS) as partial replacement of sand on the mechanical, leaching and micro-structural characteristics of ready-mixed concrete**" that represents the usage of WFS in ready mixed concrete. Natural sand was partially replaced with 0%, 10%, 20%, 30% and 40% of WFS. A range of tests were performed to examine the mechanical and physical properties of the RMC. Fresh properties such as the unit weight, slump and temperature was investigated. Unit weight of the concrete doesn't get affected with the addition to WFS in the concrete. Presence of WFS in the concrete increases the w/c ratio of fresh concrete with same slump.

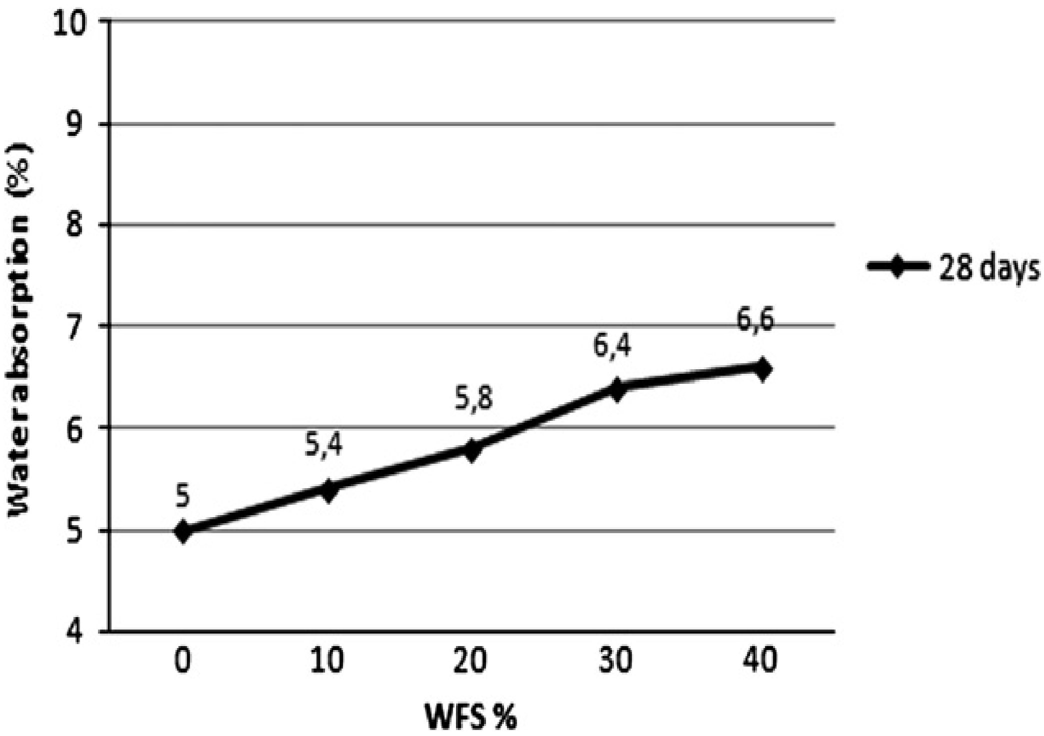


Figure 2-10 At different WFS % W.A of concrete (Basar. 2012)

Kunal et al. (2015) in research **"Comparative investigation on the influence of spent foundry sand as partial replacement of fine aggregates on the properties of two grades of concrete"** investigated the properties of concrete by partially replacing the sand with SFS with two with different grades of concrete. Concrete was investigated with M20 and M30 grade with 0, 5, 10, 15, and 20% by SFS replaced by weight of sand. Ratios of water/cement for two different grades were kept same with 0.5 for M-20 and 0.4 for M-30. Slump values for M-20 as well as for M-30 grade decreases with the increases in SFS

Arunachalam.et al. (2016) in research **"Micro and mechanical behaviour of Treated Used Foundry Sand concrete"** tries to evaluate the concrete properties by partially replacing fine aggregates with treated UFS. Generally, UFS is by-product which contains more iron content due to which it needs proper treatment before using it in concrete. Researcher used acid to treat UFS and evaluate the micro-structural and mechanical properties of concrete. TUFS was used as 0, 10, 20, 30, and 40%of weight. To specimens tested for 7, 28, 56 and 90 days. In fresh properties of concrete researcher evaluates the slump, vee-bee time and compaction factor test. All the tests results shows almost same properties that of control mix. There is just a slight or marginal decrease in the workability as tested using slump test with the increase in TUFS.

A. Torres et al. (2017)in research **"Effect of foundry waste on the mechanical properties of Portland Cement Concrete"** used waste foundry sand as a partial type replacement for coarse aggregates as well as for fine aggregates and also for both coarse and also fine type aggregates. The replacement was with 10%, 20% and 30% by mass. There were four groups one which control mix (group 1), in the second group coarse aggregates was to replaced, in the third group fine aggregates and in fourth group coarse and fine aggregates both were replaced. Group two specifies that within the increase to in WFS slump increases but marginally, whereas in group three slump decreases to with that increase in WFS and in the fourth group there was no change in slump test.

Bhardwaj et al. (2017)in research "**Waste foundry sand in concrete: A review**" done the investigation of all the past studies on the waste of foundry sand as a partial replacement were used by the researcher in this research paper. All the studies which investigated partial replacement of aggregates within the concrete with WFS. Results show that with the increase in inclusion of waste foundry sand, the concrete increases the water demand. Also the inclusion of WFS decreases the workability of the concrete and the density of the concrete. Replacement up to 20% gives same properties as of control mix according to some researcher, whereas some researcher concluded 30% as an optimum replacement

2.4.2 Properties of Hardened Concrete

Basar et al. (2012) had done the study "**The effect of waste foundry sand (WFS) as partial replacement of sand on the mechanical, leaching and micro-structural characteristics of ready-mixed concrete**" that represents the usage of WFS in ready mixed concrete. Natural type sand was partially replaced to with 0%, 10%, 20%, 30% and 40% of WFS. All strength to tests was performed to at different ages at 7, 28, 56 and 90 days. As curing age increases the strength increases. The replacement of 20% physical properties was almost same of that of control mix.

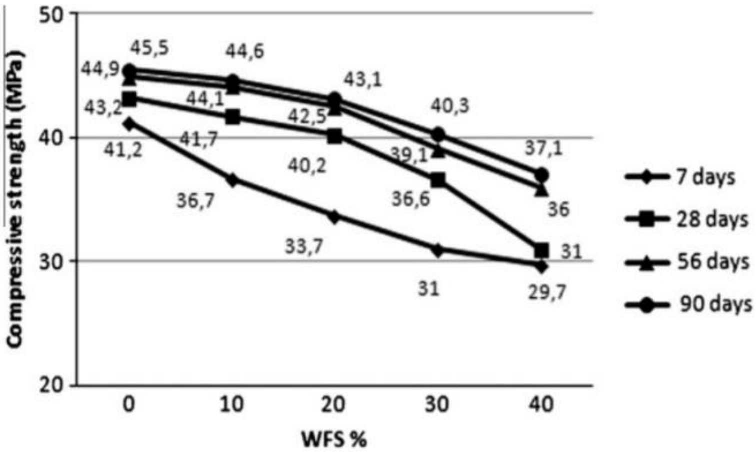


Figure2-11test results Compressive strength with different WFS (Basar. 2012)

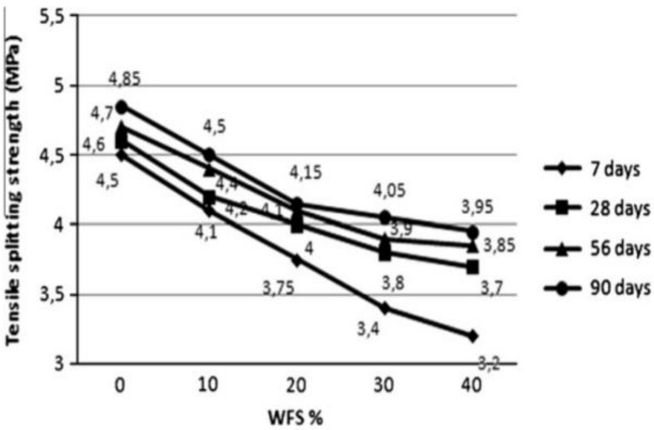


Figure2-12Splittensile strength test result for different WFS (Basar. 2012)

Table 2-6Modulus of elasticity for different WFS (Basar. 2012)

Modulus of elasticity results of specimens with WFS as a function of time (days).

Specimens	WFS %	Modulus of elasticity, (MPa)			
		7 days	28 days	56 days	90 days
M0	–	34,861	35,361	35,777	35,922
M1	10	33,689	34,987	35,583	35,705
M2	20	32,867	34,606	35,187	35,336
M3	30	32,095	33,662	34,322	34,632
M4	40	31,712	32,095	33,500	33,796

Kunal et al. (2015) in research **"Comparative investigation on the influence of spent foundry sand as partial replacement of fine aggregates on the properties of two grades of concrete"** investigated the concrete properties of by partially replacing the sand with SFS with different concrete grades. Concrete was investigated with M20 and M30 grade with 0%, 5%, 10%, 15%, and 20% by SFS replaced by weight of sand. Different physical strength properties were investigated to such to as compressive strength and others. Partially replacing the sand with SFS increases the strength properties up to 15% replacement in both M-20 as well as of concrete grade M-30also the more influence of SFS was noticed in M-20 grade of concrete. Inclusion of SFS increases the modulus of elasticity and coulombs charge decreases at all ages of concrete.

Table 2-7 Compressive strength for M20 and M30 grade with WFS as replacement (Kunal. 2015)

Compressive strength of concrete with and without spent foundry sand.

Mixture No.	Concrete type (M20 grade)					Concrete type (M30 grade)				
	M-1	M-2	M-3	M-4	M-5	N-1	N-2	N-3	N-4	N-5
7-Day strength (MPa)	19.7	22.4	24.3	25.3	24.8	26.8	29	30	31.5	30.9
28-Day strength (MPa)	30	34.4	36.8	37.8	37	40	43.3	44.9	46.8	45.3
91-Day strength (MPa)	34.5	38.2	41	41.7	40.8	42.8	45.9	46.7	47.8	46.2
365-Day strength (MPa)	37	40.5	43.6	45	44	46	49.3	52.9	53.5	53

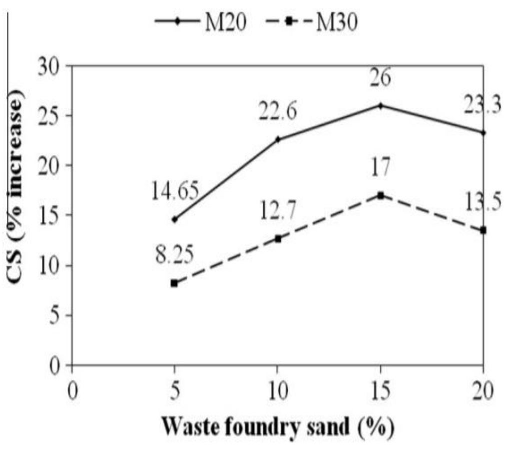


Figure 2-13 compressive strength vs WFS at 28 days (Kunal. 2015)

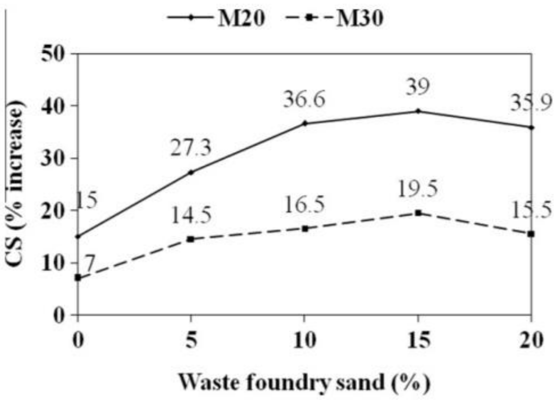


Figure 2-14 compressive strength vs WFS at 91 days (Kunal. 2015)

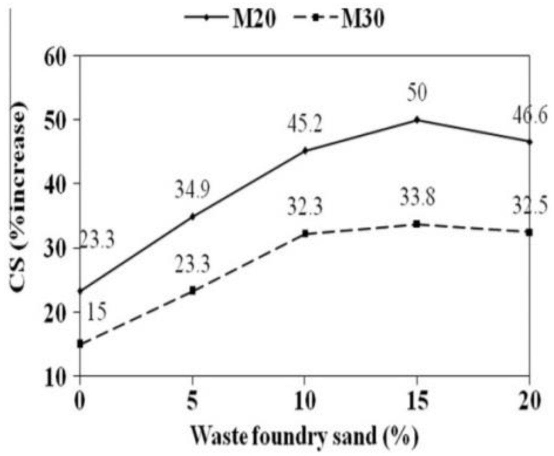
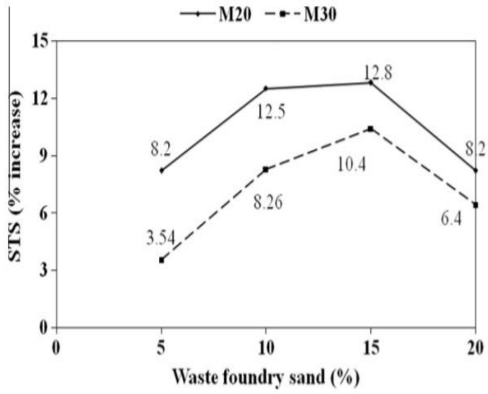


Figure 2-15 compressive strength vs WFS at 365 days (Kunal. 2015)

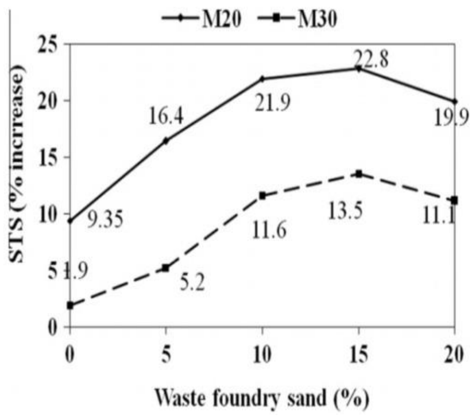
Table 2-8 split tensile strength for different grade at different WFS proportions (Kunal. 2015)

Splitting tensile strength of concrete with and without spent foundry sand.

