STRENGTH AND WORKABILITY OF CONCRETE MADE SLAG WITH GROUND GRANULATED BLAST FURNACE

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Abstract

Technology is an important and essential part for making improvements. Improvement in technology affects construction projects. Various factors that affect the construction projects identified in this research. Presence of different environmental factors present in the site may affect the nature of concrete. This research work has used potential Brick Dust waste for development of concrete with proper mixing with Portland cement. The materials that are used in the research work have lead to the formation of the new scope for modifying the testing and the utility of concrete in different purposes. It consists of testing processes for measuring the workability and strength of concrete with the help of Ground Granulated Blast Furnace. This research will help to evaluate the various tests for identifying the compression strength of concrete. Moreover, the analysis that has been done will give a new concept to the workers for enhancing the workable condition of the concrete. This research has demonstrated the availability of resources for conducting the tests of concrete and the mix design of concrete. Findings from the research will help the researcher to identify the issues faced by the workers at the time of experiments. For investigating the cement replacement potential of BDW, four types of designs are being used in the study by keeping variable levels of BDW replacement. The testing of concrete has involved slump test, compaction test, and Vee-Bee consist meter test in order to find the suitable workability of concrete. The testing program that is included in the study has determined the compressive strength and workability of concrete. The values of slump and compression will be evaluated in the study of the conventional concrete along with the production of cement and their types. This research reports the minimization of the problems that may affect the ordinary concrete making procedure and aims to discover the final results. Various components and raw materials in the cement will be evaluated in the research for getting an idea of its reactions. Moreover, this will help to evaluate the problems associated with the occurrence of fire in the clay buildings.

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Acknowledgement

I (Name of the student) would like to express sincere gratitude to my teacher (Name of the teacher) for giving me this wonderful opportunity to perform this wonderful project on the topic *STRENGTH AND WORKABILITY OF CONCRETE MADE SLAG WITH GRAND GRANULATED BLAST - FURNACE.*

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Chapter 1.0: Introduction

1.1 Introduction

Construction projects are highly focussed on several materials like steel, brick, glass, wood, cement and other similar factors. 70% of cement construction is the main construction material that is used in the projects of construction in modern days so that they can enhance their constructions robustness. Utilising the cement construction into the appropriate format is the main challenge that the present workers and owners of the construction project face in modern contemporary society. Concrete is a mixture, of course, cement and fine aggregate. HPC (High-performance concrete) follows set of standards rules and regulation in order to create their building construction in a precise manner. Slate is a durable roofing material quarried and mined in the UK. It has seen that slate production naturally increases the rate of waste and this maximizes their construction cost. In present days, cement construction is highly preferred as it is highly durable in nature and decreases the rate of waste. There are several kinds of cement which includes Portland cement, limestone aggregates, super plasticiser and slate waste aggregate. GGBS (Ground Granulated Blast furnace Slag) is the by-product of the blast furnace and it is used to make iron. It is prepared with the aids of calcium oxide, alumina, magnesia, and silica. GGBS with the combination of Portland cement increases robustness and longevity of the construction.

1.2 Background

GBBS is widely used in Europe than the UK and in Asia. Concrete made with GGBS is slowly constructed in order to maximize their strength and longevity. There are a lot of merits while owners of the construction projects used this GGBS construction structure. These GGBS construction projects are either site batched or ready mixed durable concrete in nature. Therefore, this construction projects can easily mitigate the risk related to internal reactions of ASR. It is highly resistant to the risk based on sulphates and provides the construction projects high sustainable benefits. Deb *et al.* (2014) mentioned that one main disadvantage that the construction projects faced when they are using the GGBS for their project is long time customer in nature. Setting time in an appropriate manner will decrease the rate of chaotic attitude from the projects and this will increases the performance level of the workers. This project mitigates water usage and it also requires very less energy based on their movements.

Current researchers are highly concerned with the waste material of construction projects in order to decrease the rate of waste along with project cost. Owners of the projects use improved slag cement so that they can improve their resistance and decreases the rate of risk and hazards. There is a different type of batching plant in order to decrease the rate of chaotic attitude from the construction project. As per Islam *et al*. (2014), GGBS diminish the damages that are caused due to ASR (alkali-silica reaction) and thus, they can increase their longevity along with its durability. Owners of the project perform the test before implementing this GGBS into their project. This hypothetical test helps them to predict issues and thus, they can take all the necessary steps in order to decrease pessimistic factors from this project.

1.3 Problem statement

The problem statement of the study is to analyze lack of strength and durability of ordinary Portland cement is making good quality structures. Limitations in issues in work progress and the problems faced by workers in their working environment

1.4 Research rationale

Workers of the construction programme faced security problems and this mitigates their execution level. Owners of different construction projects perform adequate research based on their governmental policies and other macro factors. This research helps them to construct their project in an appropriate manner.

As per viewpoint of Humad *et al.* (2017), it has been seen that in the UK, about 53% of the projects are incomplete because it faces a lot of government penalties and it also increases the rate of crime and scandals. Perfect market research and hypothetical test based on construction increase safety rate of the workers and it also mitigates negative issues from their projects. Systematic strategy and perfect raw material raise communication and interaction rate between the workers and owners of the construction project.

Workers follow rules and a rough sketch of the project so that they can increase their creativity along with its performance level. Perfect communication with the project workers and owners help them to keep employers updated on the issues that they face during their construction of buildings.

Henceforth, reconstructed strategy diminishes the rate of detrimental issues in an effective manner and maximizes satisfaction level of the workers based in construction. Perfect strategy

and advanced technology aid them to predict issues in a proper manner and this improves their project sustainability and longevity.

1.5 Research aim

The aim of this study is to identify the issues and problems that the workers faced during different construction programmes and the concept of workability in concrete based on the granulated furnace and its impact.

1.6 Research objectives

To understand the concepts of different construction projects related to concrete ground granulated furnace slag

To identify the issues related to the internal work area of a construction programme and maximising execution level of the workers

To analyze the impact of workability factors related to concrete with granulated blast slag furnace

To suggest recommendation to raise conductivity of the workers and to increase safety measures of workers.

1.7 Research question

What are the concepts related to workers satisfaction level in GGBS project?

What are the issues that the workers faced in their working area?

What are the impacts of testing of concrete in the laboratories to raise their construction project and to decrease their project cost?

What are the suggestions required to increase positive factors of the workers related to GGBS construction project?

1.8 Research hypothesis

H0: There is no sign of workers retention in the construction projects based on GGBS.

H1: There is the significance to increase interaction between the owners and workers in construction projects.

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1.9 Significance of the study

According to Dadsetan and Bai (2017), a systematic collaboration between workers and owners of the project increases the rate of negative issues from the construction projects. Brick dust is the partial substitute of the Portland cement related to different construction programmes. Portland cement is the energy-intensive procedure that reduces waste material and decreases the construction cost. The government of UK are highly concerned with their environment and thus, fuel ash; marvel dust can easily be reduced by using their Portland cement. Shin *et al.* (2016) mentioned that new pozzolanic material decreases the rate of waste and therefore, UK government preferred this material in their construction project instead of this Portland cement. In recent days, differently, construction projects use the combination of Brick dust waste in order to replace cement. This replacement decreases construction cost along with waste material of the projects. Traditional construction projects are eco-friendly in nature and therefore, present day's construction also uses a different strategy of traditional concepts so that they can follow green approach while making their construction.

Hand approach is used by the traditional approach in order to mitigate balling of fibers of different concretes. Fibre increases the weight of the cement and to mitigate it, modern construction projects also follow the traditional approach to eliminate this cement issue. The workers conduct sieve analysis so that they can perform perfect analysis of different particle used in the project. Sotiriadou *et al.* (2014) illustrated that coefficient curvature analysis is performed by this sieve analysis decrease the rate of detrimental factors based on the raw material of the construction projects. Water-cement ratio is the workers conduct another analysis so that they can maintain the texture of the aggregate in a proper way. The workers of the construction program to determine the specific gravity of fine aggregates use the pycnometer.

Zhao *et al.* (2015) demonstrated that GGBS is created on the hot furnace in order to convert iron oxides to liquid iron in a decent manner. This conversion of iron oxides is popularly known as hot metal and it plays a very vital role to improve the quality of the projects based on construction.

1.10 Dissertation structure

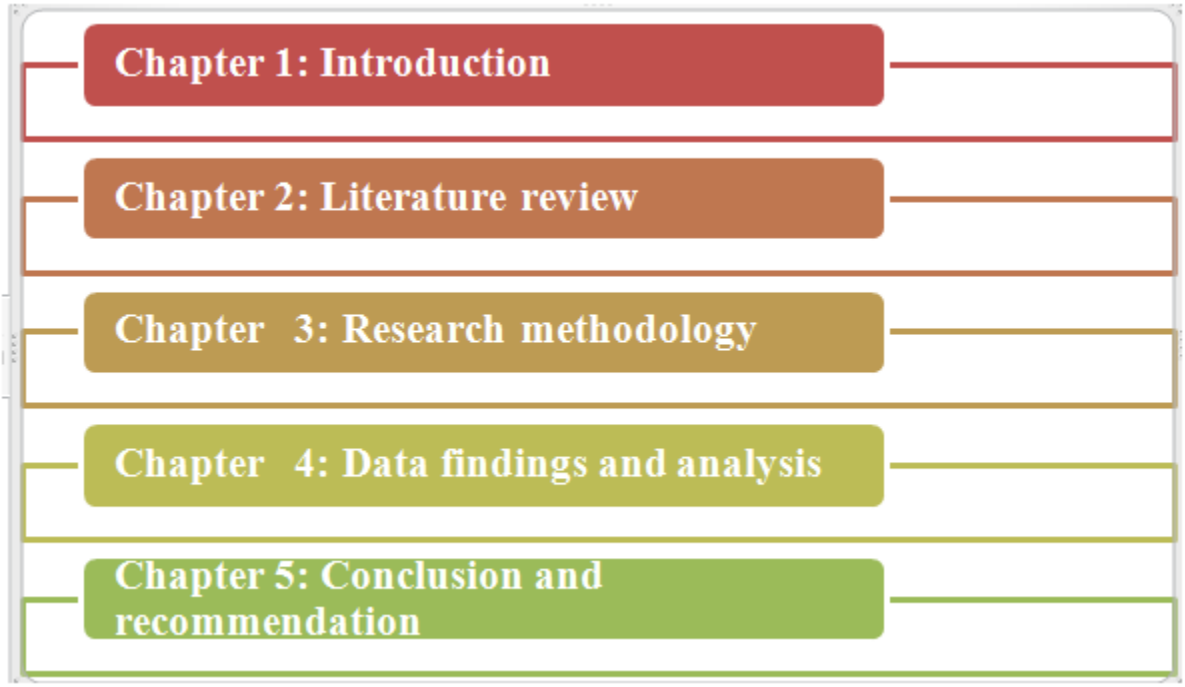

Figure 1: Dissertation structure

(Source: learner)

1.11 Summary

GGBS is basically used in the construction programmes in order to make their structure much more durable in nature. The workers execute sieve analysis in order to determine the uniformity of the raw materials used in the construction projects. Strength test is also executed so that they can mitigate the issues in the raw materials and it increases the robustness of their construction. Portland cement is combined with the different raw material in order to decrease the rate of waste. In the traditional method, brick dust is used as cement and this process is quite eco-friendly in nature. Hand approach eliminates balling of fibres and this reduces aggregation of the raw materials. The owners maintain the consistency of fresh concrete so that they can increases the performance level of the workers along with their creativity. Owners of the project follow rules and policies of the local parties and the government of UK in order to mitigate the rate of governmental penalties and scandals from the project. The systematic planning process and good communication between workers and the employers of the project helps them to eliminate negative issues based on raw materials, equipments and other factors of construction from the strategy in a perfect way.

