CHAPTER 2

LITERATURE REVIEW

2.1 GENERAL

This chapter represents the review and summary of past research in producing concrete using waste materials from industry for effective replacement of fine aggregate. Several research works were carried out to use granite waste from Stone processing industry and coal bottom ash from Thermal power plant as marginal and full replacement for fine aggregate in concrete are presented in this chapter. It also includes the literature about fresh concrete properties, strength, durability and the structural behaviour of concrete with the replacement of fine aggregate.

2.2 HIGH STRENGTH CONCRETE AND MANUFACTURED SAND

Bhikshma et al. (2009) have presented results of high strength silica fume concrete. They concluded that Cement replacement up to 12% with silica fume leads to increase in compressive strength, splitting tensile strength and flexural strength, for both M40 and M50 grades. There was a decrease in compressive strength, tensile strength and flexural strength for 28 days curing period for the replacement above 12%. The compressive strength, splitting tensile strength and flexural strength of M40 grade concrete was increased by 16.37%, 36.06% and 16.40% respectively and for M50 grade concrete 20.20%, 20.63% and 15.61% respectively over controlled concrete. The value of modulus of elasticity of concrete increases with increases in silica fume content up to a replacement level of 12%. Workability was reduced as the replacement level increases and hence water consumption will
be more for higher replacements. He concludes that the maximum replacement level of silica fume was 12% for M40 and M50 grades of concrete.

Donza et al. (2002) conducted the experiments on High-strength concrete (HSC) with different fine aggregate. HSC having similar or better mechanical strength than concrete with natural sand can be produced using crushed sand as fine aggregate. The effect of crushed sand on fresh concrete presents some disadvantages compared with natural sand. Crushed sands require a higher dosage of admixture to overcome the adverse shape and texture of particles. For each type of sand and cement content in the mixture, the optimal doses need to be studied. The shape and texture of crushed sand particles have an important effect on the interlocking of paste and aggregate particles, leading to an improvement of strength of concrete. Based on the tests results it was concluded that the crushed sand appears as the most advantageous for producing HSC.

Li Beixing et al. (2011) observed the results about the Influence of manufactured sand (MS) on strength of pavement cement concrete. The increment of microfines in MS from 4% to 20% do not adversely affect the strengths and abrasion resistance of MS concretes, when the microfines content is 10%, the pavement performances of the MS concrete achieve the best. With the increase of surface roughness of MS particles, the compressive and flexural strengths of concrete increase; while with the increase of crushing value of MS particles, the flexural strength of concrete decreases. There was no evident relationship between crushing value of MS and compressive strength of MS concrete. The abrasion resistance of the MS-PCC has better relation with surface roughness, crushing value and Los Angeles abrasion loss of the sand particles, while has no evident relation with the
silicon content of the sand. MS with large roughness, low crushing value and good abrasion resistance was suitable for producing high quality PCC.

Papayianni et al. (2005) reported the performance of concrete mixtures by the Influence of super plasticizer. From the comparison of the superplasticizers the conclusion drawn was that the type S3 of carboxylic base was of higher performance than types S1 (water diluted sulfonated polymers), S2 (synthetic polymers). It gives a higher decrease of the w/c ratio which was up to 40% in mixtures with crushed aggregates. The loss of workability through time was normal and in the case of concrete with coarse aggregates it was of the same level compared with that of the reference mixture without superplasticizers. The performance depends on the dosage. The maximum strength, which is achieved with 2% dosage, is 47 MPa (increase of 18% compared with the reference strength). Comparing the corresponding pairs of mixtures, in which superplasticizers of the same type and in the same dosage were added and which also differ only in the type of aggregates (river/crushed), it can be said that the performance of all superplasticizers with natural river aggregates was lower. Water decrease and the achieved strength were of a lower level. This can be explained by the higher amount of fine materials (0.25–1.0) mm which exists in river aggregates. In most of the mixes the inclusion of a superplasticizer produced an increase in the voids content of the concrete.

Parande et al. (2011) studied the Environmental effects on concrete using Ordinary Portland cement (OPC) and Pozzolana Portland cement (PPC). Compressive strength tested for normal water exposure (NW), the control PPC showed superior to OPC at 150 days. Specimen cured in Domestic sewage water (DSW), PPC concrete had the maximum value when compared to OPC concrete at all ages of curing.
The increase in compressive strength in PPC was due to the pozzolanic reaction between Pozzolana and calcium hydroxide there after the lime and C_2S in the cement begin to hydrate. In RCPT studies, the total electrical charge (coulombs) passed was more in OPC and less in PPC specimen.