Mixture No.	Concrete type (M20 grade)					Concrete type (M30 grade)				
	M-1	M-2	M-3	M-4	M-5	N-1	N-2	N-3	N-4	N-5
7-Day strength (MPa)	2.15	2.26	2.38	2.5	2.4	2.77	3.1	3.2	3.28	3.1
28-Day strength (MPa)	3.42	3.7	3.85	3.86	3.7	4.23	4.38	4.58	4.67	4.5
91-Day strength (MPa)	3.74	3.98	4.17	4.2	4.1	4.31	4.45	4.72	4.8	4.7
365-Day strength (MPa)	3.96	4.1	4.3	4.36	4.29	4.38	4.6	4.78	5	4.9



2-16 Split-tensile strength vs WFS at 28 days (Kunal. 2015)



2-17 Split-tensile strength vs WFS at 91 days (Kunal. 2015)

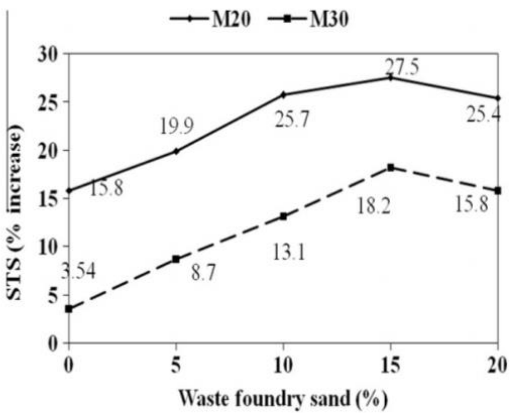


Figure 2-18 Split-tensile strength vs WFS at 365 days (Kunal. 2015)

Table 2-9 Modulus of elasticity for different concrete grade of at different WFS (Kunal. 2015)

Modulus of Elasticity (MOE) of concrete with and without spent foundry sand.

Mixture No.	Concrete type (M20 grade)					Concrete type (M30 grade)				
	M-1	M-2	M-3	M-4	M-5	N-1	N-2	N-3	N-4	N-5
7-Day MOE (GPa)	20.5	21.1	21.3	21.9	21.2	25.7	26.6	27.1	27.7	27.2
28-Day MOE (GPa)	23.8	24.4	24.6	25.2	24.8	29.9	30.4	30.7	31.3	31.1
91-Day MOE (GPa)	24.6	24.9	25.4	25.8	25.7	30.6	31	31.8	32.2	32
365-Day MOE (GPa)	25.8	26.4	27.2	27.5	27.4	32.3	32.9	33.7	34.1	33.6

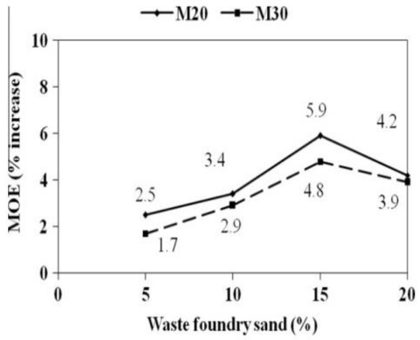


Figure 2-19 Modulus of elasticity vs WFS at 28 days (Kunal. 2015)

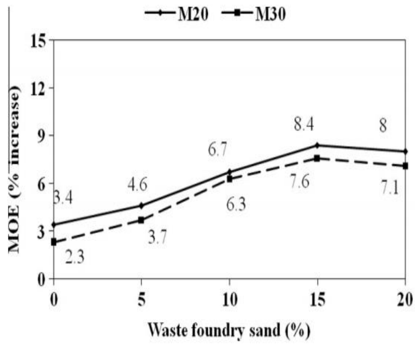


Figure 2-20 Modulus of elasticity vs WFS at 91 days (Kunal. 2015)

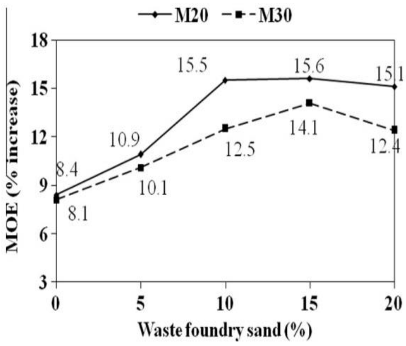


Figure 2-21Modulus of elasticity vs WFS at 365 days (Kunal. 2015)

Arunachalam.et al. (2016) in research **"Micro and mechanical behaviour of Treated Used Foundry Sand concrete"** tries evaluating the properties of concrete by replacing partially the fine aggregates with treated foundry sand. Generally, foundry sand is used as by-product which contains more iron content due to which it needs proper treatment before using it in concrete. Researcher used acid to treat used foundry sand and evaluate the micro-structural and mechanical properties of concrete. TUFS was by weight used as of 0%, 10%, 20%, 30%, and 40%. Specimens of tested for 7, 28, 56 and 90 days. Mechanical properties of concrete shows that with increase in TUFS all the strength parameters increase at all ages. Compressive strength shows 4% to 11% variation to 28 days.

Table 2-10 Compressive strength at various ages (Arunachalam. 2016)

Compressive strength at various ages.

Compressive strength (MPa)				
Mix Designation	7 days	28 days	56 days	90 days
CC	22.90	27.70	31.02	33.78
R10	24.64	28.77	33.44	36.81
R20	25.31	29.97	34.94	38.11
R30	26.42	30.73	35.90	39.61
R40	24.86	29.52	34.64	37.41

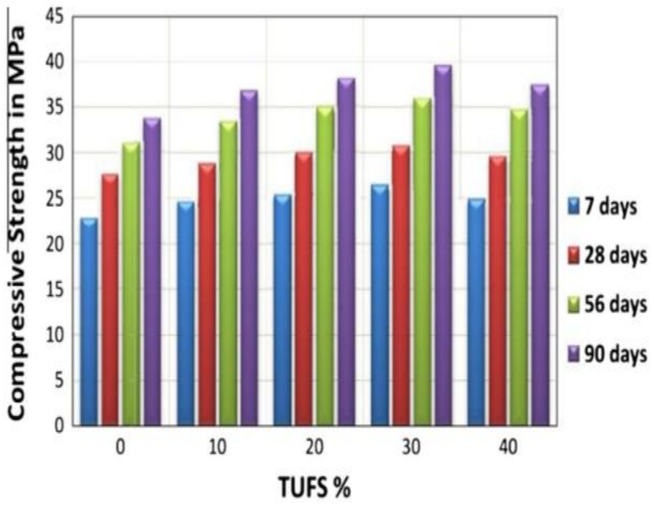


Figure 2-22 Compressive strength vs various percentage to TUFS (Arunachalam. 2016)

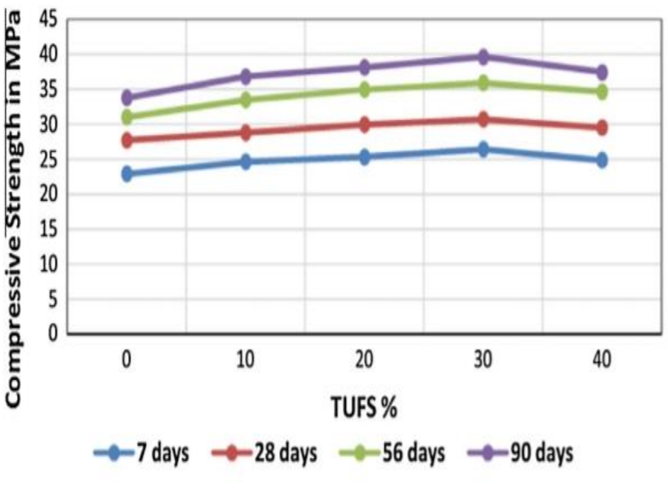


Figure 2-23 w.r.t control concrete variation in compressive strength (Arunachalam. 2016)

Table 2-11 Split tensile strength at various ages (Arunachalam. 2016)

Splitting tensile strength properties at various ages.

Splitting tensile strength (MPa)				
Mix designation	7 days	28 days	56 days	90 days
CC	1.62	2.36	2.92	3.59
R10	1.92	2.45	3.04	3.75
R20	2.01	2.54	3.18	3.98
R30	2.04	2.61	3.31	4.07
R40	2.02	2.52	3.09	3.87

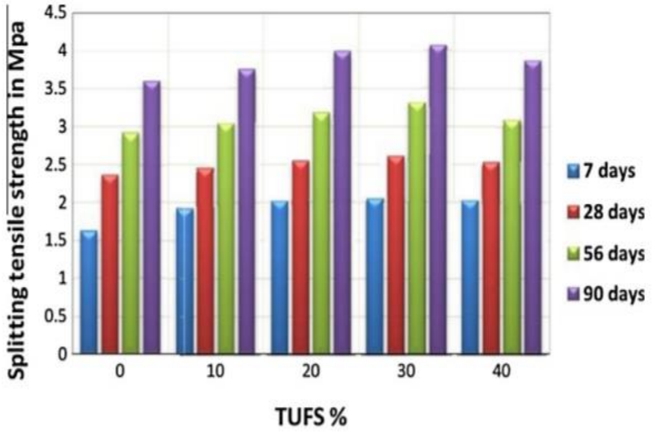


Figure 2-24 TUFS various percentage vs Split tensile strength (Arunachalam. 2016)

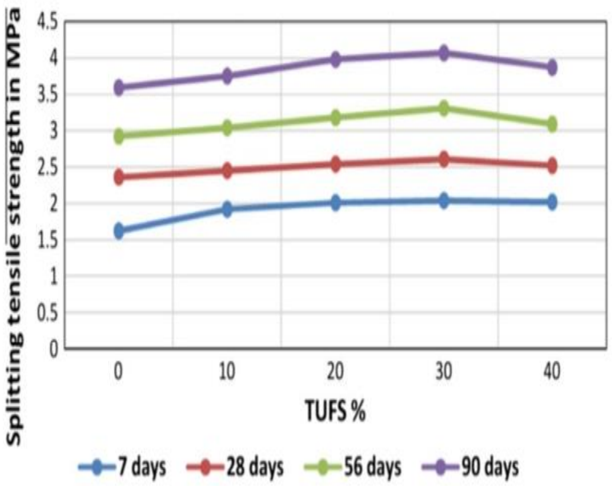


Figure 2-25 w.r.t control concrete Variation in split-tensile strength (Arunachalam. 2016)

Table 2-12 Flexural strength at various ages (Arunachalam. 2016)

Flexural strength at various ages.

Flexural strength (MPa)				
Mix designation	7 days	28 days	56 days	90 days
CC	3.11	3.78	3.98	4.26
R10	3.25	3.96	4.16	4.58
R20	3.46	4.13	4.38	4.74
R30	3.72	4.28	4.61	4.97
R40	3.43	4.09	4.31	4.68

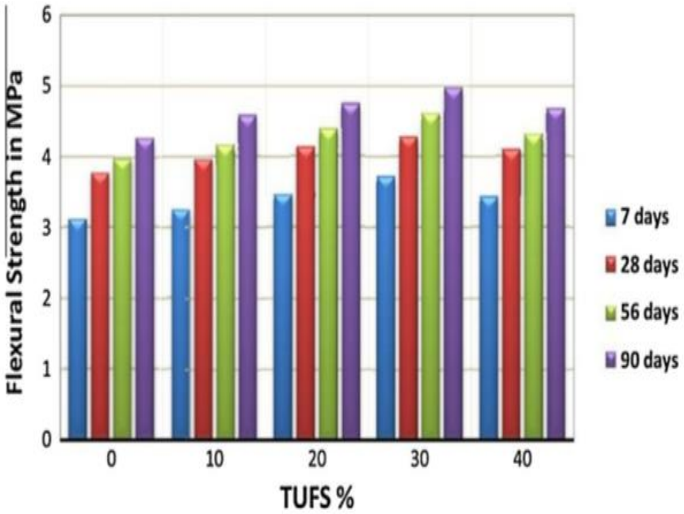


Figure 2-26 Flexural strength vs various percentage to TUFS (Arunachalam. 2016)

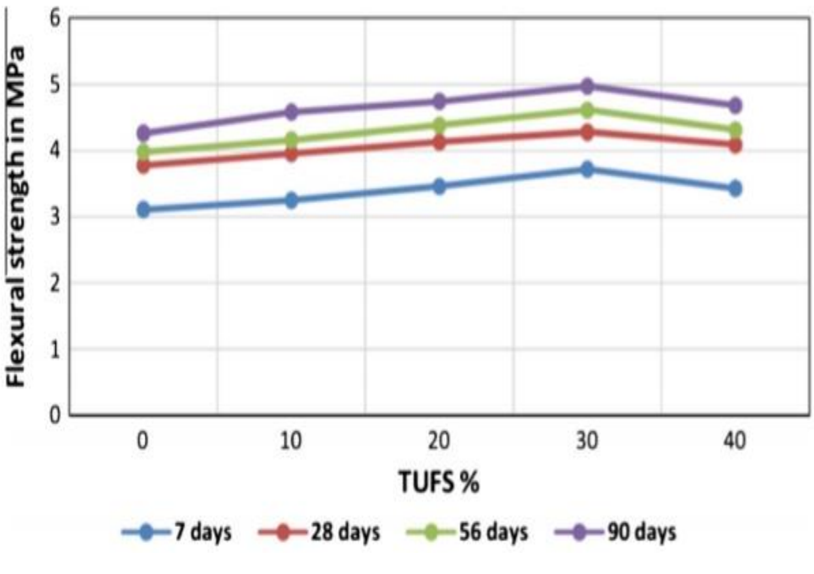


Figure 2-27 Variation in Flexural strength w.r.t control concrete (Arunachalam. 2016)

A. Torreset et al. (2017) in research **"Effect of foundry waste on the mechanical properties of Portland Cement Concrete"** used waste of foundry sand to as of partial replacement of coarse aggregates also of fine aggregates and also for both coarse and of fine aggregates. The replacement was with 10%, 20% and 30% by mass. There were four groups one which control mix (group 1), the second group coarse aggregates was to that replaced, in the third group fine aggregates and in fourth group coarse and fine aggregates both were replaced. Mechanical properties were to be investigated. Results show no such effect of fine as well as coarse foundry sand on the mechanical properties of concrete. Replacement in the case of both coarse and of fine aggregates shows that there is decrease in all the properties of strength.