Chapter 2.0: Literature review

2.1 Introduction

This section will help to understand various aspects of testing of concrete. This will help to analyze the strength and workability of concrete made by slag along with Ground Granulated Blast Furnace. In addition to this, literature review section will help the learner to understand the advantage of using GGBS in the construction site. There are various techniques that will be used in this section for determining the workability of concrete. The theories and models that are demonstrated will help to critically identify the entire research. It will discuss the theoretical perspectives based on the study or findings related to the topic. This literature review will help the learner to get enough information to do the entire research in a proper manner.

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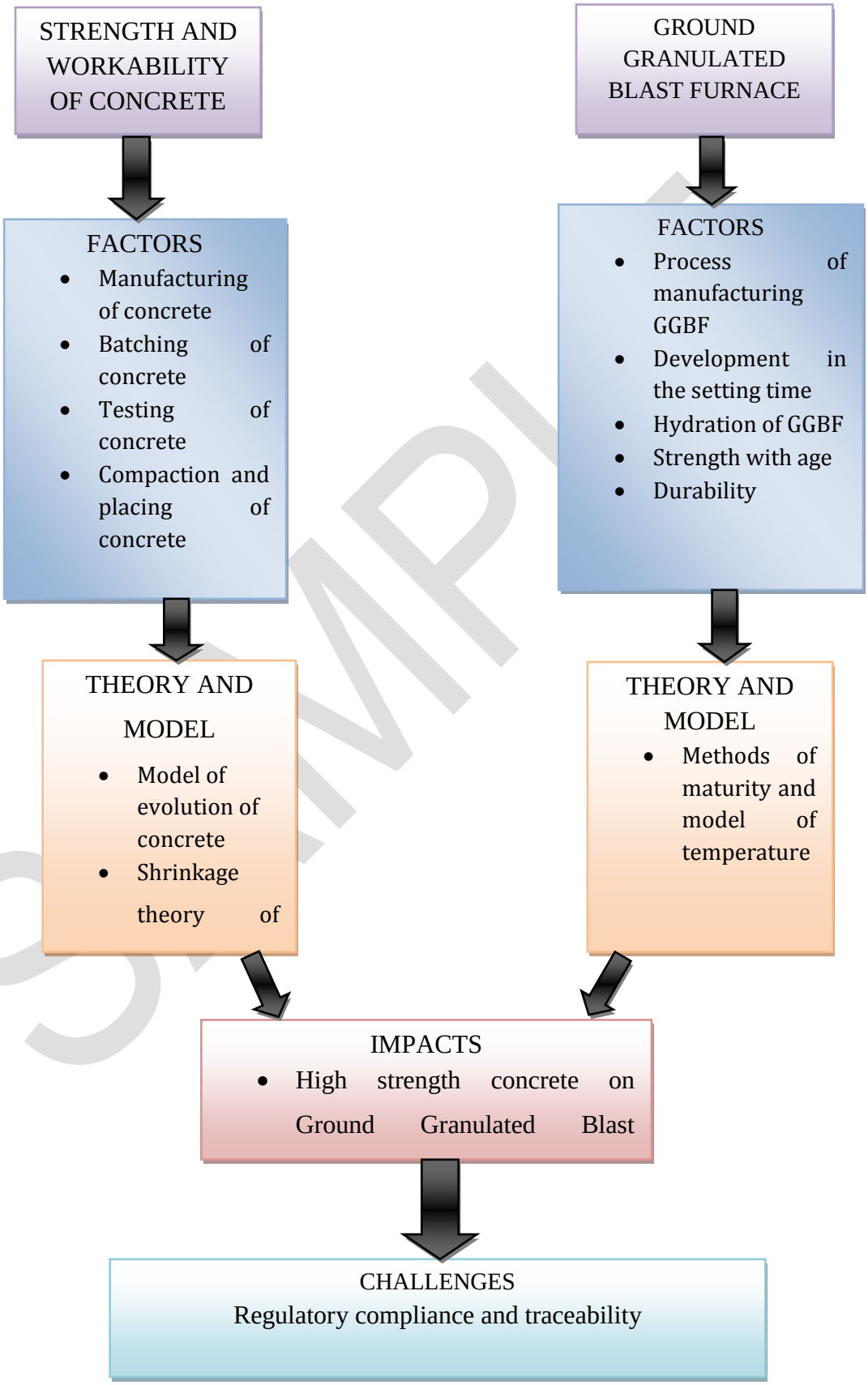
2.2 Conceptual framework



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2.3 Ground Granulated blast furnace slag (GGBS)

Ground Granulated blast furnace slag (GGBS) is a waste product or by-product from the blast furnaces used to make iron. The process includes a relatively high temperature of more than 1500 degrees centigrade. The raw materials are carefully used with their proper proportion under chemical mixtures such as coke, limestone, and coke (Oti *et al.* 2015). Although it is normally designated as GGBS in the UK, it is known in common terms as blast furnace slag cement. As it is mainly processed from the waste product from industries, the process becomes economical and conventional. Increase for GGBS has successfully improved the setting time of the concrete. Setting time of the concrete is mainly dependent on many factors such as water-cement ratio.

Finished concrete is the mixture of essential components of fine aggregates, coarse aggregates, water and cement mixed in required proportions. The primary demerits of conventional resources are evaluated that it gets depleted constantly. Apart from offering economic measures, results from previous research indicate that influence of GGBS does not sufficient degrade the strength of the concrete rather it opened new possibilities of using the concrete in different environments and situations.

Mix	Strength (N/mm)				
Days	0	2	7	28	33
20% RG Powder/80% GGBS	0	0	2	39	42
40% RG Powder/60% GGBS	0	0	0	22	29
20% RG Cake/80% GGBS	0	0	3	38	43
30% RG Cake/80% GGBS	0	0	0	35	38
50% OPC/50% GGBS	0	15	28	55	-
100% OPC	0	31	46	59	-
90% GGBS/10% lime	0	0	2	12	-

Table 1: Strength of concrete

(Source: Oti *et al.* 2015, p.250)

The amount of GGBS is mixed closely with OPC which is widely known as ordinary Portland cement. The result increases in the durability of the structure. Research indicates that GGBS has modified certain properties with is responsible for its durability. Apart from those results indicates that concrete formulated with GGBS results has resulted in a delay in setting time more than the concrete formulated with OPC.

Apart from that attacks from harsh chemicals and properties are minimized and safeguarded from harsh effects and impacts.

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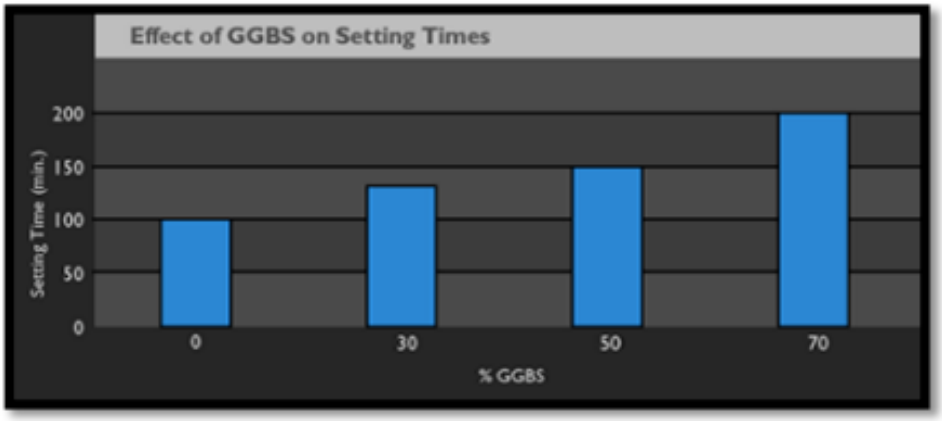

Figure 2: Effects of GGBS on setting time

(Source: Oti *et al.* 2014, p.360)

Delay in setting time of concrete is suitable for dams and other mass structures. Apart from that, results also indicate that GGBS has improved as follows:

- Improvement and development in workability properties of concrete are the results of GGBS. It has also played an important role in making placing and compaction of concrete simple and easier.
- Placing conditions are made easier and more control over the placing of concrete in different conditions is ensured.
- Risks associated with thermal cracking are eliminated
- In case of corrosive nature of the soil of the soil, risks due to corrosion of reinforcement is minimized
- Sufficiently considerable amount of protection is ensured from the attack from sulfate and other chemicals

2.4 Theories and models

Model of evolution of concrete

This is one of the most critical factors that the service life of the concrete structures by ionic aggressive nature of the reinforcement corrosion. The evolution of concrete helps to determine the strength and durability of the concrete structure. Moreover, this theory has been designed for making the structural design strong and effective. The effects of the parameters that are used and associated with the mechanical behaviour of the concrete and rust helping to identify the cracks

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and failures of the structures. Some measures are taken for recognizing the values used for the rust penetration and micro cracks in the buildings. This theory helps to improve the nature of the concrete used by the granulated blast furnace slag. The corrosion related products are used for determining the non-linear stress and predicting the values of the data.

Methods of maturity and models of temperature

The development of the concrete is dependent on the hydration rate and this is rate is again dependent on the temperature reaction. The strength of the concrete can be expressed as the crossing of time and temperature based on the maturity function. Deb *et al.* (2014) put forward the actual equivalent age principle for the Portland cement whereas, others Islam *et al.* (2014), evaluated the equivalent age principle for the group of combination in the context of Portland cement and GGBS.

Shrinkage theory of concrete

The drying shrinkage of concrete is mainly dependent on the diffusion moisture of the concrete. The solution regarding the diffusion equation provides a description of the on the shrinkage theory. Dadsetan and Bai (2017) have exploited the fact and the recent work on the theory provides a consequence on the diffusion theory for enhancing the initial shape of the curve of shrinkage in time. The asymptotic shape related to shrinkage curve is due to the diffusivity of the moisture.

2.5 Manufacturing of concrete

The manufacturing process of concrete is quite simple. At first, Portland cement is prepared and then other components such as aggregates and admixtures are added to it. All the ingredients are mixed together with Portland cement in order to make concrete. In supporting to this, Shin *et al.* (2016) mentioned that the concrete is then shifted to the construction site and placed properly by compacting and curing it.