Davoud Tavakoli & Ali Heidari (2013) presented the properties of concrete incorporating silica fume and nano-SiO\(_2\). The combination of silica fume with nano-SiO\(_2\) as a replacement for cement has been investigated in this study. The silica fume was used in quantities of 5 and 10 percent and nano-SiO\(_2\) was 0.5 and 1 percent of the cement. Silica fume and nano-SiO\(_2\) can lead to the improvement of concrete strength. Moreover, given the less water absorption as a result of using these two materials, it can be maintained that these materials enhance the concrete durability in the long term. Nano-SiO\(_2\) in low amounts can exert positive and desirable impacts on concrete. Therefore, the necessity to do further studies was strongly felt. The simultaneous use of silica fume and nano-SiO\(_2\) increase the strength and durability of concrete compared with their single use, besides, in view of the two materials, influence process in the case of their simultaneous use in concrete, all defects of concrete in all ages will be covered and caused them to strengthen each other.

Shi-cong Kou et al. (2011) carry out research to compare the natural and recycled aggregate concrete prepared with the addition of different mineral admixtures. The compressive strength of concrete containing recycled aggregate at 1, 4, 7, 28 and 90 days was lower than that of the control specimen, but could be compensated by the use of 10% SF or 15% (metkaolin) MK. The tensile splitting strength of natural and recycled aggregate concrete made with SF and MK was higher than that of the corresponding control concrete at all test ages, whereas FA and GGBS
decreased the tensile splitting strength of the concretes. SF and MK increased UPV of both the natural and recycled aggregate concrete. The rapid chloride ion penetration test indicated that the concrete containing recycled aggregate had a more open pore structure, compared to the control concrete. The use of mineral admixture resulted in a decrease in the charge passed through the concrete specimens. He conclude that SF and MK can improve both mechanical and durability properties of recycled aggregate concrete. But the use of FA and GGBS significantly improved the durability performance of the recycled aggregate concrete. The contributions of the mineral admixtures to performance improvement of the recycled aggregate concrete were higher than that to the natural aggregate concrete.

Muhannad Ismeik (2010) studied the Utilization of Silica Fume as a Partial Replacement of Fine Aggregate in Concrete. The 28-day compressive strength of silica fume concrete specimens was higher, up to 21.6%, than the control mix specimens at all w/c ratios. The strength difference between silica fume concrete specimens and control mix specimens was distinct at 5% replacement level. Strength continued to increase with age for all silica fume percentages. The optimum 28-day compressive strength has been obtained in the range of about 10 to 15% replacement of fine aggregate with silica fume. The 28-day compressive strength of concrete containing silica fume was acceptable for most structural applications and reinforced concrete construction, since the observed compressive strength was more than 27.13 MPa at 28 days for all w/c ratios used. Results of this investigation concludes that silica fume, used as a partial replacement of fine aggregate, could be conveniently used in concrete production as a means of waste product utilization and as a saving of fine aggregate resources which in turn protects the environment from pollution effects.
Pofale & Syed Raziuddin Quadri (2013) published their results on use of crusher sand in concrete with pozzolana Portland cement. The compressive strength of M25 and M30 concrete mix had increased by 22% and 16% respectively with the use of crusher sand at 40% replacement of natural sand at the levels of 30%, 40%, 50% and 60% showed an increase in compressive strength.

Compacting factor test results show that there is a decrease in workability with the increase in quantity of crusher sand as a partial replacement of natural sand. The workability can be increased by using plasticizers.

Manufactured sand particles are angular in shape and their rough surface texture improves the internal friction in the mix, hence the workability is reduced. The amount of fine particle present ensures effective packing and large dispersion of cement particles thus fomenting better hydration conditions moreover the dust particles completed the matrix interstices and reduce space for free water the combination of among the concrete components. The modified flow test results indicate that as the crusher dust quantity increases, the velocity of the flow is also increased.

Elavenil & Vijaya (2013) reported the performance of manufactured sand in concrete. The fresh properties of concrete are certainly affected by the use of manufactured sand, but the hardened properties such as flexural strength and compressive strength are not affected by the gradation.

Their particle size distribution helps in higher packing density which enhances the durability of the concrete. Research findings concluded that, compared to concrete made from river sand, high fines concrete
generally had higher mechanical properties due to fillings the pores with microfines.

Merve Basar & Nuran Deveci Aksoy (2012) submitted the report about the effect of waste foundry sand in ready mixed concrete. It exhibited almost similar geometrical, physical and chemical properties as that of regular sand (fine aggregate). Partial replacement of regular sand with foundry sand decreases the strength performance (compressive strength, tensile splitting strength and modulus of elasticity) of concrete at all ages. The strength properties of all concrete mixtures increases with curing period and the strength performance determined at 56 days are similar to that observed in the case of 90 days.

Foundry sand can be used as a replacement of 20% of regular sand without compromising the mechanical and physical properties. Microstructural properties and morphological characterization of both control mix and concrete mix having 20% foundry sand are almost the same. Foundry sand can be effectively utilized in making good quality RMC as a partial replacement of fine aggregates (20%).