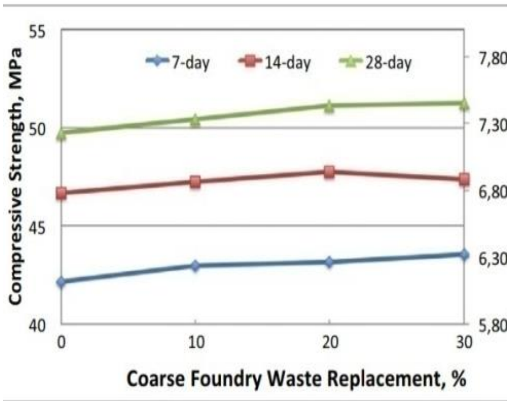


Figure2-28 compressive strength of coarse foundry waste replacement (A. Torres. 2017)

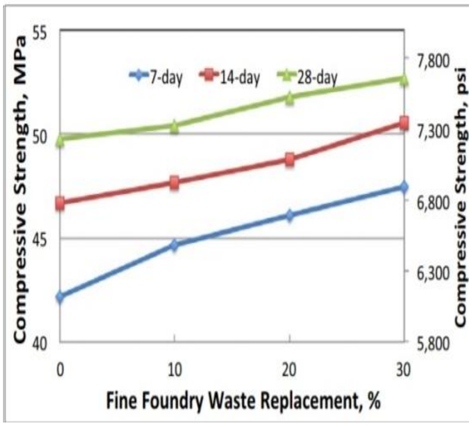


Figure2-29 compressive strength of fine foundry waste replacement (A. Torres. 2017)

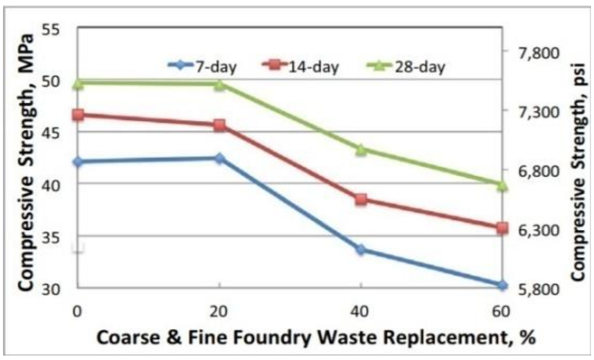


Figure2-30 compressive strength of coarse and fine both foundry waste replacement (A. Torres. 2017)

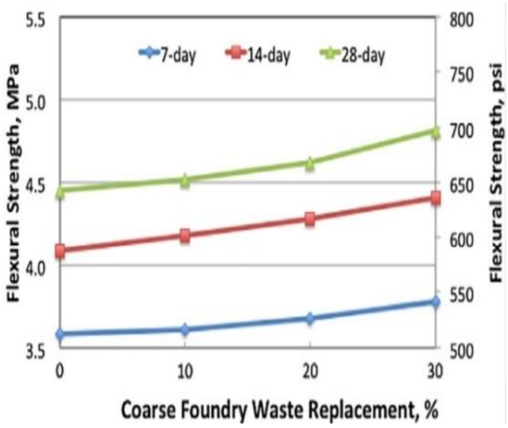


Figure 2-31 Flexural strength of coarse foundry waste replacement (A. Torres. 2017)

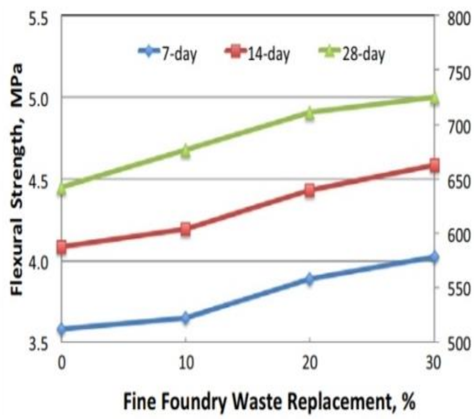


Figure 2-32 Flexural strength of fine foundry waste replacement (A. Torres. 2017)

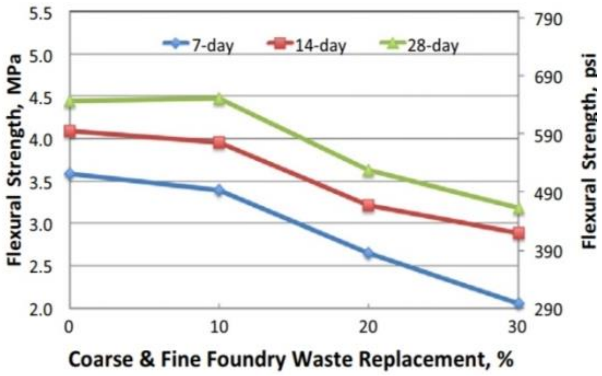


Figure 2-33 Flexural strength of coarse and fine both foundry waste replacements (A. Torres. 2017)

Bhardwaj et al. (2017) in research **"Waste foundry sand in concrete: A review"** done the investigation of all the past studies on the waste foundry sand as to partially replace concrete's natural sand. All the studies which investigated are of partial aggregates replacement in concrete to waste foundry sand. Increase in the WFS creates weak binding forces which decreases its mechanical properties. Replacement up to 20% gives same properties as of control mix according to some researcher, whereas some researcher concluded 30% as an optimum replacement.

CHAPTER 3 MATERIAL USED AND EXPERIMENTAL WORK

3.1. GENERAL

The current chapter deals with the material properties and results obtained from the numerous tests conducted on the materials. In direction to accomplish the objective of this present study, an experimental program was planned to examine the consequence of RHA, WFS and IS used as partially replacements to sand, for the compressive and flexure strengths of concrete.

3.1 MATERIALS USED

According to the IS practice codes, under the controlled conditions in the laboratory all the properties of materials use in concrete mix are determined. The characterization of materials were found out for all the ingredients which are important in concrete including cement, super-plasticizer, coarse aggregates, fine aggregates and water, which in addition to RHA, WFS and IS. The basic importance for the characterization is to test their suitability as per according to that relevant Indian standards so to design a concrete mix for particular strength.

3.1.1 CEMENT

Cement is important material in mixing of concrete as it is the link within mixing. All other materials are also important which are used in concrete mix. To make a compact mass cement, it is to bind aggregates and then to fill up the voids in mixture. It establishes of about 20 percent to volume of mixture of concrete. With any of the variation in its quantity, the compressive strength may get affected. By grinding Portland cement clinker a fine powder is produced which is referred as Portland cement or also we can say Ordinary Portland Cement and this is also most important cement type. Grade 33, Grade 43 and Grade 53 are the classification of three grades of OPC and all these grades depends on the strength of 28 days curing.

Generally, for making stronger concrete high-grade cement offers many advantages. One of the important quality is its development rate of strength which is quite faster.

OPC with Grade 43 of brand Ultra-tech cement is taken from a single lot. This cement is used throughout in the investigation of course experiments and there were no lumps in the cement. Physical properties of cement were kept according to IS standards for all experimental works. Cement was cautiously stored to avoid deterioration in its properties due to contact with the moisture

Make of the Cement: Aditya Birla Group, Ultra Tech

Type of Cement: OPC 43

Weight of Cement: 500 gm

Table 3-1 Consistency test for cement

	Sample 1	Sample 2	Sample 3
Water content (%)	27	28	29
Quantity of water (ml)	135	140	145
Penetration from bottom (mm)	8	5	2
Consistency = 28%			

Table3-2Cement Characteristics

S. No.	Characteristics	Results	IS Specifications
1	Specific Gravity	3.14	-
2	Standard Consistency (%)	28	-
3	Initial Setting Time(min)	156	30 (min)
4	Final Setting Time(min)	282	600 (max)
5	Compressive Strength 7 days 28 days	 37.8 MPa 47.2 MPa	 33 MPa(min) 43 MPa(max)

3.1.2 Coarse Aggregates

The aggregate which retained over the IS Sieve of 4.75 mm size is known as(C.A)coarse aggregates. The utmost size of coarse aggregate to concrete pavement shall be 31.5 mm. The aggregate with (W.A) water absorption as more than 2 percent shall not be used in mix design of concrete. As per IS standards soundness test for aggregate can be done. If the solution of magnesium sulphate to be use than the loss shall not be more than 18% and for solution of sodium sulphate not be more than 12% and all of this after 5 cycles to testing. Following are the types of C.A: -

a) Gravels which are crushed or stone with hardened property.

b) Stones which are natural in nature or in form of rocks which disintegrated naturally.

c) Blended stones of types given above or the gravel stones crushed partially.

The aggregate which is crushed, generally tries to increase the strength because of its angular shape, aggregate with rounded shape tries to increase flow property due its lower level of internal friction. Two sizes of C.A were used 10 and 20 mm. The laboratory tests were conducted as per IS 2386.

Table3-3C.A Characteristics

Characteristics	Value (20 mm)	Value(10 mm)
Colour	Grey	Grey
Shape	Angular	Angular

Table 3-4C.A (20 mm) Sieve Analysis

IS Sieve	Sample 1 (gm)	Sample 2 (gm)	Sample 3 (gm)	Average Weight retain (gm)	cumulative Weight retains (gm)	cumulative Weight Retain %	Passing %
37.5.mm	0	0	0	0	0	0	100
31.5 mm	0	0	0	0	0	0	100
26.5 mm	34	46	46	42	42	0.84	99.16
19 mm	578	660	466	568	610	12.20	87.80
9.5 mm	4240	4199	4298	4245.67	4855.67	97.11	2.89
4.75 mm	0	0	4	1.33	4857	97.14	2.86
2.36 mic	148	95	186	143	5000	100	0
600 mic	0	0	0	0	5000	100	0
150 mic	0	0	0	0	5000	100	0
75 mic	0	0	0	0	5000	100	0

Total Sample taken = 5000 grams

Table 3-5C.A (10 mm) Sieve Analysis

IS Sieve	Sample 1 (gm)	Sample 2 (gm)	Sample 3 (gm)	Average Weight retain (gm)	cumulative Weight retain (gm)	% cumulative Weight retain	% Passing
37.5 mm	0	0	0	0	0	0	100
31.5 mm	0	0	0	0	0	0	100
26.5 mm	0	0	0	0	0	0	100
19 mm	0	0	0	0	0	0	100
9.5 mm	673	677	685	678.33	678.33	13.57	86.43
4.75 mm	3666	3665	3672	3667.67	4346	86.92	13.08
2.36 mm	653	646	637	645.33	4991.33	99.83	0.17
600 mic	8	12	6	8.67	5000	100	0
150 mic	0	0	0	0	5000	100	0
750 mic	0	0	0	0	5000	100	0

Total Sample taken = 5000 grams

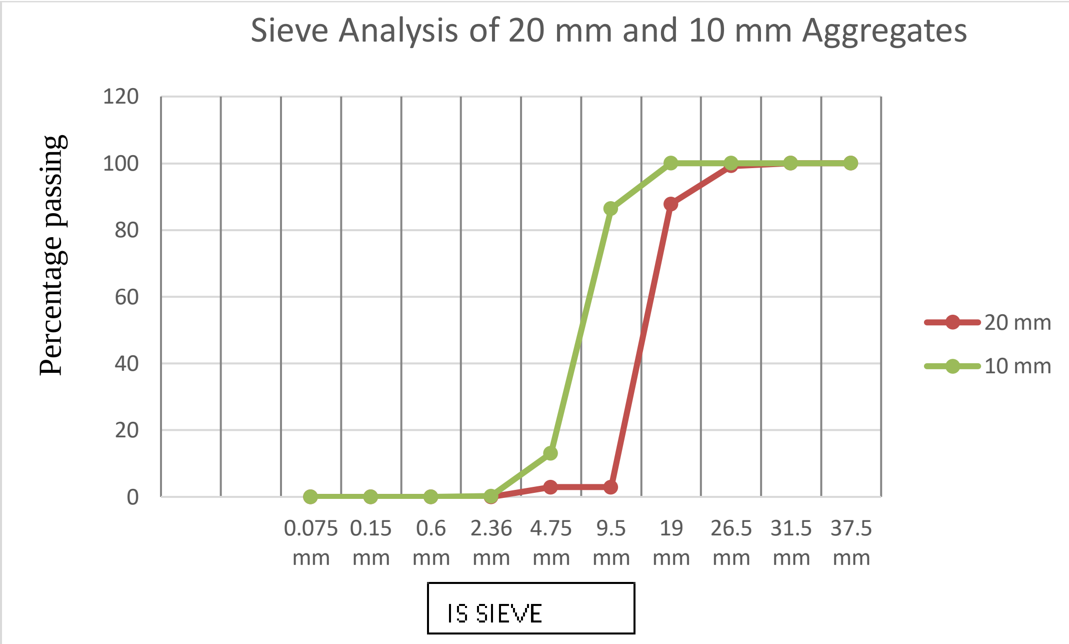


Figure 3-1Sieve Analysis graph for 20mm and 10mm coarse aggregates

The coarse aggregate of gradation of 10 mm and 20 mm as per the limits specified in IS 383: 2017.

Table 3-6Specific gravity, W.A and App. specific gravity test for 20 mm coarse aggregates

	sample 1 (gm)	sample 2 (gm)	
Weight of water in bucket	4186.0	4184.0	
Weight of Agg. + water in bucket	5425.0	5423.0	
SSD weight	2002.0	2006.0	
Weight of Oven Dried Sample	1996.0	1999.0	
			Average
Spec. Gravity	2.62	2.61	2.61
Apparent Spec. Gravity	2.64	2.63	2.63
W.A (%)	0.30	0.35	0.33

Table 3-7Specific gravity, W.A and App. specific gravity test for 10 mm coarse aggregates

	sample 1 (gm)	sample 2 (gm)	
Weight of water in bucket	4198.0	4200.0	
Weight of Agg. + water in bucket	5461.0	5462.0	
SSD weight	2005.0	2004.0	
Weight of Oven Dried Sample	1998.0	1997.0	
			Average
Spec. Gravity	2.69	2.69	2.69
Apparent Spec. Gravity	2.72	2.72	2.72
W.A (%)	0.35	0.35	0.35

Los Angeles Abrasion Test

Table 3-8 Aggregates L.A Abrasion test

L.A Abrasion Test			
Calculation and Test values	Test Number		Avg.
	1	2	Final
Specimen Weight, W_1 g	5000	5000	5000
Specimen Weight after abrasion test, retained on 1.70 mm test sieve, W2 g	3590	3548	3569
L.A abrasion value = wear percentage (%)	28.2	29.04	28.62

Aggregate Impact Value Test

AIV gives a value for the aggregate resistance, which is of the impact of sudden shock and sudden load to the aggregate, in some aggregate it differs from its slow load of resistance. This test is to be done with the help of impact testing machine, a metal hammer with 14 kg weight, IS sieves, weighing machine, measuring scale and tamping rod. The metal hammer is of 100 mm diameter and 5 cm long having a lower edge with 2 mm chamfer. The aggregates were first passed from 12.5 mm sieve and retain on 10 mm. The retained aggregates on 10 mm sieve are than for test use. The aggregates are filled in 3 layers and tamped for 25 stokes each time. Then the passing of crushed aggregates are done from 2.36 mm sieve and weigh of aggregate is done of passed one's as well as retained one's and is noted. Weight fraction of passing by 2.36 mm IS sieve is done and also the weight sample which is oven dried is taken.

$$\text{Aggregate Impact Value} = \frac{\text{Weight fraction passing 2.36 mm sieve}}{\text{weight of oven dried sample}} \times 100$$

Table 3-9Aggregate Impact Value Test for aggregates

Aggregate Impact Value Test					
Serial No.	Details	Trial Number			Avg.
		1	2	3	
1	Aggregate Total weight in sample filling the cylindrical measure = W_1 g	340	334	343	339
2	Aggregate Weight by passing 2.36 mm sieve after the test = W_2 g	54	53	56	54.3
3	Retained Aggregate Weight of on 2.36 mm sieve after the test = W_3 g	286	281	287	284.6
4	Weight Difference= W_1 - (W_2 + W_3) g	0	0	0	0
5	Aggregate Impact Value = percent fines (%)	15.88	15.86	16.32	16.02

To remove dirt and dust from aggregates, they were washed and after that dried to surface dry condition. The coarse aggregates are also tested for sieve analysis.