Batching of concrete

Batching is a process used for mixing the ingredients of concrete into a mixer or batching plant. In order to produce concrete uniformly, all the ingredients need to be accurately mixed with one another. It has been found that there are two methods for batching that are volume batching and weight batching. Volume batching is the one that is used generally for constructing small concrete. Gauge boxes can be used for measuring the coarse and fine aggregates. On the other hand, weight batching is used more than the volume batching as it has been found more perfect

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in order as it leads to mixing the concrete in a uniform proportion. For doing weight batching, three types of types of equipment are used that are as follow:

- **Manual:** This type of batching is used where the batching of concrete is done in a manual process.
- Semi-automatic: In this case, semi-automatic batching are done for batching the aggregates of bin gates.
- Automatic: Here, the materials used are activated automatically and the batching plant consists of 2, 4 or 6 bins,

Preparation of Portland cement

All the ingredients of the cement such as alumina, limestone, and silica are mixed together in required proportion for preheating the materials. The materials are burned at 2500 degree and these materials are diffused to a substance called clinker. The clinking material is cooled and it is finely powdered in a ball mill. On the contrary, Cheah *et al*, (2017) proposed that the ball mill is rotated with all the steel balls that may be of different size and grinded in the clinker. When the preparation goes on, a special compound named Gypsum is added in the process of grinding. Finally, when the cement is prepared different compounds are found such as tetra calcium alumina ferrite, tricalcium silicate, and tricalcium aluminates. At this point, on the other hand, Samad *et al.* (2017) declared that the raw materials presented in cement when reacts with water, these compounds (C3A, C3S, C4AF, and C2S) are formed that are known as the Bogus compound.

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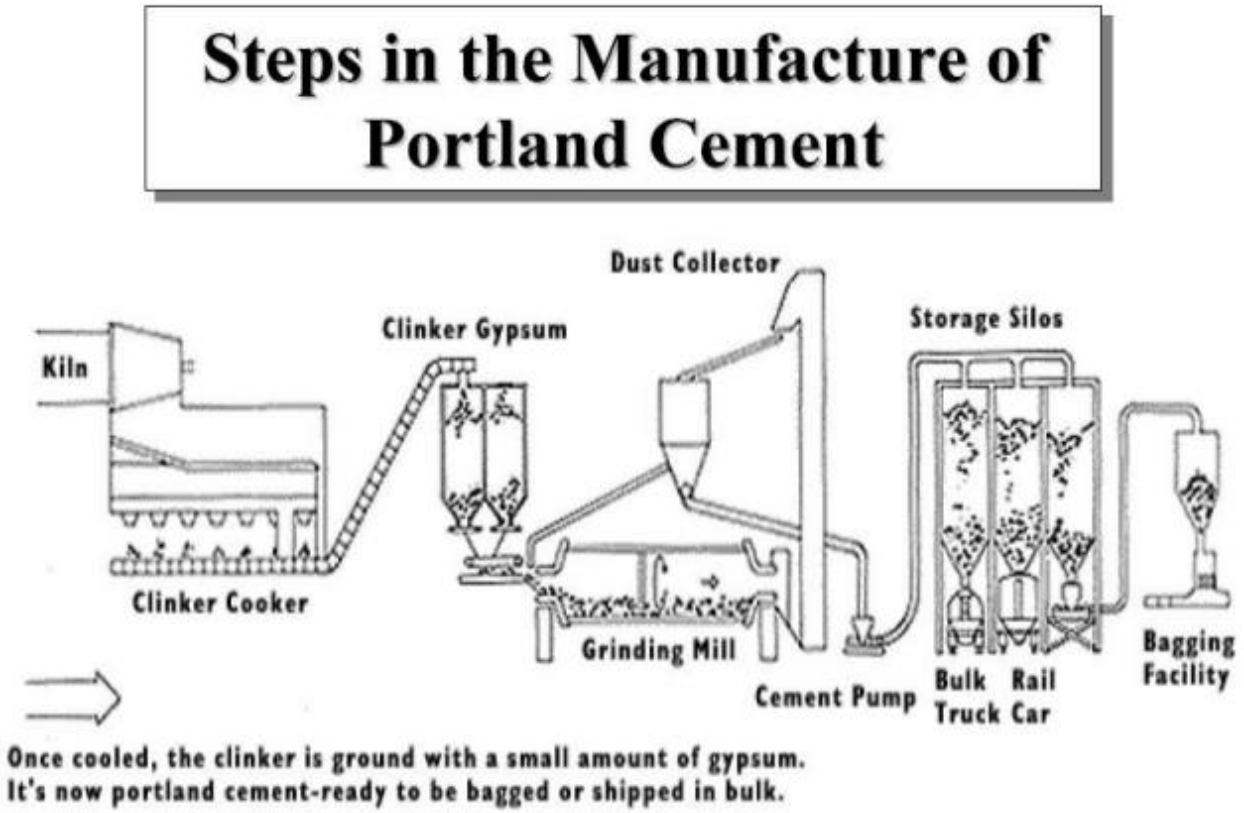

Figure 3: Preparation of Portland cement

(Source: Cheah *et al.* 2017, p.230)

Mixing

The Portland cement is mixed with several components like fine aggregates, coarse aggregate, water, and admixtures. As opined by Mo *et al.* (2017), all the aggregates are blended and then added in the ready-mix concrete at a normal temperature. This operation of mixing requires stirring of the aggregates along with the cement paste. This helps to blend all the other ingredients properly at a uniform rate. Cheah *et al.* (2017) suggested that the workers may use a variety of mixers and batches for mixing the ingredients in the site. This is then transported to the work site for curing and compaction. The transport of the mixture uses various transporting vehicles like belt conveyors, wheelbarrows, and cart.

Compacting and placing of concrete

These two methods are used simultaneously at the work site. Chore and Joshi (2015) commented

that placing of concrete needs to be done very carefully without having any segregation in the mixture in order to remove the air bubbles. The rate of compaction and placing needs to be equal and this is done by using vibrators. It has been found that if the site uses an internal vibrator, controlled vibration arises for compacting the concrete. On the other hand, the external vibrator is used mainly for precast of concrete or giving a particular shape to the concrete this is usually not possible by internal vibrators.

Curing

Once the concrete is placed properly and compacted, curing is done in order to make sure that the concrete does not dry quickly. The strength of concrete is basically enhanced by the moisture level at the time of hardening process. Here, Majhi *et al.* (2018) figured out that shrinkage of concrete may occur if the cement get solidifies. In order to reduce this problem, it is said that concrete can be kept in the damp condition and set it properly and make it harden.

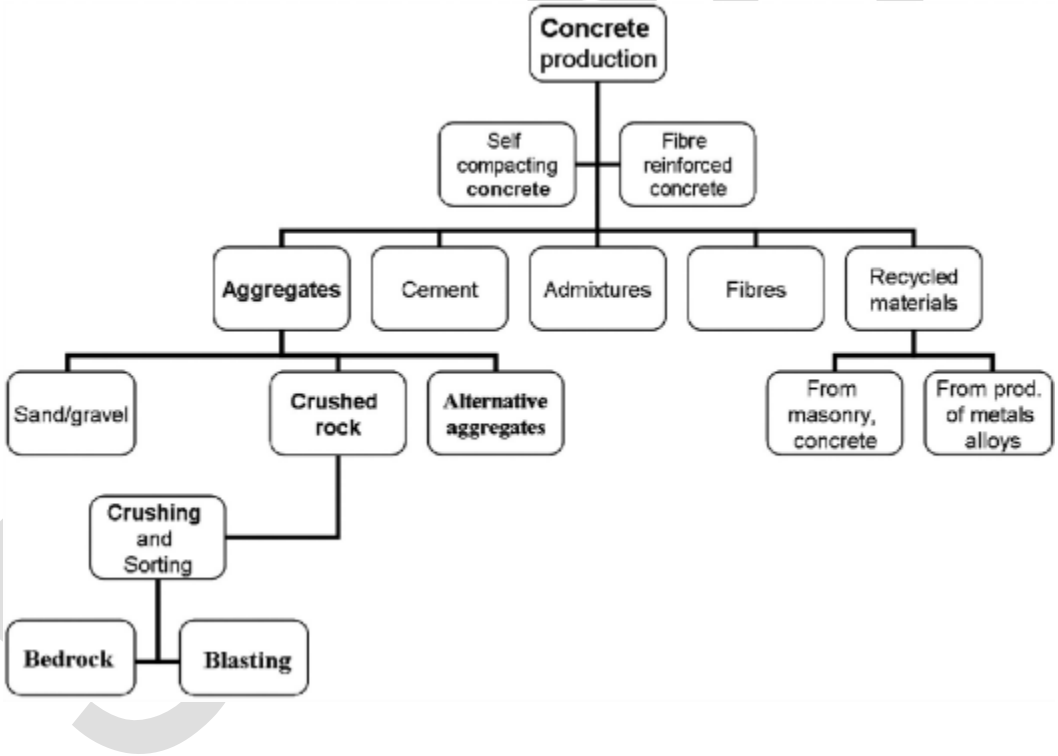

Figure 4: Concrete Production

(Source: Mo *et al.* 2016, p.20)

2.6 Testing of concrete

There are various methods for determining the workability of concrete and this will be evaluated in this section.

Slump test

Slump test is most suitable for the concrete having high workability. As commented by Zhao *et al*. (2015), slump test is done by using a slump cone having a top diameter of 10cm, a bottom diameter of 20cm and height of 30cm. This test is carried out on a fat and smooth surface. All the ingredients of concrete are mixed thoroughly and then required an amount of water is added to it for getting the results. The concrete is then placed in a mold up to one-fourth height of it. Supporting to this, Kovtun *et al.* (2015) stated that the concrete is compacted for 25 times using a tamping rod. Then, the mold is again filled with concrete till half of it and compacted for 25 times. After that, again the concrete has to be filled till three fourth of its height and each of the layers is compacted at 25 times uniformly. When the compaction is completed, the mold is removed immediately by moving it in a vertical direction. At this point, when the concrete settlement gets stopped, concrete subsidence is measured in millimetres and this is the ultimate slump of the concrete (**Refer to appendix 3**).

On the contrary, it has been found that this process of measuring workability is not appropriate for the concrete that contains a coarse aggregate of 40 mm diameter. In addition to this, slump test is not suitable for dry mix concrete.