3.1.3 Fine Aggregates

The Fine aggregates are which pass by the 4.75 mm IS sieve. The following are different types of fine aggregates:

1. The naturally disintegration of rocks produce sand known to be natural sand.
2. By the crushing of the stone which is hard in nature known to be crushed stone sand.
3. By the crushing of the natural gravel and produce sand known to be crushed natural gravel sand.

According to size, the fine aggregate may be described as coarse, medium and fine sands. IS: 383-2017 gives fine aggregates four grading zones (Grade I to IV) which depends on the distribution to particle size. From grading I and to grading IV it becomes gradually finer.

Conforming to grading II fine aggregates were collected which were in light brown colour. As per the guidelines in IS 383-2017 aggregates were tested for physical properties and sieve analysis. Fine aggregates specific gravity was calculated and comes out to be 2.96. Fineness Modulus was calculated by sieve analysis.

Table 3-10Fine Aggregates Sieve Analysis

IS Sieve	Sample 1 (gm)	Sample 2 (gm)	Sample 3 (gm)	Average retain Weight (gm)	cumulative Weight retain (gm)	cumulative Weight retain (%)	% Passing
9.5 mm	0	0	0	0	0	0	100
4.75 mm	190	195	198	194.33	194.33	5.55	94.45
2.36 mm	751	742	741	744.67	939	26.83	73.17
1.18 mm	1006	1002	1001	1003	1942	55.49	44.51
600 mic	901	908	905	904.67	2846.67	81.33	18.67
300 mic	419	421	423	421	3267.67	93.36	6.64
150 mic	209	210	208	209	3476.67	99.33	0.67
pan	24	22	24	23.33	3500	100	0

Total Sample Value = 3500 grams

Sum = 361.89

FM = 3.61

Table 3-11Specific gravity, W.A and App. specific gravity test for fine aggregates

	sample 1 (gm)	sample 2 (gm)	
Weight in SSD Condition	502.0	502.0	
Weight of Water + AGG. In Pycnometer	1808.0	1810.0	
Weight of only Water in Pycnometer	1479.0	1471.0	
Weight of Oven Dried Sample	498.0	497.0	
			Average
Specific Gravity	2.88	3.05	2.96
Apparent Specific Gravity	2.95	3.15	3.05
Water Absorption (%)	0.80	1.01	0.90

3.1.4 RICE HUSK ASH

Husk is generated as of by-product by Rice milling industries. During this process 78 percentage of rice is generated, that also of different types of rice and the rest of the 22% generated is a by-product known to be Husk or as rice husk. Husk itself contains 75% of organic matter and when the husk is burnt its weight remains 25% of the husk as ash known as Rice Husk Ash. Generally, RHA is in grey black colour.

This rice husk ash had been studied by many researchers in past which says that it can enhances the properties of concrete. Partially adding RHA to concrete increases its mechanical as well as durability properties. As a by-product material it also decreases the cost of concrete and making it an economical construction method. RHA as a waste utilization also will decrease the environmental pollution and also the carbon dioxide emission which is due to its burning in industries.

Rice Husk Ash was bought from Vishal Paper Mill near main village, district Patiala. The RHA Specific gravity is 1.46. Its chemical and physical properties are given below.

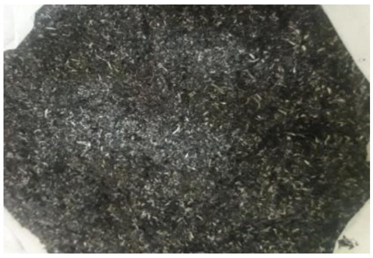


Figure 3-2 Picture of RHA

SEM Analysis Test

In SEM analysis test of RHA the pictures show that the particles are in the irregular shape. This particles picture with 1000 resolution pictures shows to tightly packed. Three of the pictures show the irregularity in the shapes of the particles in the material.

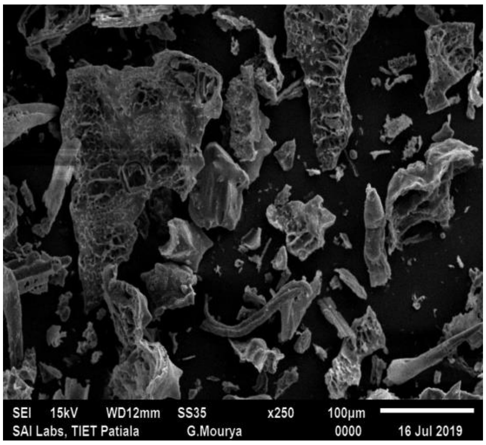


Figure 3-3 SEM analysis for RHA with 250 resolution

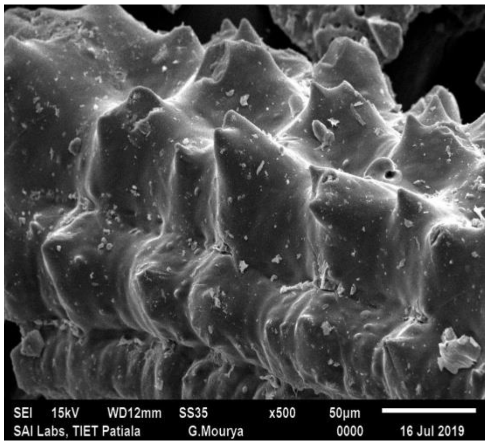


Figure 3-4 SEM analysis for RHA with 500 resolution

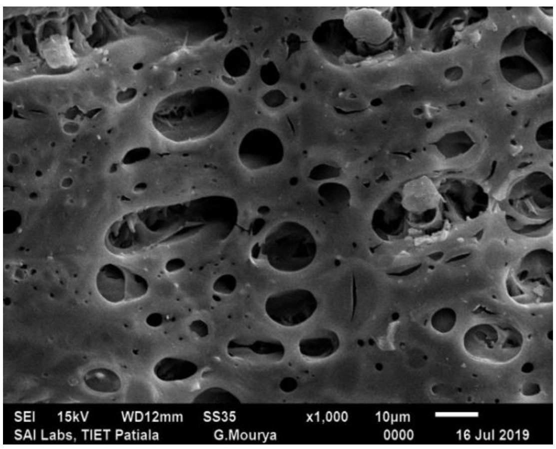


Figure 3-5 SEM analysis for RHA with 1000 resolution

EDS Analysis Test

The EDS Analysis Test for RHA gives the highest percentage of Si (weight %) as 44.66, (Atomic %) as 32.19 and (compound %) as 95.53. as in the figure of EDS also we can see the highest value of Si. If here we talk about compound % than K with 2.75 % follows the Si and also in weight and atomic % it is 2.29 and 1.18 %, respectively.

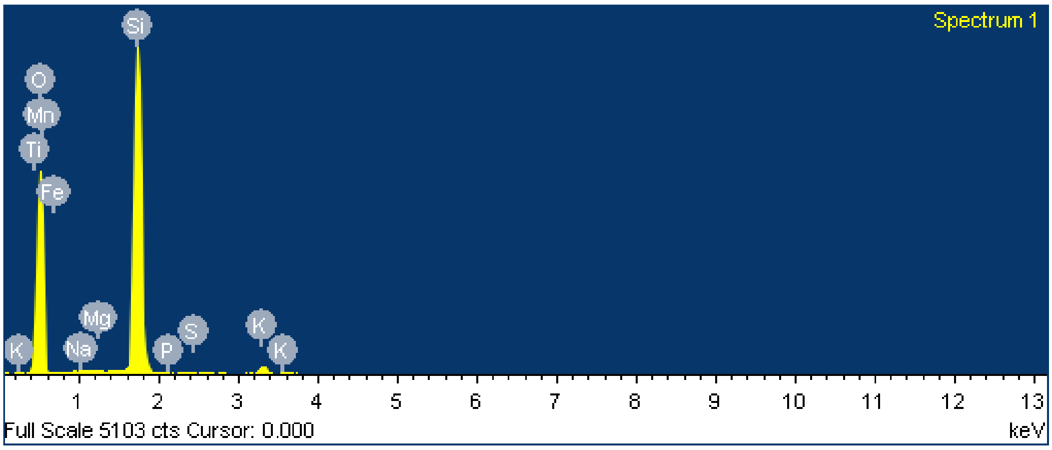


Figure 3-6 EDS analysis test for RHA

Table 3-12 EDS analysis test for RHA showing different elements present in RHA

Element	Weight%	Atomic %	compound%
Na	0.17	0.15	0.22
Mg	0.34	0.28	0.56
Si	44.66	32.19	95.53
P	0.11	0.07	0.25
S	0.2	0.12	0.49
K	2.29	1.18	2.76
Ti	0.07	0.03	0.12
Mn	0	0	0
Fe	0.05	0.02	0.06
O	52.12	65.95	
Total	100		

3.1.5 IRON SLAG

Iron and steel slag refer to the type of metal production slag that is generated during the manufacturing process of steel products. The term "slag" originally referring to the slag produced by metal manufacturing processes, however, is now also used to describe the slag that comes from molten waste material when waste and other substances are disposed of into an incineration plant. Iron Slag is generally in black colour. Recent studies states that usage of Iron Slag in concrete enhances its mechanical properties.

Figure 3-7 Picture of IS

SEM Analysis Test

In SEM analysis test of Iron Slag, the pictures show that the particles are in the solid and irregular shape. Also, the test pictures with highest resolution of 5000 shows that the particles are loosely packed

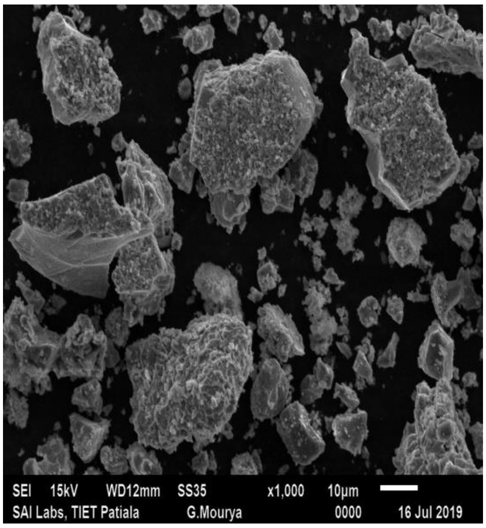


Figure 3-8SEM analysis for IS with 1000 resolution

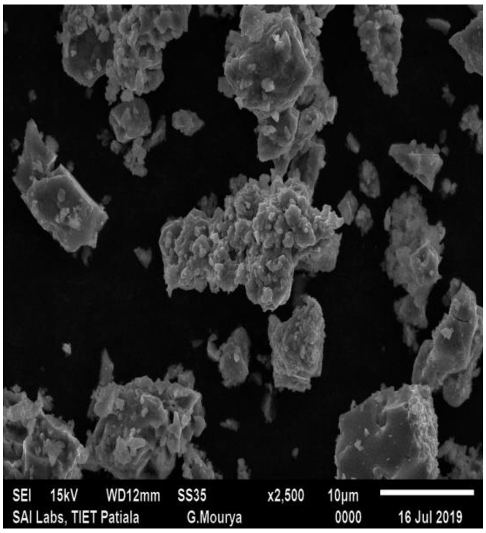


Figure 3-9SEM analysis for RHA with 2500 resolution

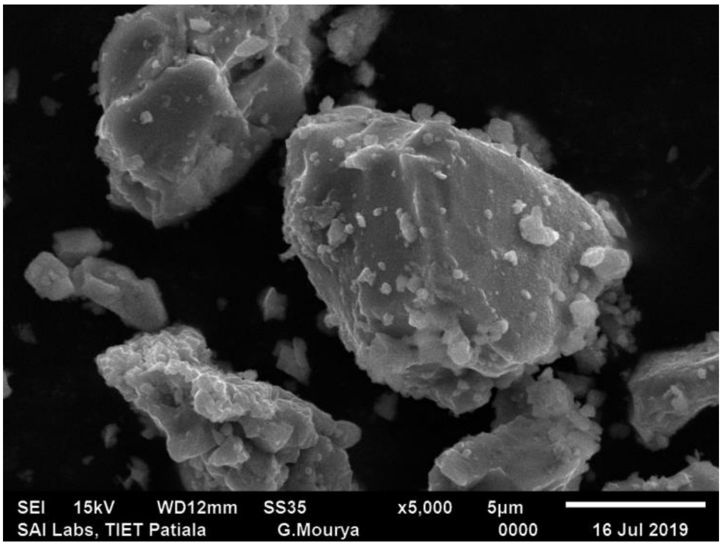


Figure 3-10SEM analysis for IS with 5000 resolution

EDS Analysis Test

The EDS Analysis Test for Iron Slag gives the weight % as Fe as the highest with 50.55 % and O with 35.99 % as the second highest. Atomic % as O as the highest with 56.14 % and Fe with 22.59 % as the second highest.

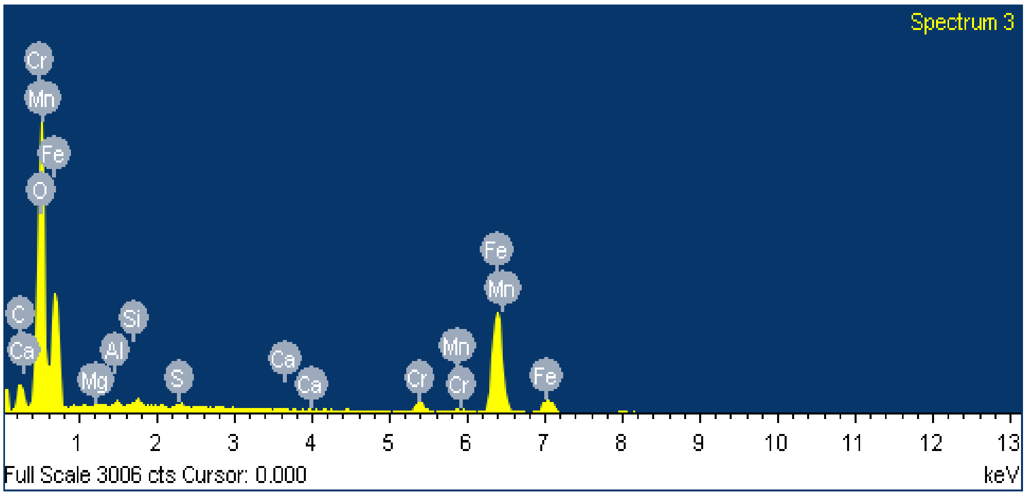


Figure 3-11EDS analysis test for IS

Table 3-13 EDS analysis test for IS showing different elements present

Element	Weight%	Atomic %
C	8.88	18.46
O	35.99	56.14
Mg	0.24	0.25
Al	0.37	0.34
Si	0.48	0.43
Si	0.46	0.36
Ca	0.03	0.02
Cr	2.52	1.21
Mn	0.46	0.21
Fe	50.55	22.59
Total	100	0.99
Total	100	

3.1.6 WASTE FOUNDRY SAND

Industries of Non-ferrous and ferrous metals generate a by- product to be named as to be waste sand foundry. It is one of those promising materials to which one can used as an alternative to the aggregates in concrete, as the presence of natural sand is coming to extinction stage in coming future. As a sand to residual casting it been in recent studies to be evaluate its properties by adding to concrete as a replacement. This sand is threat to the environment if not dumped properly with proper treatment.

Figure 3-12 Picture of WFS

Studies shows, that inclusion of waste foundry sand increases the mechanical properties of concrete, due to the presence of finer particles in the WFS. These finer particles make the bond strong if used in proper proportion. As a waste material it also decreases the cost of concrete and making it an economical construction method.

SEM Analysis Test

In SEM analysis test of WFS the pictures show that the particles are in the solid, irregular shape and also some are in sphere shape. Picture with 500 magnification shows a round shape particle. Also, the test pictures with highest resolution of 2000 shows that the particles are loosely packed.

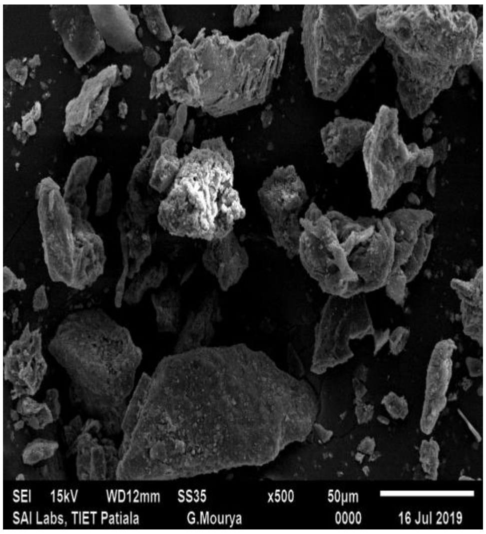


Figure 3-13 **SEM analysis for WFS with 500 resolution**

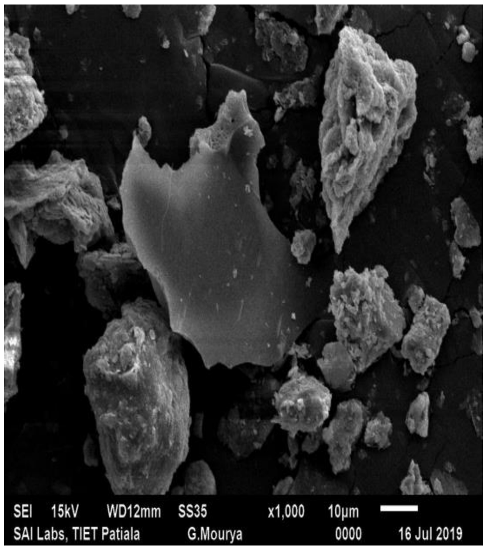


Figure 3-14 **SEM analysis for WFS with 1000 resolution**

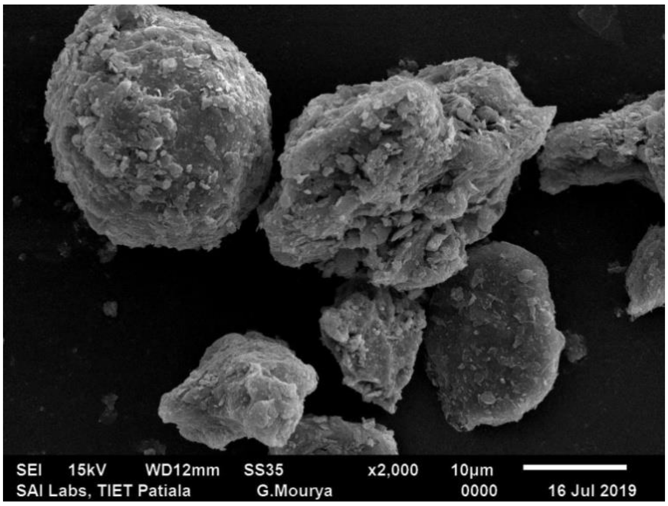


Figure 3-15SEM analysis for WFS with 2000 resolution

EDS Analysis Test

The EDS Analysis Test for WFS gives the weight % as O as highest with 47.14 % and Si with 24.06 % as the second highest. Atomic % as O as highest with 52.52 % and C with 22.56 % as second highest.

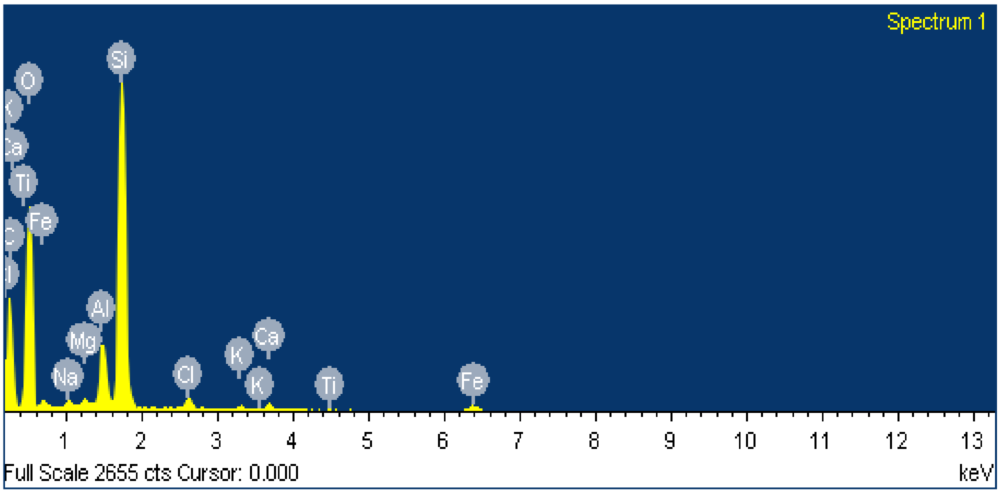


Figure 3-16EDS analysis test for WFS

Table 3-14EDS analysis test for WFS showing different elements present

Element	Weight%	Atomic %
C	17.9	26.56
O	47.14	52.52
Na	0.51	0.39
Mg	0.36	0.27
Al	3.95	2.61
Si	24.06	15.27
Cl	1.24	0.62
K	0.46	0.21
Ca	1.08	0.48
Ti	0.2	0.07
Fe	3.11	0.99
Total	100	

3.1.7. Water

The potable water with good quality was used. This water does not contain any of the contaminants and is considered suitable for concrete mixing. In the test laboratory potable water was available and is used in concrete mix.

3.1.8. Super plasticizer

Improved plasticizer which is relatively new version known to be Super plasticizer. Normal plasticizer chemical properties differ from superplasticizer. The use of the superplasticizer allows water to be reduced by 20 to 30 percent and not reducing the workability with comparison to that of normal plasticizer which only reduces water to 15 percent. The reaction mechanism of superplasticizer and that of plasticizer is almost same but superplasticizers are high reducers of water. With the use of the super plasticizer it has made it possible to use rice husk ash, iron slag and in other by-products to make high-performance concretes. When fibre-reinforced concrete is produced and the method of dosing high-strength concrete is the most common method in particular. In general, it is advisable to add the super plasticizer to per unit weight of cement as1-2%. Adding too much superplasticizer would be resulted in excessive detachment of the concrete and would not be recommended.

Superplasticizers are type of chemical additives that can be added to concrete mixtures for the workability improvement. For stronger cement, a small amount of water is added, making the concrete mix impractical, requiring the water reducers to use, superplasticizers, plasticizers or dispersants.

The manufacturer provided technical data are to the following:

Table3-15 Technical specifications for Super Plasticizer

Characteristic	Specified value
Product Name	SikaPlast 4202 NS
colour / Appearance	liquid of Light brown
Chemical base	Modified polycarboxylate
Relative density	1.10 kg/l (25^{0}c)
pH	≥6

The recommended usage of superplasticizer is 0.6 % to 2 % by the weight of cement material.1 % of cement materials selected for the range of required workability.

CHAPTER 4 MIX DESIGN AND CASTING

4.1 PAVEMENT QUALITY CONCRETE

As per the guidelines given in IRC 58-2015, the minimum grade of concrete for national highways is M40. As M40 grade of concrete has good abrasion value as compared to lower concrete which is good for high traffic roads. IRC 58-2015 gives the minimum flexural strength value as 4.5 for 28 days of curing.

The design of mix for the PQC is done according to the guidelines given in IRC 44-2017. Materials used in the design was coarse aggregate with 10 and 20 mm size, cement, super plasticizer, fine aggregates, iron slag, rice husk ash and WFS. The fine aggregates were replaced partially with iron slag and waste foundry sand. The iron slag was replaced with 20 %, 40 % and 60 % of weight of fine aggregates and waste foundry sand was replaced by 10 %, 20 % and 30 % of weight of natural sand. The cement was also been replaced by rice husk ash with the proportions of 10 %, 20 % and 30 % by weight of cement. The mixes with these replacements were made using Taguchi method. The mixes with (RHS-IS-WFS) are the following:

1. CM (0-0-0)
2. M1 (10-20-10)
3. M2 (10-40-20)
4. M3 (10-60-30)
5. M4 (20-20-20)
6. M5 (20-40-30)
7. M6 (20-60-10)
8. M7 (30-20-30)
9. M8 (30-40-10)
10. M9 (30-60-20)

Table 4-1Specification for mix design

A	Grade of concrete	M-40
B	Cement type	OPC 43
C	Nominal Maximum size of aggregates	20 mm
D	Maximum water to cement ratio	0.5
E	Degree to supervision	Good
F	Chemical type admixture	Super-Plasticizer
G	Maximum cement content	450 kg/m^3
H	Minimum cement content	350 kg/m^3

4.1.1 Aggregate properties

Table 4-2 Specific gravity values for materials used

Specific gravity	Value
Cement	3.14
C.A 20 mm	2.61
C.A 10 mm	2.69
Fine Aggregates	2.96
Rice Husk Ash	1.46
Iron Slag	4.35
Waste Foundry Sand	1.62

Table 4-3 Water Absorption values for materials used

Water Absorption	Value (%)
C.A 20 mm	0.33
C.A 10 mm	0.35
Fine Aggregates	0.90
Iron Slag	8.2
Waste Foundry Sand	1.62

4.1.2 Design strength of concrete

As per the IRC 44: 2017, the concrete desired strength at curing of 28 days known as characteristic strength of mix should be designed for higher strength so to take care of tolerance strength and degree of quality. The equation for this is given below:

$$f'_{cr} = f_{cr} + 1.65 \times S_f \quad (1)$$

Where,

f'_{cr}= mean target strength

f_{cr} = characteristic strength required at curing of 28 days (40 MPa)

S_f = standard deviation of flexural strength, N/mm^2

Approximate air content

The approximate air entrapped in the normal concrete with nominal size 19 mm as per IRC 44:2017 is 1.0 % as in this case.

Water cement ratio

The ratio of water cement for the target characteristic strength to 48.25 MPa is 0.36 for OPC 43 grade of cement. This value conforms to the table 9 IRC 44:2017.

From table 10, water = 186 kg/m^3 (50 mm slump)

For 25 mm slump, water = $186 - \frac{3}{100} \times 186 = 180\ kg/m^3$

Water content reduced by 20% as super plasticizer is used.

Content of water = $180 - (0.20 \times 180) = 144\ kg/m^3$

Content of water = 144 kg/m^3

Ratio of Water/cement = 0.38

So, Cement = 400 kg/m^3

As per IRC: 15, to minimum of cement content to be is 360 kg/m^3 and maximum content of cement is 450 kg/m^3. Therefore, in this case cement content is 400 kg/m^3 which are within to the limits.

The proportioning of 20mm coarse aggregate, coarse aggregate 10mm and natural sand or F.A is 32 %, 32 % and 36 % respectively.

The absolute concrete volume = 1 – volume of air = 1 – 0.01 = 0.99 m^3

Cement Volume = (cement mass /spec. gravity) × (1/1000)

= (400/3.14) × (1/1000) = 0.127 m^3

Water Volume= (water mass/spec. gravity) × (1/1000)

= (144/1) × (1/1000) = 0.144 m^3

Super plasticizer Vol. (1% by mass) = (mass of super plasticizer/spec. gravity) × (1/1000)

= (4/1.1) × (1/1000) = 0.003 m^3

All aggregates Vol. of (e) = (0.99 – (0.127 + 0.144 + 0.003)) = 0.716 m^3

20 mm coarse aggregate Mass = (e) × 0.32 × spec. gravity × 1000 = 598 kg/m^3

10 mm coarse aggregate Mass = (e) × 0.32 × spec. gravity × 1000 = 616.33 kg/m^3

Fine aggregate Mass= (e) × 0.36 × spec. gravity × 1000 = 762.96 kg/m^3.