Type of Construction	Recommend slump in mm	
	Minimum	Maximum
Pavements	25	50
Mass concrete structure	25	50
Unreinforced footings	25	75
Caissons and bridge decks	25	75
Reinforced foundation, footings and walls	50	100
Reinforced slabs and beams	30	125
Columns	75	125

Table 2: Slump values for the concrete works

(Source: Jin *et al.* 2015, p.230)

Compaction test

This method is suitable for measuring the workability of concrete mainly in laboratories. The procedure for compaction test is done on the clean surface of the mould. This takes place in the areas using a hand scoop in the upper hopper. The doors of the Hooper are then opened for giving facility to the concrete for moving down in the lower hopper. Here, Zhao *et al*. (2015) added one point that the concrete of upper hopper can be pushed downward using a steel rod. The weight of the cylinder needs to be near about 10 gram. The cylinder is then filled with the mixture of concrete that should not be more than 5 cm and all the layers are not be compacted up to 100 percent. The value is then calculated by using the given formula.

$$\text{Factor of compaction} = \frac{\text{Weight of the concrete having partially compacted}}{\text{Weight of the concrete that is fully compacted}}$$

Figure 5: Test apparatus of Compaction

(Source: Ardalan *et al.* 2017, p.29)

Test of Vee-Bee consistometer

The vee-bee consistometer method is used for especially dry concrete those are having low workability. In this test, all the ingredients of the concrete are mixed thoroughly and water is then added to the mixture. Now, the mixture is poured into the cone of slump using a funnel that is fitted in the stand. At this time, Arora *et al.* (2015) expressed that the slump cone is to be removed by rotating the stand in order to touch the top of concrete by the transparent disc. The vibrator that is present is started where the cylinder is placed. It has been found that due to the action of vibration, the concrete that is present starts occupying and remoulding the cylindrical container. Supporting to this line, Moustafa and ElGawady (2015) commented the vibration in the cylinder will continue till the surface of the concrete becomes horizontal.

Comparison of the measurement of workability by three different methods

Workability Description	Slump in mm	Vee-bee Time in Seconds	Compacting Factor
Extremely dry	–	32 – 18	
Very stiff	–	18 – 10	0.70
Stiff	0 – 25	10 – 5	0.75
Stiff plastic	25 – 50	5 – 3	0.85
Plastic	75 – 100	3 – 0	0.90
Flowing	150 – 175	–	0.95

Table 3: Comparison of Slump test, compacting test and Vee-Bee Consist meter test

(Source: Ardalan *et al.* 2017, p.23)

2.7 Impact of high strength concrete on Ground Granulated Blast furnace

Granulated Blast Furnace is mainly used for the quality production of the slag cement such as cement of high Slag Blast furnace (HSBFC) and Portland Blast Furnace Cement (PBFC). As stated by Ardalan *et al.* (2017), GGBF is used for reducing the damage and risks that are caused by the reaction of alkali and silica. This provides high resistance to the chloride related substances in order to minimize the chances of corrosion reinforcement in the attacks caused by sulphates and other high chloride related chemicals. GGBF cement is mainly added to the

concrete at the time of batching using Portland cement and aggregates. In view of this point, Qasrawi (2016) mentioned that GGBF is required for replacing the Portland cement directly based on one-to-one weight. GGBF is obtained by mixing the molten slag from the blast furnace in order to produce a granulated product into a fine powder. It has been found that the concrete that is wet are more workable than the dry concrete (**Refer to appendix 4**).

The impact of using GGBS in the blast furnace is to produce high strength and workable concrete. This helps to reduce the iron oxides from the liquids of hot metal. Moreover, the blast furnace is large and the concrete is put with the refractory bricks. On the other hand, it has been observed that GGBS is used for making durable concrete along with the combination of ordinary cement or using the pozzolanic materials. Here, with the help of GGBS the quantity of cement is reduced and the entire amount is replaced. The major uses of GGBS are in the manufacturing of slag cement and high blast furnace cement slag. The concrete that is made with GGBS cement usually set slowly in compared to the concrete that is made with ordinary Portland cement. It has been found that the Portland cement is mostly dependent on GGBS and they continuously gain strength in the condition of production. This leads to the lowering of the heat of hydration and the temperature rises in order to avoid the cold joints that may affect the schedule of construction whenever a quick setting is needed (ijser.org 2018).

2.8 Literature gap

Certain gaps are found while conducting this study which creates a barrier to collecting valid information related to the findings and lacks the proper evaluation. Year gaps are also found which creates lack of information or incomplete information based on the topic. During the manufacturing process of concrete, it has been found that different types of gases are produced and these are not good for the health of the workers. Kovtun *et al.* (2015) presented a table of recommendation in order to elapse the time before making a framework of concrete having a specific grade of concrete. The air temperature and the type of cement are used in the manufacturing process for enhancing the workability need to be maintained. Research has found that there is a lack of evidence in producing workable concrete in order to maintain the consistency of the concrete. On the contrary, Qasrawi (2016) has contradicted that a concrete that have high consistency is more mobile and is right for use in the construction site. Tests are conducted for evaluating the values of the consistency test of concrete. However, it has been found that the tests are done very casually as the workers think that they can manipulate the

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value of the strength. Qasrawi (2016) have suggested that research has to be done for enhancing the physical properties of concrete so that no issues are found that in the construction project.

2.9 Summary

In the entire literature review section, the workability factors of concrete are critically evaluated for getting a true sense of the strength and workability of concrete. The study says that there are few gaps that are to be fulfilled in the upcoming research. Various tests that are performed for measuring the workability of concrete help getting information and data about their strength along with durability. Furthermore, the study has analyzed the entire process of manufacturing of concrete in order to identify the various steps indulged in the process. The analysis that has been done in this section will help the learner for getting a brief idea of the strength of concrete. The study has helped to identify the usage of a ground granulated blast furnace. It has shown that its uses included better workability and makes the compaction easier. The use of GGBS has helped in producing high resistance concrete for preventing damage from the attack of sulphates. This will provide a scope to the carry out the research in the forward direction.

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Chapter 3.0: Research methodology

3.1 Introduction

Research methodology focuses on the appropriate strategy and it helps the construction projects to mitigate their issues in a proper way. This research process will aid the higher members of the project to perform test hypotheses on their projects. Owners of the construction assignment perform several analyses in order to create their strategy perfect and durable in nature. In this research methodology section, research approach, research philosophy, research data along with its data type will be thoroughly explained. Different data collection tools are present so that they can conduct their research in a precise manner and it will have a positive impact on their construction projects. Research method will help to collect appropriate data based on their further analysis and increases the satisfaction level of the workers.

3.2 Research philosophy

The maintain component of a research is considered as research philosophy. As per the viewpoint of Deb *et al*. (2014), positivism, realism, and interpretivism are parts of research philosophy. In realism, the researchers gathered information from the contemporary era and try to draw a conclusion. On the other hand, in case of interpretive, the proper interpretation is done in order to get an effective outcome. However, positivism involves collecting data from current phenomenon and analyzing it for solving the issue in a lucrative way. The positivism research philosophy is found to be used in the study as it requires the focus of the researcher and the idea of identifying the best workability is based on the truth in a precise manner. In this section, positivism has been used for describing the strength of the concrete by GGBS as it has been proved to be one of the best ways to enhance the workability of the concrete. Positivism is preferred in the study as it is preferable for identifying the workability of concrete and improvement of other properties of concrete important in project management. Moreover, the sense of positivism has been taken in the study for identifying the variation of concrete for making a similar project in the construction field (Sevinç *et al.* 2017). Positivism helps to maintain a positive culture and encourages researchers to complete the research in a proper way. Proper management of construction is better ensured through identifying its positive influences which is made possible through positivism as a result it is preferred. It avoids negative vibes and enhances the researcher not to give up while conducting a research. The idea of positivism helps

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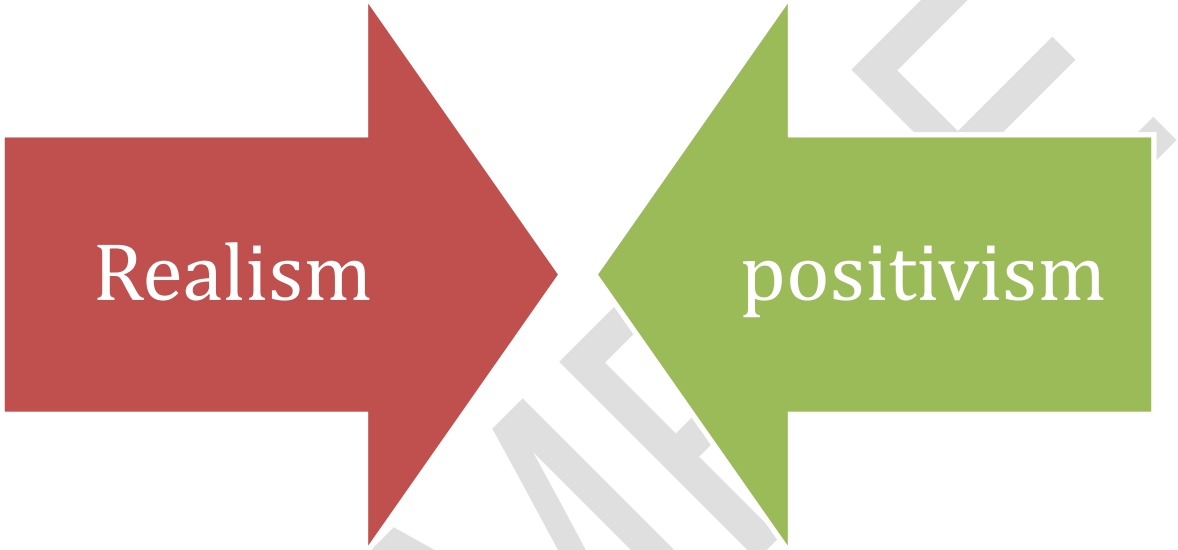
to adhere the factual knowledge that is gained by observing the measurement and apparatus (Veiga 2016).