Table 4-4Mix design for control mix

Water (kg/m^3)	**Cement** (kg/m^3)	**C.A 20 mm** (kg/m^3)	**C.A 10 mm** (kg/m^3)	**F.A** (kg/m^3)	**Density** (kg/m^3)
144	400	598	616	763	2521

Mix Design of Mix-1 (RHA-IS-FS) as (10-20-10) for PQC:

RHA = 10 % of cement = 400 × 0.10 = 40 kg/m^3

Cement content = 400 – 40 = 360 kg/m^3

Iron Slag 20% of Natural Sand = 763 × 0.20 = 152.6 kg/m^3

Iron slag content on equivalent volume basis = $\frac{152.6 \times 4.35}{2.96}$ = 224.26 kg/m^3

Waste Foundry Sand 10% of Natural Sand = 763 × 0.10 = 76.3 kg/m^3

Waste Foundry Sand content on equivalent volume basis = $\frac{76.3 \times 2.86}{2.96}$ = 73.72 kg/m^3

Natural Sand = 763 - 224.26 – 73.72 = 464.96 kg/m^3

Water absorbed by Iron Slag = $\frac{224.26 \times 8.7}{100}$ = 19.51 kg/m^3

Water absorbed by Waste Foundry Sand = $\frac{73{,}72 \times 1.62}{100}$ = 1.19 kg/m^3

Therefore, the weight of the material in dry state:

IS = 224.26 – 19.51 = 204.75 kg/m^3

WFS = 73.72 – 1.19 = 72.53 kg/m^3

Total quantity of water = 144 + 19.51 + 1.19 = 164.7 kg/m^3

Table 4-5For mix-1designMix

Material	Water	Cement	RHA	20 mm	10 mm	F.A	I.S	W.F.S	Density
Weight (kg/m^3)	164.7	360	40	598	616	464 .96	204 .75	72.53	2520.9 4

Mix Design of Mix-2 (RHA-IS-FS) as (10-40-20) for PQC:

RHA = 10 % of cement = 400 × 0.10 = 40 kg/m^3

Cement content = 400 – 40 = 360 kg/m^3

Iron Slag 20% of Natural Sand = 763 × 0.40 = 305.2 kg/m^3

Iron slag content on equivalent volume basis = $\frac{305.2 \times 4.35}{2.96}$ = 448.52 kg/m^3

Waste Foundry Sand 10% of Natural Sand = 763 × 0.20 = 152.6 kg/m^3

Waste Foundry Sand content on equivalent volume basis = $\frac{152.6 \times 2.86}{2.96}$ = 147.44 kg/m^3

Natural Sand = 763 – 305.2 – 152.6 = 305.2 kg/m^3

Water absorbed by Iron Slag = $\frac{448.52 \times 8.7}{100}$ = 39.02 kg/m^3

Water absorbed by Waste Foundry Sand = $\frac{147.44 \times 1.62}{100}$ = 2.38 kg/m^3

Therefore, the weight of the material in dry state:

IS = 448.52 – 39.02 = 409.5 kg/m^3

WFS = 147.44 – 2.38 = 145.06 kg/m^3

Total quantity of water = 144 + 39.02 + 2.380 = 185.39 kg/m^3

Table4-6For mix-2designMix

Material	Water	Cement	RHA	20 mm	10 mm	F.A	I.S	W.F.S	Density
Weight (kg/m^3)	185.39	360	40	598	616	305.2	209.5	145.06	2459.15

Mix Design of Mix-3 (RHA-IS-FS) as (10-60-30) for PQC:

RHA = 10 % of cement = 400 × 0.10 = 40 kg/m^3

Cement content = 400 – 40 = 360 kg/m^3

Iron Slag 60% of Natural Sand = 763 × 0.60 = 457.8 kg/m^3

Iron slag content on equivalent volume basis = $\frac{457.8 \times 4.35}{2.96}$ = 672.78 kg/m^3

Waste Foundry Sand 30% of Natural Sand = 763 × 0.30 = 228.9 kg/m^3

Waste Foundry Sand content on equivalent volume basis = $\frac{228.9 \times 2.86}{2.96}$ = 221.16 kg/m^3

Natural Sand = 763 – 457.8 – 228.9 = 76.3kg/m^3

Water absorbed by Iron Slag = $\frac{672.78 \times 8.7}{100}$ = 58.53 kg/m^3

Water absorbed by Waste Foundry Sand = $\frac{221.16 \times 1.62}{100}$ = 3.58 kg/m^3

Therefore, the weight of the material in dry state:

IS = 672.78 – 58.53 = 614.25 kg/m^3

WFS = 221.16 – 3.58 = 217.58 kg/m^3

Total quantity of water = 144 + 58.53 + 3.58 = 206.11 kg/m^3

Table 4-7Mix design for mix-3

Material	Water	Cement	RHA	20 mm	10 mm	F.A	I.S	W.F.S	Density
Weight (kg/m^3)	206.11	360	40	598	616	76.3	614.25	217.58	2728.24

Mix Design of Mix-4 (RHA-IS-FS) as (20-20-20) for PQC:

RHA = 20 % of cement = 400 × 0.20 = 80 kg/m^3

Cement content = 400 – 80 = 320 kg/m^3

Iron Slag 20% of Natural Sand = 763 × 0.20 = 152.6 kg/m^3

Iron slag content on equivalent volume basis = $\frac{152.6 \times 4.35}{2.96}$ = 224.26 kg/m^3

Waste Foundry Sand 20% of Natural Sand = 763 × 0.20 = 152.6 kg/m^3

Waste Foundry Sand content on equivalent volume basis = $\frac{152.6 \times 2.86}{2.96}$ = 147.44 kg/m^3

Natural Sand = 763 – 152.6 – 152.6 = 457.8 kg/m^3

Water absorbed by Iron Slag = $\frac{224.26 \times 8.7}{100}$ = 19.51 kg/m^3

Water absorbed by Waste Foundry Sand = $\frac{147.44 \times 1.62}{100}$ = 2.38 kg/m^3

Therefore, the weight of the material in dry state:

IS = 224.26 – 19.51 = 204.75 kg/m^3

WFS = 147.44 – 2.38 = 145.06 kg/m^3

Total quantity of water = 144 + 19.51 + 2.38 = 165.88 kg/m^3

Table 4-8Mix design for mix-4

	Water	Cement	RHA	20 mm	10 mm	F.A	I.S	W.F.S	Density
Weight (kg/m^3)	165.88	320	80	598	616	457.8	204.75	145.06	2587.5

Mix Design of Mix-5 (RHA-IS-FS) as (20-40-30) for PQC:

RHA = 20 % of cement = 400 × 0.20 = 80 kg/m^3

Cement content = 400 – 80 = 320 kg/m^3

Iron Slag 40% of Natural Sand = 763 × 0.40 = 305.2 kg/m^3

Iron slag content on equivalent volume basis = $\frac{305.2 \times 4.35}{2.96}$ = 448.52 kg/m^3

Waste Foundry Sand 30% of Natural Sand = 763 × 0.30 = 228.9 kg/m^3

Waste Foundry Sand content on equivalent volume basis = $\frac{228.9 \times 2.86}{2.96}$ = 221.16 kg/m^3

Natural Sand = 763 – 305.2 – 228.9 = 228.9 kg/m^3

Water absorbed by Iron Slag = $\frac{448.52 \times 8.7}{100}$ = 39.02 kg/m^3

Water absorbed by Waste Foundry Sand = $\frac{221.16 \times 1.62}{100}$ = 3.58 kg/m^3

Therefore, the weight of the material in dry state:

IS = 448.52 – 39.02 = 409.5 kg/m^3

WFS = 221.16 – 3.58 = 217.58 kg/m^3

Total quantity of water = 144 + 39.02 + 3.58 = 186.6 kg/m^3

Table 4-9Mix design for mix-5

Material	Water	Cement	RHA	20 mm	10 mm	F.A	I.S	W.F.S	Density
Weight (kg/m^3)	186.6	320	80	598	616	228.9	409.5	217.58	2656.58

Mix Design of Mix-6 (RHA-IS-FS) as (20-60-10) for PQC:

RHA = 20 % of cement = 400 × 0.20 = 80 kg/m^3

Cement content = 400 – 80 = 320 kg/m^3

Iron Slag 60% of Natural Sand = 763 × 0.60 = 457.8 kg/m^3

Iron slag content on equivalent volume basis = $\frac{457.8 \times 4.35}{2.96}$ = 672.78 kg/m^3

Waste Foundry Sand 10% of Natural Sand = 763 × 0.10 = 76.3 kg/m^3

Waste Foundry Sand content on equivalent volume basis = $\frac{76.3 \times 2.86}{2.96}$ = 73.72 kg/m^3

Natural Sand = 763 – 457.8 – 73.72 = 228.9 kg/m^3

Water absorbed by Iron Slag = $\frac{672.78 \times 8.7}{100}$ = 58.53 kg/m^3

Water absorbed by Waste Foundry Sand = $\frac{73{,}72 \times 1.62}{100}$ = 1.19 kg/m^3

Therefore, the weight of the material in dry state:

IS = 672.78 – 58.53 = 614.25 kg/m^3

WFS = 73.72 – 1.19 = 72.53kg/m^3

Total quantity of water = 144 + 58.53 + 1.19 = 203.72 kg/m^3

Table 4-10Mix design for mix-6

Material	Water	Cement	RHA	20 mm	10 mm	F.A	I.S	W.F.S	Density
Weight (kg/m^3)	203.72	320	80	598	616	228.9	614.25	72.53	2733.4

Mix Design of Mix-7 (RHA-IS-FS) as (30-20-30) for PQC:

RHA = 30 % of cement = 400 × 0.30 = 120 kg/m^3

Cement content = 400 – 120 = 280 kg/m^3

Iron Slag 20% of Natural Sand = 763 × 0.20 = 152.6 kg/m^3

Iron slag content on equivalent volume basis = $\frac{152.6 \times 4.35}{2.96}$ = 224.26 kg/m^3

Waste Foundry Sand 30% of Natural Sand = 763 × 0.30 = 228.9 kg/m^3

Waste Foundry Sand content on equivalent volume basis = $\frac{228.9 \times 2.86}{2.96}$ = 221.16 kg/m^3

Natural Sand = 763 – 152.6 – 228.9 = 381.5 kg/m^3

Water absorbed by Iron Slag = $\frac{224.26 \times 8.7}{100}$ = 19.51 kg/m^3

Water absorbed by Waste Foundry Sand = $\frac{221.16 \times 1.62}{100}$ = 3.58 kg/m^3

Therefore, the weight of the material in dry state:

IS = 224.26 – 19.51 = 204.75 kg/m^3

WFS = 221.16 – 3.58 = 217.58 kg/m^3

Total quantity of water = 144 + 19.51 + 1.19 = 167.09 kg/m^3

Table 4-11Mix design for mix-7

Material	Water	Cement	RHA	20 mm	10 mm	F.A	I.S	W.F.S	Density
Weight (kg/m^3)	167.09	280	120	598	616	381 .5	204. 75	217.58	2584.9 2

Mix Design of Mix-8 (RHA-IS-FS) as (30-40-10) for PQC:

RHA = 30 % of cement = 400 × 0.30 = 120 kg/m^3

Cement content = 400 – 120 = 280 kg/m^3

Iron Slag 40% of Natural Sand = 763 × 0.40 = 305.2 kg/m^3

Iron slag content on equivalent volume basis = $\frac{305.2 \times 4.35}{2.96}$ = 448.52 kg/m^3

Waste Foundry Sand 10% of Natural Sand = 763 × 0.10 = 76.3 kg/m^3

Waste Foundry Sand content on equivalent volume basis = $\frac{76.3 \times 2.86}{2.96}$ = 73.72 kg/m^3

Natural Sand = 763 – 305.2 – 76.3 = 381.5 kg/m^3

Water absorbed by Iron Slag = $\frac{448.52 \times 8.7}{100}$ = 39.02 kg/m^3

Water absorbed by Waste Foundry Sand = $\frac{73,72 \times 1.62}{100}$ = 1.19 kg/m^3

Therefore, the weight of the material in dry state:

IS = 448.52 – 39.02 = 409.5 kg/m^3

WFS = 73.72 – 1.19 = 72.53 kg/m^3

Total quantity of water = 144 + 39.02 + 1.19 = 184.21 kg/m^3

Table 4-12Mix design for mix-8

Material	Water	Cement	RHA	20 mm	10 mm	F.A	I.S	W.F.S	Density
Weight (kg/m^3)	184.21	280	120	598	616	381.5	409 .5	72.53	2661.74

Mix Design of Mix-9 (RHA-IS-FS) as (30-60-20) for PQC:

RHA = 30 % of cement = 400 × 0.30 = 120 kg/m^3

Cement content = 400 – 120 = 280 kg/m^3

Iron Slag 60% of Natural Sand = 763 × 0.60 = 457.8 kg/m^3

Iron slag content on equivalent volume basis = $\frac{457.8 \times 4.35}{2.96}$ = 672.78 kg/m^3

Waste Foundry Sand 20% of Natural Sand = 763 × 0.20 = 152.6 kg/m^3

Waste Foundry Sand content on equivalent volume basis = $\frac{152.6 \times 2.86}{2.96}$ = 147.44 kg/m^3

Natural Sand = 763 – 457.8 – 152.6 = 152.6 kg/m^3

Water absorbed by Iron Slag = $\frac{672.78 \times 8.7}{100}$ = 58.53 kg/m^3

Water absorbed by Waste Foundry Sand = $\frac{147.44 \times 1.62}{100}$ = 2.38 kg/m^3

Therefore, the weight of the material in dry state:

IS = 672.78 – 58.53 = 614.25 kg/m^3

WFS = 147.44 – 2.38 = 145.06 kg/m^3

Total quantity of water = 144 + 19.51 + 1.19 = 164.7 kg/m^3

Table 4-13Mix design for mix-9

Material	Water	Cement	RHA	20 mm	10 mm	F.A	I.S	W.F.S	Density
Weight (kg/m^3)	204.9	280	120	598	616	152.6	614.25	145.06	2730.81

4.2 CASTING AND CURING OF CONCRETE SAMPLES FOR PQC:

According to the design mix as per IRC 44: 2017 first all quantities of the materials were measured and then mix the material using potable water from laboratory using the technique of hand mixing. The whole process was done as per IS standards and proper care was taken in preparation of mixes. The slump test were performed immediately after the mixing of concrete. According to guidelines specified in IS codes, casting moulds were used of size 15 cm for casting of cubes and 70 cm for casting of beams. For compaction of concrete in moulds the table vibrator was used. The marking of specimens was done after the compaction of concrete moulds and after 24 hours, the specimens were demoulded to put in the curing tanks for specified time as for 28 and 7 days.

After the casting, the samples were demoulded after 24 hrs. When the demoulding process was done then the samples were kept in the curing tank for 7 and 28 days as per the requirement. All the cubes and beams were kept in the curing tank for the specified time. The casting of the concrete samples was done as per the procedure guidelines given in IS codes. According to the design mix first weight of all the material were calculated and then the materials were mixed accordingly. The mixed material was then filled in the moulds accordingly. These materials were then compacted using compaction table. Then the casted samples were kept for 24 hrs and after that demoulding of the sample was done. Immediately after the demoulding process, the samples were put into the curing tank for their specified time as 7 days and 28 days.

Figure4-1Concrete Hand mixing

Figure4-2 Freshly prepared samples

Figure 4-3 Marking done on the Samples

Figure 4-4Curing tanks used

CHAPTER 5 CONCRETE TESTING METHODS AND RESULTS

5.1. Compressive strength

Specimens compressive strength of the size 15 × 15 × 15 (cm) was determined. The samples are examined for 7 days and 28 days and tested in (CTU) compression testing machine. The strength of the concrete was taken as an Average of three cubes. The concrete sample was immediately tested after taking out of the curing tank, removing dirt or any such material to have smooth surface.