3.3 Research approach

In a time of conducting the research, it is necessary to follow appropriate approach. Deductive and inductive are two approaches, which are used for research purpose. Inductive approach is used in order to develop the new theory by gathering information from existing theory of construction. On the other hand, in case of a deductive approach, researchers make research on existing theory and try to extract an effective outcome or conclusion. Deductive approach is used by the researcher as it generally begins with the hypothesis which an inductive approach does not use. The basic aim of using the deductive approach in this study is to highlight the strength of concrete using GGBS by using several theories. Deductive approach plays an important role in the process and performs better analysis. It highlights the importance of GGBS in concrete and effectively manages project management process. As a result, the project management techniques get quit easier and better. The most important advantage of the theory is that impacts on the concrete strength as a result of chemical additions can be determined. This provides a

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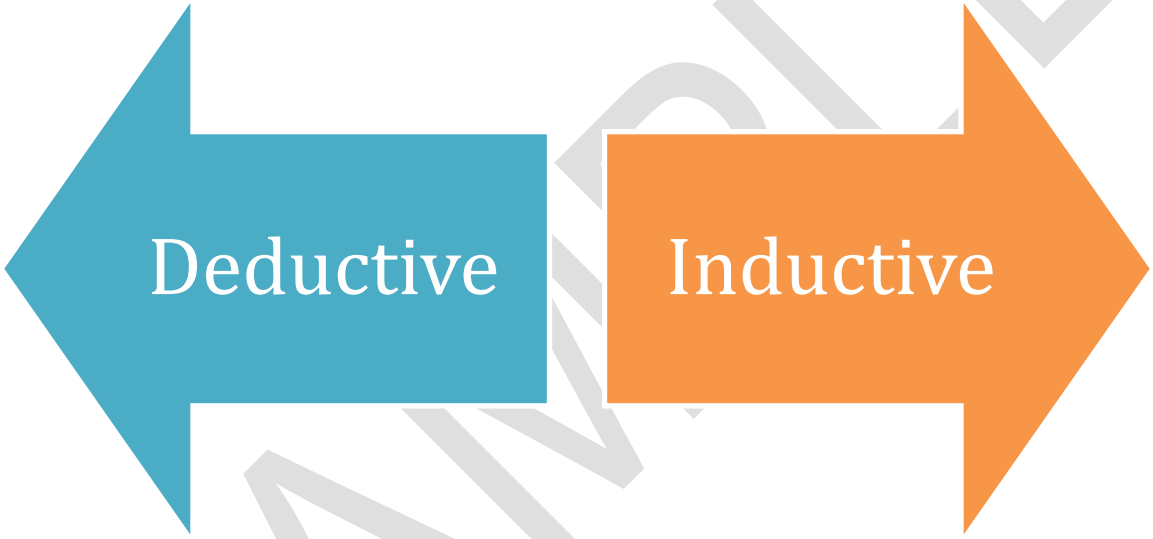
scope of research from the data that are emerged through deductive approach. In the opinion of Filous and Silver (2016), the deductive approach of provides the researcher to do data analysis by exploring the existing research from a different arena. Moreover, it has been found that deductive approach is more beneficial than the inductive approach in the evaluation of strength and workability of concrete using GGBS as it helps to critically evaluate the information found about different types of concrete and their effects in the construction projects (Gentles *et al*. 2015). Analysis of critical analysis is important and more important in project management.



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3.4 Research design

Research design involves the concept of explanatory, exploratory and descriptive. In case of explanatory design, the researchers have tried to explain the collected information properly related to GGBS. However, on the contrary, in case of exploratory, information are gathered in order to develop new conception. In case of descriptive design, proper data is collected. It assists to get a fruitful outcome in a different construction project. Descriptive research design depicts data and information in an accurate way and it helped in the project management with proper knowledge. Descriptive research is necessary and favorable for project management. It plays an important and essential role in determining the adequate material properties. Project management

is incomplete without identifying the significance of different materials. In this study, to find the strength and durability of concrete, descriptive research will help to analyze its effect and will provide the exact information about the nature of the concrete. It has been found that the use of explanatory research design will help to conduct a survey based on the information that has been collected. Descriptive analysis method helps to identify the material conditions and its application which may be essential in project management. Descriptive research design will help to know that in the UK more than 7.7 million tons of GGBS is manufactured for determining the workability of concrete (Lewis, 2015).

3.5 Research data type

Data obtained and collection process is obtained from secondary sources. Secondary sources of data are preferred in the study as it gives more reliable and authentic data. As per observation, the impacts of GGBS on the concrete have drastic effects on overall strength and properties. Observation of case results is essential for different material properties which is essential in project management. Secondary analysis helps to highlight the material properties and its impacts on final results. The properties of the ordinary concrete prepared from ordinary Portland cement is improved and developed. The properties of the concrete in the previous time were not effective enough. The properties of chemical composition in GBBS offers sufficient impacts on the quality of concrete, secondary analysis makes it possible as a result, it is preferred. Studying the results and analysis on the impacts of concrete, results indicated that apart from the strength of concrete other essential properties such as resistance to shrinkage and improvement in durability as well. Data is collected on the basics of practical sources. Data collected from practical sources indicates reliable and practical data types (Gentles *et al*. 2015).

3.6 Data collection method

Primary and secondary methods are involved in various studies to collect data for completion of the study. Primary Data involves participants to gather views or opinions related to the study or findings. The secondary method helps to collect valid or authentic data from various secondary sources like journals, magazines, online sites and articles or reports. This study will involve a secondary method to gather appropriate data so that proper analysis can be done by evaluating the issues and making interventions for improvement or future development for construction work (Sotiriadou *et al.* 2014). This study will involve observation and survey to gather valid data

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for completion of the research. Authentic data sources are important to be determined and collected to investigate better project management. Properties of materials and its reaction with the primary materials are important in overall project management. Authentic data is collected from graphs and charts pointing out the effects of each property of GGBS on the properties of the concrete. Secondary data sources helps to conduct better material selection by conducting proper research and data gathering through research journals. Determination of this results helps in better project management. The results and analysis from the sources give sufficient amount of authentic results. Qualitative data, as well as quantitative data, is beneficial in the study. The major process in the study deals with numerical and data analysis, as a result, this method offers best results on numerical analysis. Apart from that, qualitative data is utilized for arriving at better approaches. Qualitative methods of data collections such as observations, texts, and other essential sources are utilized to improve the process.

3.7 Data collection tools

Data collection is the way for explaining the process of collecting data. The method of data collection will help the researcher to analyze the topic in a proper manner. Here, in the study researcher has used secondary data collection techniques for gathering all the data about concrete and GGBS. The existing data found on slump test and compressive strength of Portland cement will help the researcher to evaluate the graphs and data based on the percentage of the values available for all grades of concrete. Data has been collected from various sources such as books, journals, newspapers, and magazines for doing secondary analysis on the strength and workability of concrete using GGBS (Ban *et al.* 2017). The data that are collected has given adequate information as the researcher has collected them by doing a proper investigation on the types of concrete. Data collection tools and process mainly includes research journals and reactions. This helps in determining the influence and affection of overall materials on final results. The data collected is useful for project management. As per Özbay *et al*. (2016), the data that are published in the journals illustrated that using GGBS has given better results and is found that replacing the types of cement with GGBS to minimize the water content in order to obtain the slump value that is quite effective. Secondary data has helped the researcher to identify the engineering properties by doing research on the physical properties of the various components of Portland cement. Manorama *et al.* (2015) mentioned that the properties of Portland cement are collected for having a clear analysis of their nature and functions in the

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construction projects. This information is very essential that has provided the researcher to evaluate the percentage of the properties such as water absorption percentage and impact values of cement.

3.8 Sampling techniques

Sampling techniques help to ensure the convenience and gathering of the exhaustive and intensive data. As the study focuses on the generalization of the data, proper sampling technique has been used for identifying the data. Random sampling techniques offers positive results in selection of group of samples from other samples. Different samples can be selected and may be used for arriving at most appropriate one. Collection of samples from different groups helps better project management. In this research, the non-probability sampling method is used for determining the hypothesis to discuss the sampling process of the study. The factor that has led to use random sampling methods is the availability of resources and sequential sampling.

3.9 Population and sample size

Population and sampling size helps to gather authentic data form valid sources by completing the study in a proper way. In this study, sources and information have been taken from different websites and articles of UK. Different observations are done in order to verify the data and information that are available for making the research more authentic. The study conducted has discovered that the use of GGBS provides an advantage in raising the standard of workability and strength.

3.10 Data analysis

Data analysis is done to make the research strong and effective. There are two types of data analysis that are primary and secondary analysis. This study will involve secondary analysis by reviewing authentic journals, articles, reports related to the strength and workability of concrete using GGBS. Secondary analysis is preferred in the study as the majority of the study is necessary to be performed by studying authentic information sources such as journals. As a result secondary analysis is preferred. Apart from that, it helps in better project management. The research is done based on the quantitative studies that have involved interpretation and critical analysis of the presented data in order to find the reason behind the occurrence of the findings and plan interventions.

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3.11 Data reliability and validity

Data gathered by the researcher in identifying the issue related to the nature of concrete and benefits of using GGBS in measuring the workability has provided a scope to analyze the significance of types of cement. The data collected by using secondary research are found to be accurate as it matches with the existing research. The data in the study is obtained from secondary sources such as books, journals and other authentic sources which is essential for arriving at accurate results. Accuracy in results and tasks helps in better project management. The data collected are more specific and it helps to enhance the understanding of the root cause of conducting the research. In addition, secondary data analysis has provided a comparison to the data that are collected in the study. It has been found that the kinds of data that are collected are available in various journals. The data are properly verified by comparing several books in order to conduct the research in an appropriate manner. Descriptive research has provided clear and true data on the various factors of Portland cement and the tensile strength of concrete. The factors have helped to identify the exact values of consistency of the ready-mix concrete.

3.12 Ethical consideration

The research works and other fundamental essentials are performed with respect to the minimum amount of destruction to the environment. The laws of the environment and criteria on minimum and maximum discharge limits were taken under considerations prior the research. Certain concerns are given like Theft and copying of data or using it without permission has not been done. Data Protection Act 1998 is involved to maintain proper codes and standards (Legislation.gov.uk 2018).

3.13 Timeline

(Refer to Appendix)

3.14 Summary

From the entire methodology of the research, it has been found that the study has done a secondary analysis in order to find the exact information and analysis of the topic as per the research. Moreover, the research design and philosophy that has been discussed in this section will provide a direct link for measuring the strength and workability of various types of concrete. This section has discussed all the components that are required for doing the research in a proper

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way. Secondary analysis is preferred in the study as the majority of the study is necessary to be performed by studying authentic information sources such as journals. As a result secondary analysis is preferred. Apart from that, it helps in better project management. Moreover, the research methodology has shown that the research will proceed with secondary analysis for describing the views of various articles and journals along with the evaluation of data. This section has demonstrated that data analysis is a systematic process for evaluating the data for achieving the purpose of the research. However, this section has mentioned the limitations that have occurred at the time of conducting the research.

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Chapter 4: Data findings and analysis

4.1 Introduction

Collection of data from authentic sources and practical consideration; offers reliable data sources. Authentic data and relevant findings indicate the impacts of different material composition on overall results. Analysis of graphical results offers a better understanding of the material properties. In this study, analysis of data will be performed on secondary methods. Knowledge of material constituents helps in development and improvement of the product and helps it making it suitable for multi purposes.

This section deals with the analysis of impacts of different material properties on the final results. It shows the impacts of addition or subtraction of additives or admixtures on attaining the desired results. This study will involve analysis of secondary data which helps to arrive at reliable results. The sources of data involve trade, technical journals, and government publications.

4.2 Secondary analysis

Findings and discussion-Thematic analysis

4.2.1 Impacts of brick dust waste (BDW)

Research indicates that BDW may be an essential substitute of Portland cement in making concrete. It also results in the overall economy as well. BDW is a waste product from the brick industries, which is available in abundance. The main advantage, in this case, is that pressure on the environment is considerably reduced. In addition to it, it will help to establish a balance between environmental sustainability and demand on construction. Deb *et al*. (2014) mentioned that BDW has pozzolanic materials, which are highly responsible for obtaining the sufficiently higher amount of strength, and increases its overall durability as well. Alteration or changes in different chemical properties inquire changes in overall final properties. In order to investigate the results, a certain percentage of BDW is replaced with ordinary cement. The following tables indicate the increase in the levels of strength as result of the addition of BDW.