Compressive strength = load of failure / cross sectional area (mm^2)

Table 5-1Results of Compressive strength

Compressive Strength (MPa)			
MIX	Concrete Type (M-40)	7 DAYS	28 DAYS
CM	RHA-0%/IS-0%/WFS-0%	31.13	48.4
M1	RHA-10%/IS-20%/WFS-10%	26.07	40.8
M2	RHA-10%/IS-40%/WFS-20%	24.27	38.27
M3	RHA-10%/IS-60%/WFS-30%	20.93	30.33
M4	RHA-20%/IS-20%/WFS-20%	25.2	39.2
M5	RHA-20%/IS-40%/WFS-30%	22.13	34
M6	RHA-20%/IS-60%/WFS-10%	19.07	31.53
M7	RHA-30%/IS-20%/WFS-30%	19.13	32
M8	RHA-30%/IS-40%/WFS-10%	15.53	29.07
M9	RHA-30%/IS-60%/WFS-20%	14.87	27.73

Figure 5-1 Compression Testing Machine

Figure 5-2 Cracks on cube after testing

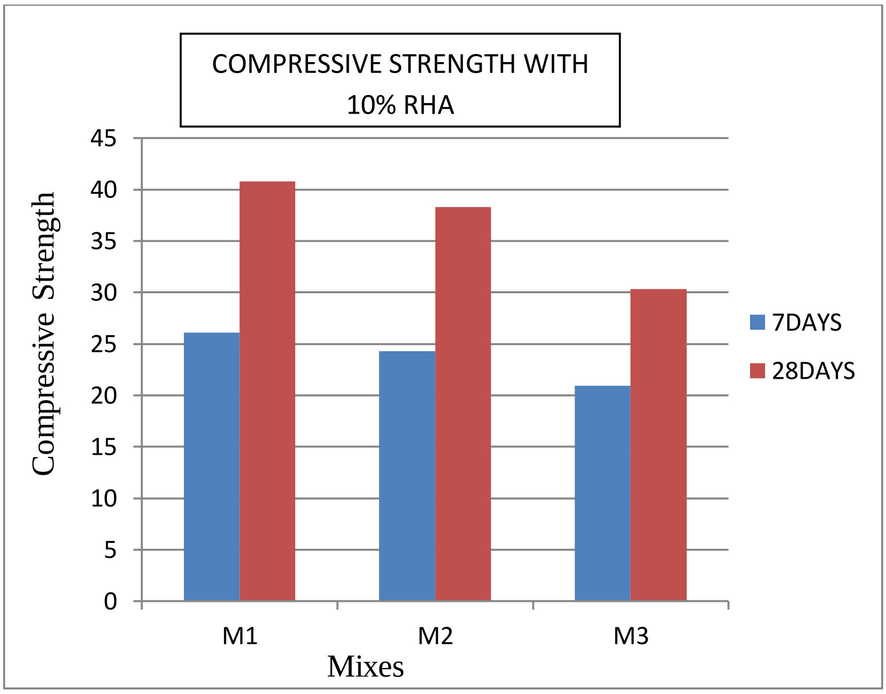


Figure5-3Graph for compressive strength of mixes having 10% RHA

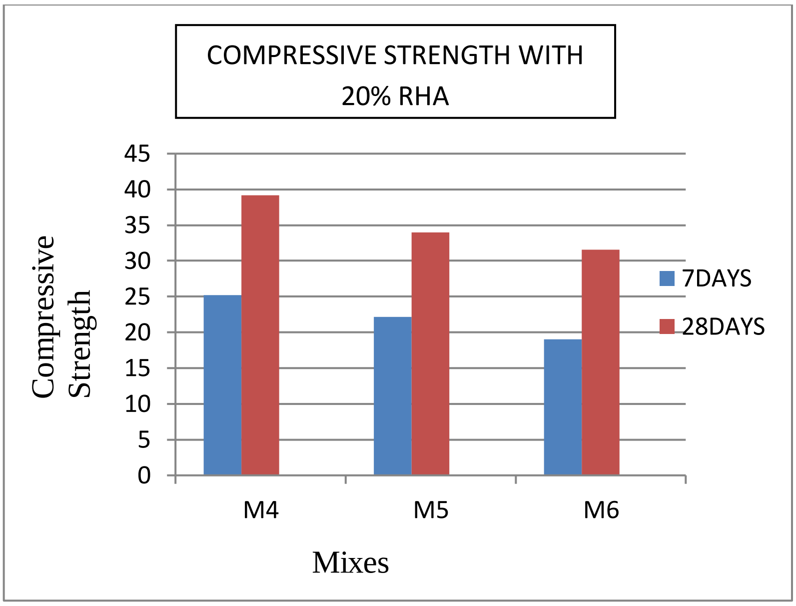


Figure5-4 Graph for compressive strength of mixes having 20% RHA

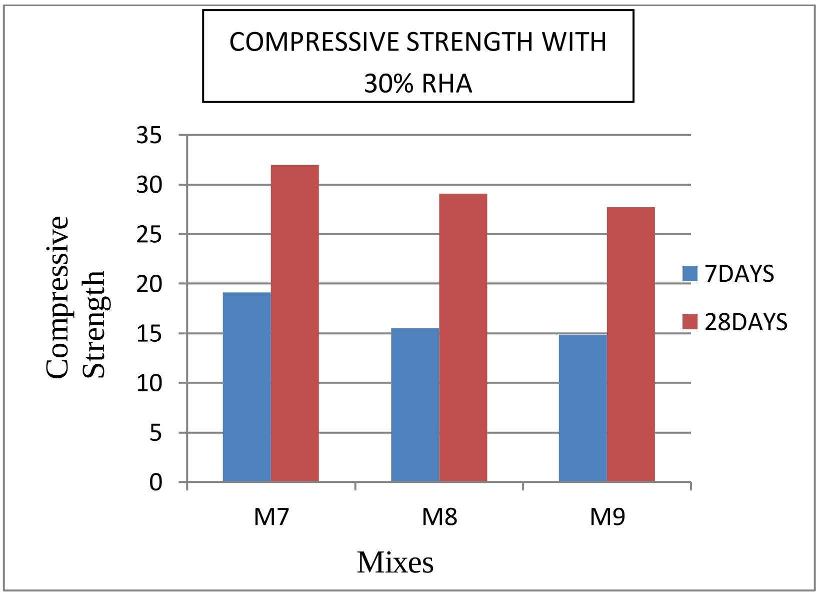


Figure 5-5 Graph for compressive strength of mixes having 30% RHA

5.2. Flexural Strength

Table 5-2Concrete Flexural Strength Results

Flexural Strength (MPa)		
MIX	Concrete Type (M-40)	28 Days
CM	RHA-0%/IS-0%/WFS-0%	5.05
M1	RHA-10%/IS-20%/WFS-10%	4.56
M2	RHA-10%/IS-40%/WFS-20%	4.26
M3	RHA-10%/IS-60%/WFS-30%	3.51
M4	RHA-20%/IS-20%/WFS-20%	4.4
M5	RHA-20%/IS-40%/WFS-30%	3.86
M6	RHA-20%/IS-60%/WFS-10%	3.61
M7	RHA-30%/IS-20%/WFS-30%	3.74
M8	RHA-30%/IS-40%/WFS-10%	3.42
M9	RHA-30%/IS-60%/WFS-20%	2.97

Figure 5-6 Universal Testing Machine

Figure 5-7 Cracks in Beam after testing

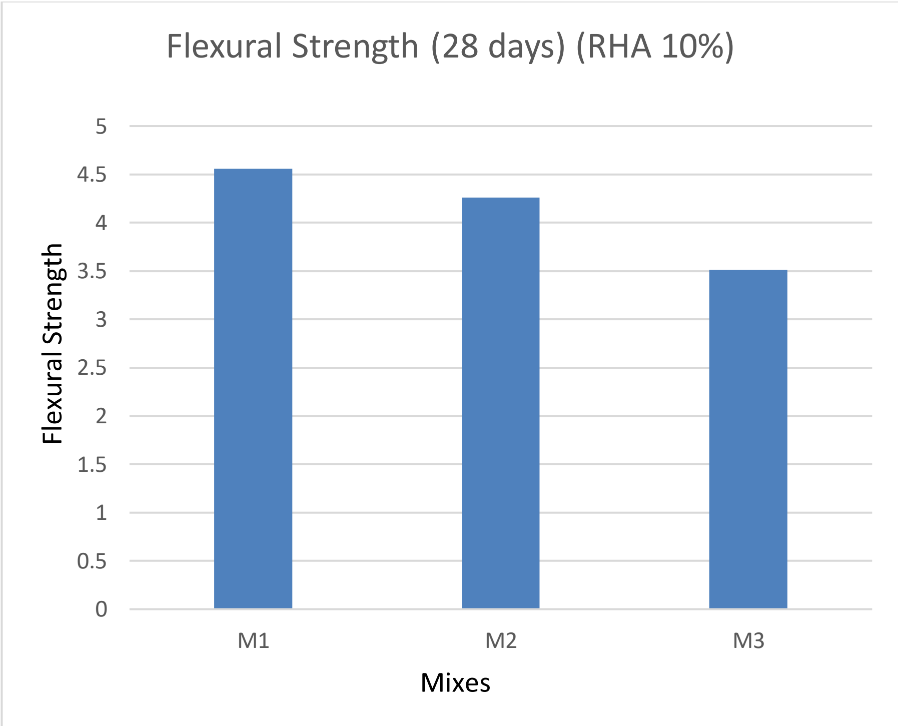


Figure 5-8Graph for flexural strength of mixes having 10% RHA

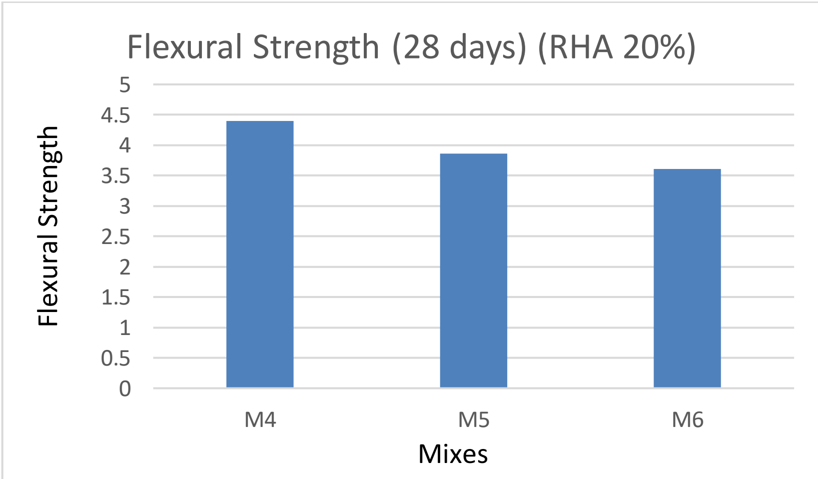


Figure 5-9Graph for flexural strength of mixes having 20% RHA

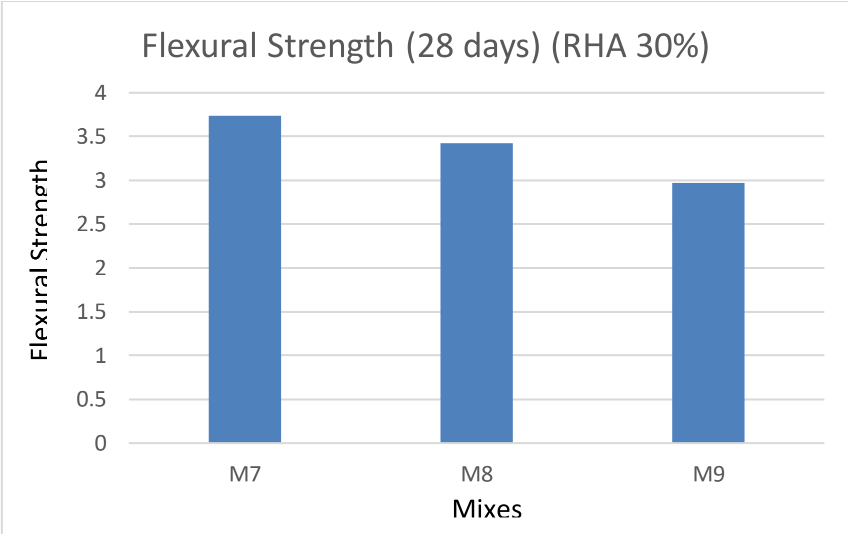


Figure 5-10Graph for flexural strength of mixes having 30% RHA

5.3 MINITAB ANALYSIS

The different mixes formed using Taguchi method were tested for flexural strength and compressive strength. These results do not provide the clear vision which shows that how the materials (RHA, IS, WFS) affects the values of compressive strength, and also flexural strength.

Table 5-3 Minitab analysis

Level	RHA	IS	WFS
1	36.47	37.33	33.80
2	34.91	33.78	35.07
3	29.60	29.87	32.11
Delta	6.87	7.47	2.96
Rank	2	1	3

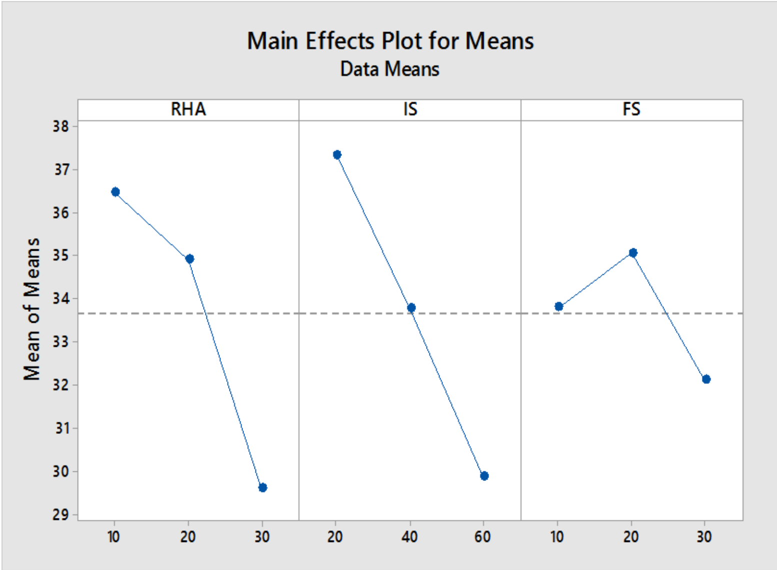


Figure 5-11 Graph representing Minitab Analysis

The graphs using Minitab analysis clearly states that the rise for 10 % RHA and further, decreases for 20 % and 30 % replacement. RHA graph shows rise for 10 % and falls in graph for 20 % and further a big fall for 30 %. For Iron Slag 20 % replacement shows the optimum value for the test results, whereas for 40 % and 60 % values show a big fall. Though, Waste Foundry Sand shows 20 % as an optimum replacement for strength of PQC. WFS graph shows no change for 10 %, rise in graph for 20 % and a big fall for 30 %. According to the Minitab analysis the optimum combination for the strength is 10 % RHA, 20 % for Iron Slag and 20 % for Waste Foundry Sand.

CHAPTER 6 DESIGN AND ANALYSIS OF PAVEMENT QUALITY CONCRETE

Considering flexural strength value attained for ideal mixes in flexural strength test. A rigid pavement or pavement quality concrete slab is designed as per the guidelines of IRC 58-2016. By the end construction period, design for the slab for four lane for national highway with 3000 commercial vehicles. The slab thickness design is such that the cumulative fatigue damage due to effect of all stresses should be less than one.

6.1 DESIGN OF SLAB THICKNESS

Rigid pavement details

Carriage way – Four lanes (divided two-way) Tied concrete shoulder – Yes

Width of Lane – 3.5 m Spacing for Transverse joint–4.5 m

Yes, dowel bars has transverse joints

Table 6-1 Structural details of pavement

Reaction of Sub-Grade modulus	50.33 MPa/m
Thickness of granular sub-base	150 mm
Thickness DLC	150 mm
Effective modulus for reaction of sub-grade	285 MPa/m
Concrete Unit weight	24 kn/m^3
Concrete Elastic modulus	30000 MPa
Concrete's Poisson ratio	0.15
Beta value for dowelled joints	0.66
Max.temperature in slab in day-time, (of cracking for bottom-up) (for Punjab)	15.8^{o}C
Max. temperature in differential in slab for night-time, (of cracking for top-down) = {(daytime/2) +5}	12.9^{o}C

Table 6-2 Design traffic Estimation

Design period	30 years
Total CVPD for two-way at end of construction period	6000
Avg. annual rate growth of traffic	7.5 %
Cumulative construction traffic during design period, A	226444692
Avg. no. of axles per commercial vehicles, B	2.35
During design period Cumulative no. of axles, C = A*B	532145025
In predominant direction Proportion of traffic, D	0.50
Factor of Lateral placement, E	0.250
Factor to select the traffic for 12 hrs day time, F, 40 % traffic	0.4
Factor to select the traffic for 12 hrs night time, F, 60 % traffic	0.6
BUC analysis for Design axle repetition(for 6 hrs day time), H = C×D×E×F/2	13303626
TDC analysis for Design axle repetition (for 6 hrs day time), J = C×D×E×G×I/2	0.55
Proportion of vehicles of transverse joint with of spacing between front and the first rear axle less than the spacing, I	10975491

Table 6-3 For Fatigue analysis of design axle load repetitions

Type of axle	Proportion	Bottom up	Top down
Front single steering	0.450	5986632	4938971
Rear single	0.150	1995544	1646324
Tandem	0.250	3325906	2743873
Tridem	0.150	1995544	1646324

Table6-4Spectrum Axle Load

Single Axle(Rear)			Tandem Axle (Rear)			Tridem Axle(Rear)		
Group of Load(kN)	Group of Load MidPoint (kN)	(%)Frequency	Group of Load(kN)	Group of Load MidPoint (kN)	(%)Frequency	Group of Load(kN)	Group of Load MidPoint (kN)	(%)Frequency
185-195	190	18.15	380 - 400	390	14.5	530-560	545	5.23
175-185	180	17.43	360 - 380	370	10.5	500-530	515	4.85
165-175	170	18.27	340 - 360	350	3.63	470-500	485	3.44
155-165	160	12.98	320 - 340	330	2.5	440-470	455	7.12
145-155	150	2.98	300 - 320	310	2.69	410-440	425	10.11
135-145	140	1.62	280 - 300	290	1.26	380-410	395	12.01
125-135	130	2.62	260 - 280	270	3.9	350-380	365	15.57
115-125	120	2.65	240 - 260	250	5.19	320-350	335	13.28
105-115	110	2.65	220 - 240	230	6.3	290-320	305	4.55
95-105	100	3.25	200 - 220	210	6.4	260-290	275	3.16
85-95	90	3.25	180 - 200	190	8.9	230-260	245	3.1
< 85	80	14.15	< 180	170	34.23	< 230	215	17.58
		100			100			100

Table 6-5 positive temperature differential and BUC analysis for Design axle repetition(for 6 hrs day time).

Rear Single Axles					Rear Tandem Axles				
Expected Repetitions (ni)	Flex Stress MPa	Stress Ratio (SR)	Allowable Repetitions (Ni)	Fatigue Damage (ni/Ni)	Expected Repetitions (ni)	Flex Stress MPa	Stress Ratio (SR)	Allowable Repetitions (Ni)	Fatigue Damage (ni/Ni)
362191	3.001	0.540	165299	2.191	482256	2.576	0.464	9550837.9	0.050
347823	2.891	0.520	320924	1.084	349220	2.476	0.446	I	0
364586	2.781	0.501	738462	0.494	120730	2.377	0.428	I	0
259022	2.671	0.481	2266519	0.114	83148	2.278	0.410	I	0
59467	2.561	0.461	12669001	0.005	89467	2.179	0.392	I	0
32328	2.451	0.441	I	0	41906	2.08	0.374	I	0
52283	2.341	0.421	I	0	129710	1.981	0.357	I	0
52882	2.231	0.402	I	0	172615	1.882	0.339	I	0
52882	2.121	0.382	I	0	209532	1.783	0.321	I	0
64855	2.011	0.362	I	0	212858	1.684	0.303	I	0
64855	1.901	0.342	I	0	296006	1.584	0.285	I	0
282369	1.791	0.322	I	0	1138458	1.485	0.267	I	0
1995544	Fat Dam from Sing. Axles =			3.88764	3325906	Fat Dam from T and Axles =			0.0505
Total Bottom-up Fatigue Damage due to single and tandem axle loads =					3.888	+	0.050	=	3.9381

Slab thickness design for concrete:

Assume slab thickness h, = 240 mm. So, radius of relative stiffness = 0.59 I = Infinite

For control mix of concrete M40 grade, the 28 days flexural strength achieved is 5.05 MPa. 90 days strength using conversion factor is $5.05 \times 1.1 = 5.55$ MPa.

Table 6-6 negative temperature differential and TDC analysis for Design axle repetition (for 6 hrs night time)

Single Axles (Rear)					Tandem Axles (Rear) (Stress computed for 50% of axle load)					Tridem Axles (Rear) (Stress computed for 33% of axle load)				
Expected Repetitions (ni)	Flex Stress MPa	Stress Ratio (SR)	Allowable Repetitions (Ni)	Fatigue Damage (ni/Ni)	Expected Repetitions (ni)	Flex Stress MPa	Stress Ratio (SR)	Allowable Repetitions (Ni)	Fatigue Damage (ni/Ni)	Expected Repetitions (ni)	Flex Stress MPa	Stress Ratio (SR)	Allowable Repetitions (Ni)	Fatigue Damage (ni/Ni)
298808	2.71	0.48	1344831	0.222	397862	2.75	0.49	929006	0.428	86103	2.65	0.478	2785575	0.031
286954	2.64	0.47	3293021	0.087	288107	2.68	0.48	2041034	0.141	79847	2.57	0.464	8915798	0.009
300783	2.56	0.46	11352462	0.026	99603	2.60	0.46	5768308	0.017	56634	2.50	0.451	55204671	0.001
213693	2.49	0.44	I	0	68597	2.52	0.45	26693693	0.003	117218	2.42	0.437	I	0
49060	2.41	0.43	I	0	73810	2.45	0.44	I	0	166443	2.35	0.424	I	0
26670	2.34	0.42	I	0	34573	2.37	0.42	I	0	197723	2.27	0.410	I	0
43134	2.26	0.40	I	0	107011	2.30	0.41	I	0	256333	2.20	0.396	I	0
43628	2.18	0.39	I	0	142407	2.22	0.40	I	0	218632	2.12	0.383	I	0
43628	2.11	0.38	I	0	172864	2.15	0.38	I	0	74908	2.05	0.369	I	0
53506	2.03	0.36	I	0	175608	2.07	0.37	I	0	52024	1.97	0.356	I	0
53506	1.96	0.35	I	0	244205	2	0.36	I	0	51036	1.89	0.342	I	0
232955	1.88	0.34	I	0	939228	1.92	0.34	I	0	289424	1.82	0.328	I	0
1646324	Fatigue Damage from Single Axles =			0.3358	2743873	Fatigue Damage from Tandem Axles =			0.589	1646324	Fatigue Damage from Tridem Axles =			0.0408
Total Top-Down Fatigue Damage =								0.335824	+	0.589260	+	0.04089	=	0.96597

I = Infinit

Sum of CFS for BUC and TDC = 4.904

Deign is unsafe as sum of BUC and TDC is greater than 1(>1)

As the design is UNSAFE the thickness will be increased till the sum of BUC and TDC comes out to be less than 1. Similarly, the thickness is increased by 2 mm till the sum of BUC and TDC comes out to be <1.

Table 6-7 Fatigue Damage on various thicknesses for control mix

S. No.	Assumed Thickness (mm)	Radius of relative stiffness	Fatigue damage
1	240	0.59	4.904
2	242	0.59	3.9
3	244	0.60	3.076
4	246	0.60	2.401
5	248	0.60	1.858
6	250	0.61	1.425
7	252	0.61	1.078
8	253	0.61	0.929
9	254	0.61	0.798
10	255	0.62	0.686

The adequate thickness as per design is 253 mm or 25.3 cm.

Slab design for mix-1 with (RHA-IS-WFS) (10%-20%-10%)

Similarly, as per the results of flexural strength of concrete, mix-1 got the strength as per the concrete Flexural strength for 28 days of concrete is 4.56 MPa and for 90 days it is 5.01 MPa.

Table 6-8 Fatigue Damage on various thicknesses for mix-1

S. No.	Assumed Thickness (mm)	Radius of relative stiffness	Fatigue damage
1	260	0.63	5.440
2	262	0.63	4.477
3	264	0.63	3.660
4	266	0.64	2.978
5	268	0.64	2.407
6	270	0.64	1.926
7	272	0.65	1.531
8	274	0.65	1.204
9	276	0.65	0.934
10	278	0.66	0.715

The adequate thickness as per the design is 27.6 cm for M1 mix with flexure of 4.56 for 28 days and 5.016 for 90 days.

6.2 ECONOMIC ANALYSIS

The cost of the slab can be calculated in terms of 1 m^3. Construction cost is estimated by cost of the materials used in the construction and the cost of the material will depend upon the material quantity and its unit price. The economic analysis is as per the rate list of CSIR-CRRI, New Delhi.

Table 6-9 Unit rate of material according to CSIR

S. No.	Item	Specifications	Current cost (INR)
1	Cement	Ultra tech OPC 43	INR 300/bag
2	Coarse aggregate 20 mm	10 mm	INR50/cubic feet
3	Coarse aggregate 10 mm	20 mm	INR50/cubic feet
4	Fine aggregate	Natural sand	INR45/cubic feet
5	Super plasticizer	Modified PCE	INR 58/kg
6	Rice Husk Ash	RHA	INR 0/kg
7	Iron Slag	IS	INR 0/kg
8	Waste Foundry Sand	WFS	INR 0/kg

Table 6-10 Unit rate per Kilogram

Material	Rate/cubic feet	Density kg/m^3	Rate/cum	Rate/kg
10 mm C.A	50	1600	1765.74	1.10
20 mm C. A	50	1700	1765.74	1.04
Natural sand	45	1360	1589.16	1.17

The cost of the 1 $m^3$of control mix M40 PQC is calculated based on the quantities of the materials.

Table 6-11 Cost of production of 1m^3 of control mix of M40 Grade concrete

Item	Quantity (kg/cum)	Rate (Rs/kg)	Cost (Rs/cum)
cement OPC 43	400	6	2400
Fine aggregate	763	1.17	892.71
C.A 20 mm	598	1.04	621.92
C.A 10 mm	616	1.1	677.6
superplasticizer	4	58	232
		Total Cost	4824.23

The cost for Mix 1 with 10% Rice Husk Ash, 20% Iron Slag and 10% Waste Foundry Sand for 1m^3 PQC is calculated. Its calculations are based on the amounts of materials as in the table below:

Table 6-12Cost production of 1m^3 of mix-1 of M40 Grade concrete with RHA-IS-WFS

Item	Quantity (kg/cum)	Rate (Rs/kg)	Cost (Rs/cum)
cement OPC 43	360	6	2160
Fine aggregate	464.96	1.17	544.0032
C.A 20 mm	598	1.04	621.92
C.A 10 mm	616	1.1	677.6
superplasticizer	4	58	232
RHA	40	0	0
IS	204.75	0	409.5
WFS	72.53	0	0
		Total cost	4235.52

The economic analysis for the PQC is determined by comparing the adequate thickness of the two PQC concrete slab, that is one which is convention concrete or control mix and one with 10% RHA, 20% IS and 10% WFS or Mix-1. The calculation for 3.5 m width one lane of PQC for 1 Km length with adequate length of 0.253 m of conventional concrete and 0.276 m for Mix-1 is as given in table.

Table 6-13 Cost comparison between two mixes

Type of Concrete	Dimension	Volume (cumecs)	Rate of Concrete (Rs / cum)	Total Cost (Rupees)
Conventional Concrete	1000×3.5×0.253	885.5	4824.23	4271856
Concrete with Mix-1	1000×3.5×0.276	966	4235.52	4091512

From the above table it is clear that the Mix-1, the cost of concrete decreased by Rs 180344 per lane per Km. The percentage decrease in cost of concrete from above table is 4.22 %.

CONCLUSION

From the thesis investigation conclusions comes out are given below:

1. The optimum Mix for the PQC with RHA, IS and WFS is Mix-1.
2. Mix-1 with 10% RHA, 20% IS and 10% WFS is the mix which have flexural strength of 4.56 MPa and compressive strength with 26.07 MPa and on the other hand 40.8 MPa with 7 and 28 curing days with respectively.
3. As per the Minitab Analysis the optimum replacement percentage for RHA10%, 20% for Iron Slag and 20% for Waste Foundry Sand.
4. In SEM test of analysis for RHA the pictures show that the particles are in the irregular shape
5. In SEM test of analysis for Iron Slag the pictures show that the particles are in the solid and irregular shape
6. In SEM test of analysis for Iron Slag the pictures show that the particles are in the solid, irregular shape and also some are in sphere shape.
7. As per the economic analysis cost for PQC decreases by 4.22 % for Mix-1 (M1) to the comparison of control mix.
8. Waste industrial materials in usage will reduce environment pollution and also decreases the cost for the PQC construction.

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