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Addition % of BDW	Increase in strength
10 %	3.73
20 %	3.74
30 %	3.766
40 %	3.768

Table 4.2.1: Results on the basics of BDW addition

(Source: Oti *et al*. 2014, p.400)

Results from the above table indicate the development and improvement of strength due to BDW. The tests are conducted with water binding ratio of 0.60 and are tested at intervals of 7 days, 14 days and 28 days each in compressive strength testing machine. The result indicates that the strength is increased as a result of its addition.

4.2.2 Impacts of different mix materials

The target slump range for 28 days cube strength of concrete is scheduled as 100 to 150 mm, W/C ratio is maintained at 0.60 and the mix proportioning of concrete is 1:2:3. The mix ratios involve proper ratios of cement, coarse aggregates, and fine aggregates. The following table highlights the different combinations

Code of mix	Replacement %	Brick dust waste	Portland Cement
MC(Control)	0	0.0	6.0
MC 1	10	0.60	5.40
MC 2	20	1.20	4.80
MC 3	30	1.80	4.20
MC 4	40	2.40	3.60

Table 4.2.2: Composition of different material compositions

(Source: Oti *et al*. 2014, p.450)

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4.2.3 Preparation of samples and slump testing

Controlled concrete or controlled mix indicated as (MC) are prepared as per the ratios and standard sizes of cubes of 100mm * 100mm * 100mm. The preparation of the test specimens was performed as per BS EN 206 [18]. As per the properties and mode of the MC, BDW is used to replace certain amounts of Portland cement (PC) in the mixes. The values obtained at slump test are mentioned as below:

Code of mix	Indications	Value of slump in mm
MC(Control)		148
MC 1	Mix developed by replacement of 10% of PC with BDW	110
MC 2	20% of the PC was replaced with BDW	70
MC 3	30% replacement with BDW	40
MC 4	40 % replacement	100

Table 4.2.3: Slump values for all mixes

(Source: Oti *et al*. 2014, p.250)

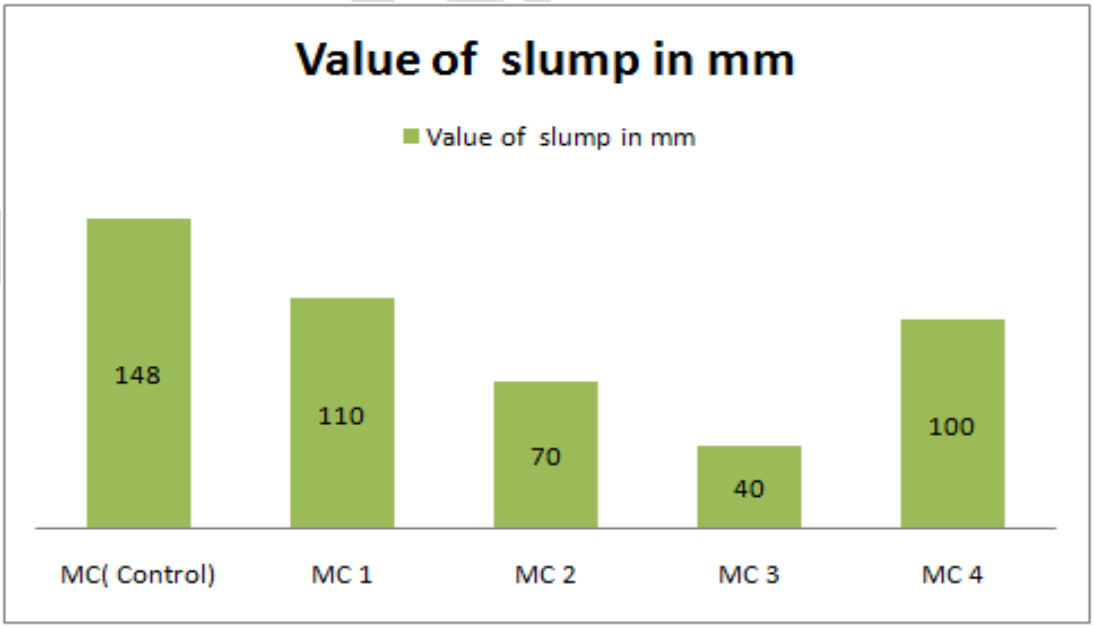

Figure 4.2.3.1: Value of slump

(Source: Oti *et al*. 2014, p.200)

As per the above graphical representation, it is noted that highest value of slump among the cases is obtained for MC1, MC4 and MC control. Results from research indicate the value of slump that was reduced sufficiently with the percentage replacement of PC with BWD. The highest value of slump was achieved for MC (Control). The lowest value of slump was attained at 30 % percentage replacement. However, it is noted that 40 % replacement of PC results in a rise in slump value.

4.2.4 Compressive testing

The test for compression was performed in compression testing machine. The cube after casting is tested at intervals of 7 days, 14 days and 28 days. The graph for the results of compression testing is shown below:

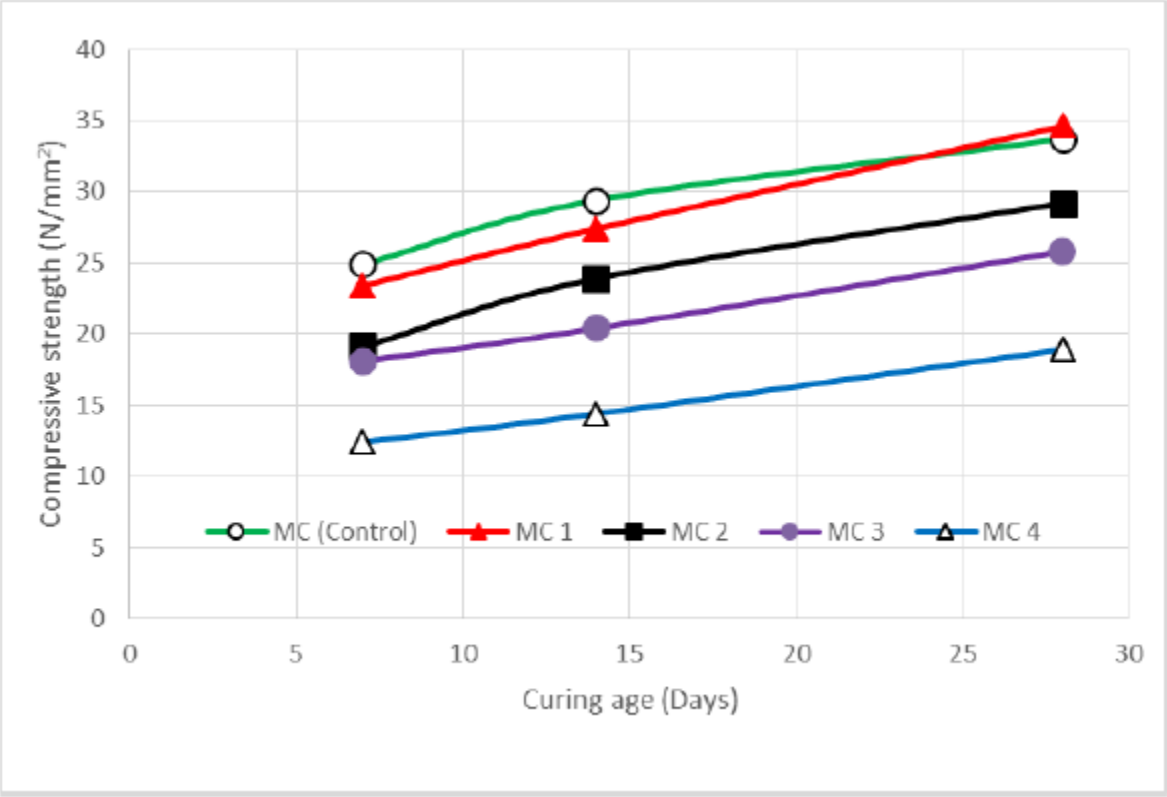

Figure 4.2.4: Strength of the concrete with curing

(Source: Oti *et al*. 2014, p.350)

Results from graphical representation indicate that all samples have undertaken progressive growth with the passage of time and curing period. However, it is noted that results from sample MC(Control), MC1 and MC2 is much better in comparison with others. These samples were above the target strength of 28 MPa (28N/mm2). Although MC1 undertook slow pace of increase rate, it performed better from the rest of others, others factors remaining constant. Thus, it may be concluded that replacement of 10 % of PC with BWD results in better slump value and better compressive strength (**Refer to appendix 2**).

4.2.5 Impacts of temperature on concrete

In this case, the compressive strength of concrete made up with different materials such as GGBS (Ground Granulated Blast Furnace Slag), Waste Glass Powder (WGP), Rice Husk Ash (RHA) is exposed at the sufficiently higher amount of temperature of 780 degrees centigrade. The time duration of exposure was kept at 60 minutes. After attaining the adequate amount of temperature, it is relatively cooled for about 280 minutes. The percentage amount of overall PC in the concrete was reduced by up to 20 % with each of different materials. Results indicate the percentage of the strength of concrete undergoes a reduction in different temperatures. The following indicates the reduction of strength of concrete with temperature:

Temperature Exposed	Reduction in strength of concrete
200 to 250 degrees centigrade	Initial degradation in strength is observed
300 degrees	15 to 40% amount of strength
400 degrees	50 % of the strength is lost
Beyond 400 degrees	65 % of the strength is lost

Table 4.2.5.1: Reduction of concrete strength with temperature influence

(Source: Oti *et al*. 2014, p.355)

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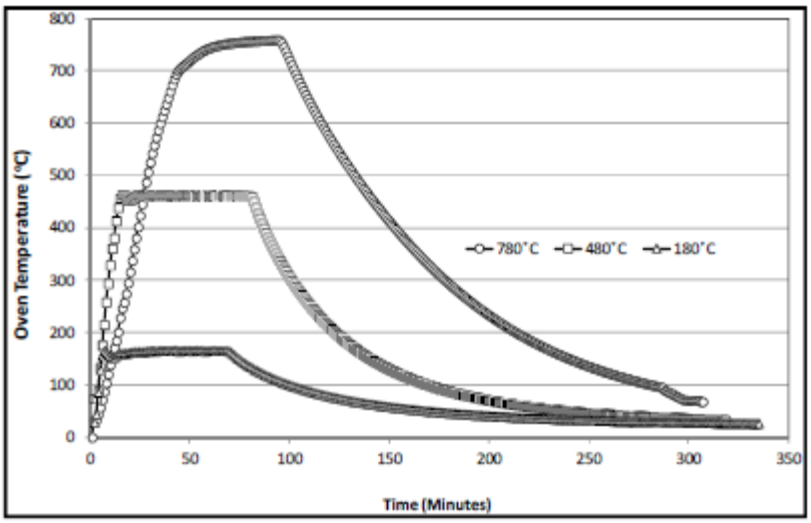

Figure 4.2.5.2: Impacts of temperature on concrete

(Source: Oti *et al*. 2014, p.357)

The influence and the impacts of temperature on the properties of the concrete are observed. The amounts and the effects as a result of the reduction due to the effects of heating are observed (Islam *et al*. 2014). The current materials such as GGBS, WGP, and RHA are applied and it has replaced certain portions of Portland cement and analyzing the results. The related results are represented in the following figure:

Indications	Constituents
JO2	20% of the amount of the total mix was replaced with GGBS
JO3	20% of the amount of overall mix was replaced with PFA
JO4	20% of the amount of the mix was replaced with RHA
JO5	This mix is replaced 20% with GPW

Table 4.2.5.3: Impact of concrete properties on addition

(Source: Oti *et al*. 2014, p.375)

The above table indicates the amount of percentage reduction of the amount of Portland cement with other different material constituents such as GGBS, PVA, WGP and other materials. Alteration or changes in the properties of materials increase certain material compositions. The mode of testing procedure was performed with standard cube sizes of dimensions of 100mm *

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100mm* 100mm. The consistency of the fresh concrete and workability was tested as per BS EN 1239 part 2 and the compressive strength was performed as per the code was performed as per EN 1239 part 3. The curing of the concrete was performed at an interval of 3,7, 14, 56 and 90 days intervals.

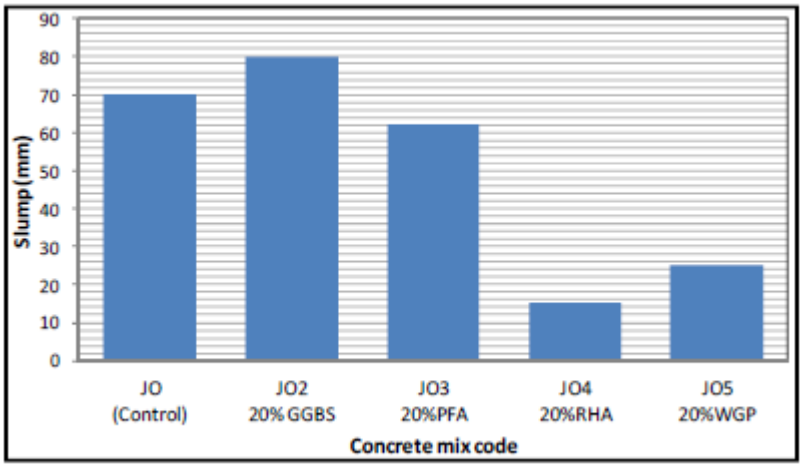

Figure 4.2.5.4: Results of slump test for different mixes

(Source: Oti *et al*. 2014, p.358)

Results obtained from slump test indicate that sample number comprising of 20% of GGBS was able to yield a higher proportion of slump in comparison with others. Sample number JO4 consisting of 20% of RHA consisted of least value of slump. As per sample number 3, consisting of 20% of PFA, 60 mm value of the slump was attained. However, the target value of slump was accomplished with the control sample. Results also indicate that none of the mixers are able to yield the value of slump as 70 mm. The results of the test indicate that amount of workability of the concrete can be successfully reduced with 20% replacement of PC with RHA. The consistency of different patterns of the samples of the concrete was different. As per results when 20% of Portland cement was replaced with GGBS, the value of the slump undertook increase in a slump. As per this result, it may be implemented that putting certain portions or amounts of GGBS in the concrete, the overall mixture gets stiffer and increases in the amount of slump by up to 14%.

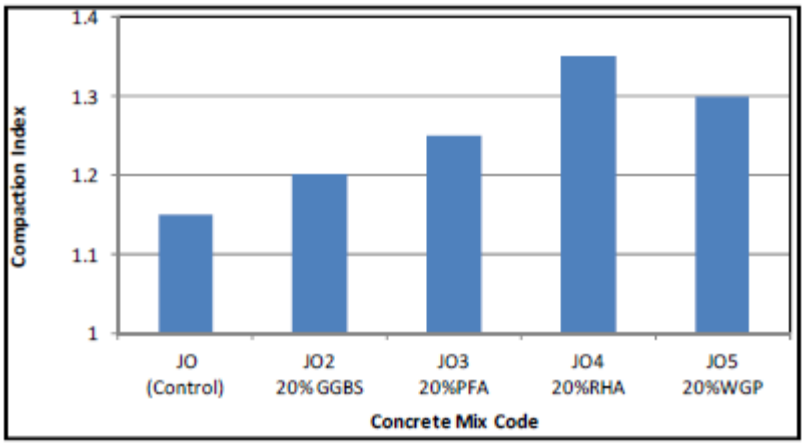

Figure 4.2.5.5: Results of compaction index for different mixes

(Source: Oti *et al*. 2014, p.56)

The compaction index is a measure which determines the number of efforts necessary for ensuring full and overall compaction. As per the above results, it can be essentially noted that sample number 4, which consists of replacement of 20% RHA gives results as highest compaction index. Humad *et al.* (2017) mentioned that the compaction index is a ratio of the weight of partially compacted concrete/ weight of the fully compacted concrete. Compaction may be essentially performed with the help of vibrators.

4.2.6 Impacts of slate waste on concrete

Slate is generally naturally available material. It is of sufficient durable in nature. The production process of slate yields sufficient amount of wastage during its manufacturing. The waste product is collected from the plants and is essentially used for the manufacture of concrete. Dadsetan and Bai (2017) mentioned that waste from the slates may be beneficial in terms of natural aggregates. Wastage from the industries and its uses in the concrete making may be used for placing lower pressure on the natural environment.

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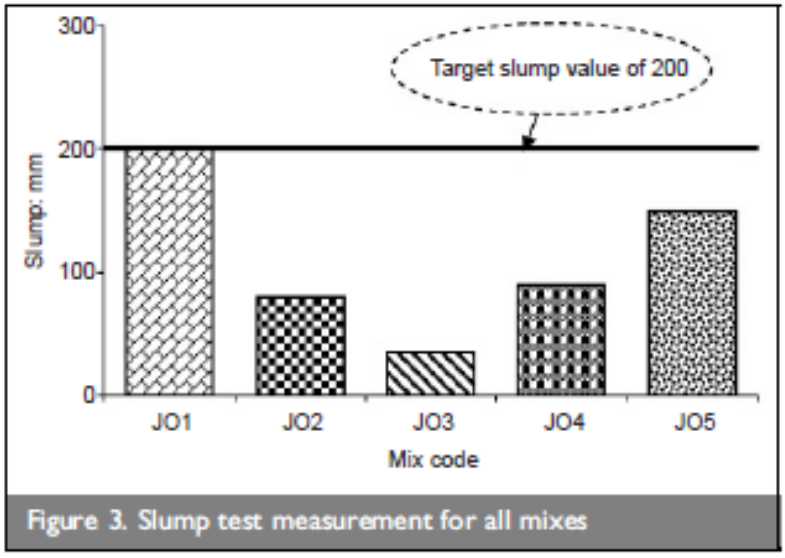

Figure 4.2.6: Impact of slump value

(Source: Oti *et al*. 2015, p.134)

The above figure shows the importance and essentials of slate waste on the workability of the concrete. The target slump was basically obtained as 200 mm. Among all other test samples, it is obtained that controlled mix was able to achieve the target. Apart from that lower values of a slump are generally obtained for all other samples. The observed values of the results of the slump were sufficiently lower for sample number 3. The rate of drop in workability was ensured for sample 3. The value of the slump helps in deciding the workability of concrete to be made suitable and uses as well.

Analysis

Based on the above finding and analysis, the impacts of different properties or modifications on the strength and the properties of concrete are modified. Influence of Brick waste has also strongly impacted on the results. Results from research indicate that BWD plays an important and essential part in increasing overall strength of the concrete as well as its durability. Modifications and alterations such as replacement of certain percentage of PC with materials such as GGBS, PFA, RHS, and GPW have affected overall results of the concrete in an effective way. For instance as per 20% replacement of properties and addition of GGBS the value of slump gradually increased, increasing the overall workability. It is found that replacement with

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20% of RHA in the mix essentially results as low amount of workability of concrete ensuring the lower value of slump making the mixture steeper. The results and statics in the process mainly indicate overall efficiency and progressive results as well. The factors affecting the basic nature of the concrete are indicated as per these results. The results are effective and helping in building and assuring the overall progressive development of the same.

Results indicated that 20% replacement and the addition of WGP modified the number of slump values. Apart from all these effects, the impact of temperature on the effects of the concrete is developed. It is noted that within the temperature of 200 to 250 degrees centigrade, Initial degradation in strength and slight amounts of changes in the strength is observed. At a specific temperature of around 300 degrees, it is noted that changes in strength get reduced from 15 to 40%. Above this temperature ranging from about 400 degrees, it is observed that 50% of the overall amount of strength is reduced. Above the temperature above of 400 degrees, 65% of the overall strength is reduced.

4.3 Summary

Studies and process from the above analysis indicate the results and analysis from the studies mainly point out the influences of different material properties on overall results. Results from the above studies also indicate the number of changes and development of properties to arrive at desired results. The amounts and changes in essential constituents make the concrete to be durable and the scope of its usages can be expanded in further domains. This helps to make good quality of concrete. This study helps the researchers to determine the best possible ways and techniques to change its effects. The results per the case are that structures are much stronger durable and lower cost as well. The results of the studies play an essential way for managing and handling the basic requirements as per its basic fundamentals and approaches. It helps in making most of the improvements for ensuring overall safety and durability of the structure. The factors affecting the basic nature of the concrete are indicated as per these results. The results are effective and helping in building and assuring overall progressive development of the same

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Chapter 5: Conclusion and recommendation

5.1 Conclusion

The entire research has been done very minutely in order to enhance the potentiality of the research. Different chapters of the research have illustrated various aspects for understanding the research properly. Moreover, the research has been done for ensuring the strength and workability of fresh concrete by using Ground Granulated Blast Furnace. Tests of concrete can be performed for identifying the workability factors required for measuring the types of cement and its significance. Different journals and articles are used for presenting a clear concept of the research. In addition to this, a sense of positivism is found in the study as it is done based on the true fact. The analysis is done as per the topic and its requirement. Moreover, ideas and concepts of the concrete related to GGBS shows that they are the best ways to measure various strengths and workability. The study has found that the workers are facing problems in the construction projects as too much time is taken to measure the strength of concrete. Hence, the use of GGBS has found to be effective for measuring the workability and strength in a short duration. In conclusion, it can be said that if the workers in the constructional site use GGBS in manufacturing and testing of concrete then, the projects will be completed within a short duration of time. Therefore, the observations have declared that GGBS is a better replacement in cement in compared to other alternatives.

5.2 Linking with objectives

Objective 1:

To link this objective, in 2.3 concepts of GGBS had shown that GGBS is basically a waste product that is used for the making of iron. This is also used for making of concrete in order to enhance the setting time of the concrete. Similarly, 4.4 has presented that 14% of GGBS is required for the entire mixture of the concrete. This has shown that only a nominal percentage is required for completing the test in a systematic manner. Moreover, the research has linked both the concept of data analysis part.

Objective 2:

To link this objective, the concept in 2.5 of the manufacturing process of concrete had shown that the process is to be done very consciously in order to maintain the systematic approach.

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Similarly, 4.2.2.1 has presented the value of slump and has illustrated that 40% replacement in the Portland cement is required for raising the slump value.

Objective 3:

To link this objective, the concept of 2.6 of testing of concrete has shown that testing requires lots of patience in order to complete the construction projects in a proper manner. Different types of test are used for different types of concrete for measuring the workability and strength. Likewise, 4.2.2.2 has presented that compressive strength of the concrete is found after 7 days, 14 days and 28 days of curing. The process required 10% replacement in the Portland cement for reducing the costs of the construction projects.

Objective 4:

To link this objective, the concept of 2.7 has shown a suggestive approach for reducing the heat of hydration in controlling the temperature that may arise in the construction projects. This will help the workers to reduce the cold joints at the time of quick setting cement. Likewise, 4.2.2.3 has illustrated the fact that the impacts of temperature has adversely affected Portland cement and reduced up to 20% along with various materials. The consistency of the fresh concrete is found to be tested as per the guidance of BS EN 1239 part 2.

5.3 Recommendation

Suggestive steps need to be taken for measuring the strength of the concrete as a single mistake during that time can lead to the loss of destruction of the project. The data collected should be properly done to take the research in the forward direction. The following points are recommended in the study at the time of measuring workability of all types of concrete using GGBS:

- **Using proper apparatus:** The workers have to use proper types of equipment like tamping rod, scale, mixers, measuring apparatus for conducting the test for concrete. It has been found that if proper types of equipment are not used at the time of testing concrete, the desired workable and strength value cannot be achieved. Workers must know the ways to use these types of equipment and their supervisors have to make them learn the ways to operate the types of equipment.
- **Adequate knowledge:** Knowledge about the construction projects is very important before preceding the test of concrete using GGBS. If the workers will have enough information then they will not have to depend on anyone else for performing the tests.

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Knowledge about various types of test such as slump tests, consistometer tests and compaction tests for measuring the exact value of the strength.

- **Use of safety types of equipment:** it has been found that many times workers do not use safety pieces of equipment like jackets, safety shoes and gloves in the laboratories at the time of performing the tests on concrete. The investigation has to be done by the workers for enhancing the life safety in the construction sites.

5.4 Limitation

The research conduct for identifying the strength and workability of concrete using GGBS is found to have certain limitations related to lack of time, monetary issues, lack of proper sources and information. The research has found that the study has failed to investigate few journals due to lack of money. Moreover, it has been found that only a few researchers are done based on the workability of concrete using GGBS and therefore, there is a shortage of sources and data in the study. Another limitation is the research does not have much time as the time allocated for the research is very short.

5.5 Future scope of the study

This study plays an efficient and important role in highlighting the importance's of the different material properties on over strength and durability of concrete. This study will help to design proper future scopes that will play an important role in the development and making improvements on concrete making process. The concrete making process and relevant stages can be improved to make the product suitable for purposes beyond the standard uses. This study will help future researchers to identify the issues related to the construction project and implement interventions by taking the present research into consideration.

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Appendices

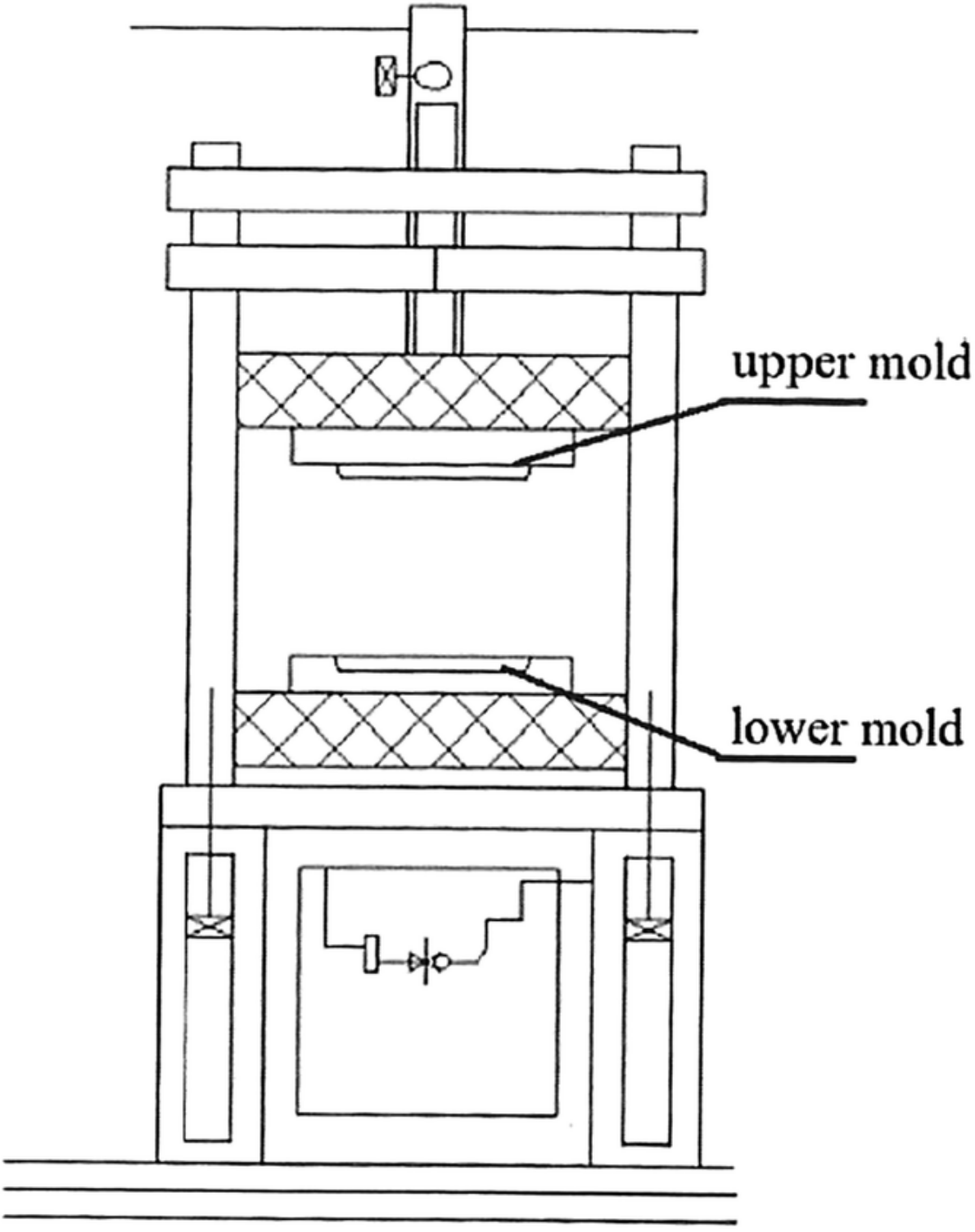
Appendix 1

Activities	Week 1 to 3	Week 4 to 8	Week 9 to 10	Week 11 to 17	Week 18-21	Week 22 to 23	Week 23	Week 24 to 28
Selection of the site								
Costing								
Rentals								
Construction								
Recruitment of workers								
Equipment purchasing costs								
Raw materials purchasing costs								
Testing the concrete								

Figure 1: Gantt chart

(Source: self-created)

Appendix 2

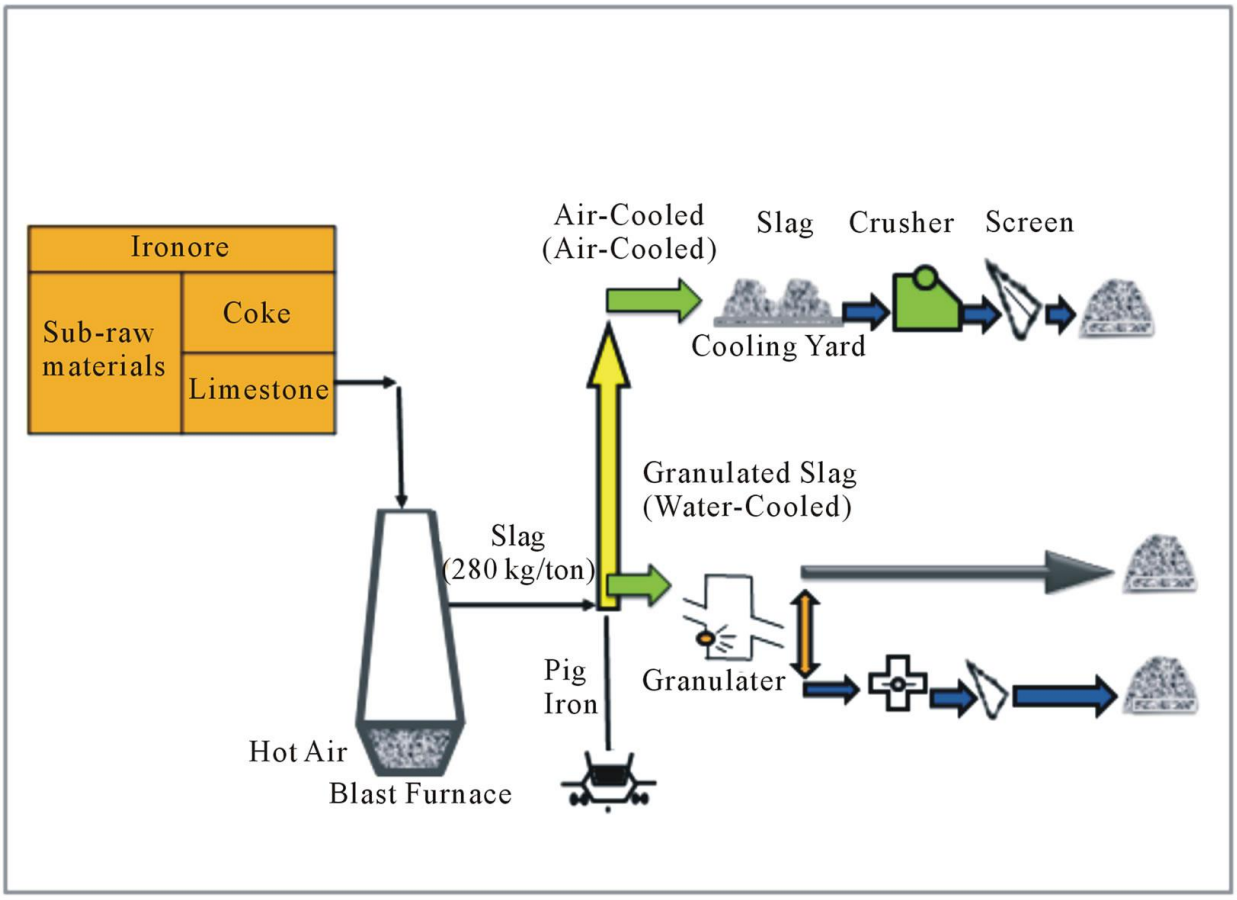


Appendix 3

Types of slump

SAMP

Appendix 4



SAMPLE