Mohamed Lyes Kamel Khouadjia et al. (2015) presented the workability properties and compressive strength of concrete with several local sand and mineral additions. The behaviour of concrete is influenced by sand type. It depends on the rate of fines and particle shape. Concrete with few fine particles has better performance if mineral additions and dune sand are used as a crushed sand replacement to fill granular voids. Slag and pozzolan increase of the water need in concrete with a high rate of fine particles. The use of slag provides a positive effect on the compressive strength at an early age. However, natural pozzolan provides a positive effect on the compressive strengths in the long term.
Nimitha.Vijayaraghavan & Wayal (2013a) discussed about the effects of manufactured sand on compressive strength and workability of concrete. All the mixes of concrete for the replacement of natural sand by manufactured sand when compared to control mix expose higher compressive strengths. In 50% replacement with admixture the compressive strength increases by 5.7%. In 100% replacement of natural sand by crushed sand, the compressive strength increases by 7.03%, which is maximum. Concrete mix becomes tough with increase in proportion of manufactured sand. They concluded that the river sand can be fully replaced by manufactured sand.

Nimitha.Vijayaraghavan & Wayal (2013b) studied and presented their results about the effect of manufactured sand on durability properties of concrete. Manufactured sands are made by crushing aggregate to sizes appropriate for use as a fine aggregate. Due to irregular shape of the aggregates there is a good bond among the particles thereby reducing the voids in concrete. The resistance to penetration of water is increased with increasing proportion of manufactured sand in concrete. They concluded that the river sand can be fully replaced by manufactured sand. The use of manufactured sand in the construction industry helps to prevent unnecessary damages to the environment.

Nithyambigai (2015) presented the effects of Partial Replacement of Manufactured Sand and Fly Ash in Concrete. The Fly ash and M-Sand replacement for M35 grade of cement concrete has compared with the compressive strength of concrete with control mix for 28 days and 56 days. Compressive strength attained by using 25 % replacement showed good results and can be recommended for multi-storey buildings where high strength is required. The use of fly ash and M-Sand in concrete will reduce the cost of concrete. Use of M-Sand as partial replacement of fine aggregate is suitable replacement to natural sand in concrete manufacturing.
Praveen Kumar & Radhakrishna (2015) discussed the strength and workability of cement mortar with manufactured sand. The workability of mortar increases with partial replacements up to 80%. The strength of M-sand mortar is high when compared to natural sand cement mortar at all replacement levels. Since workability of 100% M-sand cement mortar is less, but strength is more, use of admixtures can be made to achieve workability in par with natural sand cement mortar. The mortar with M-sand is recommended for masonry work.

Priyanka Ajadhava & Dilip K Kulkarni (2012) presented their research work on an investigation on the properties of concrete containing manufactured sand. The effect of concrete with partial replacement of manufactured sand on the properties of normal strength concrete with water cement ratio of 0.45 and 28 day’s compressive, split tensile and flexural strength of 20MPa and workability were studied. The compressive, split tensile and flexural strength of concrete with 60% replacement of natural sand by manufactured sand reveals higher strength as compared to reference mix. Manufactured sand has a potential to provide alternative to natural sand and helps in maintaining the environment as well as economical balance. The manufactured sand found to have good gradation and resulted in good cohesive concrete. This sand is considered as an ideal for concrete.

Ilangovana et al. (2008) discussed about the strength and durability properties of concrete containing quarry rock dust as fine aggregate. Natural river sand, if replaced by hundred percent quarry dust from quarries, gives equal or better than the reference concrete made with Natural Sand, in terms of compressive and flexural strength studies. The Durability of Quarry Rock Dust concrete under sulphate and acid action is higher inferior to the Conventional Concrete. Permeability Test results shows that the permeability of Quarry Rock Dust concrete is less compared to that of conventional
concrete. They concluded that the replacement of natural sand with Quarry Rock Dust, as full replacement in concrete is possible.

Ramazan Demirboga & Rustem Gul (2006) studied the effects of Production of high strength concrete by use of industrial by-products (slag). Slag was used to replace natural aggregates increased the density of concrete up to 10%. The compressive strength of slag concretes was approximately 60–80% higher than that of control concretes for different w/c ratios. Artificially manufactured aggregates are more expensive to produce and the available source of natural aggregates may be at a considerable distance from the point of use, in which case the cost of transporting is a disadvantage. An artificial aggregate from industrial wastes prevents environmental pollution. It is concluded that slag, in combination with other supplementary cementitious materials, can be utilized in making high-strength concretes up to 60MPa.

Mohamed Amin & Khaled Abu el-hassan (2015) found the effect of using different types of nano materials on mechanical properties of high strength concrete. The improving percentage of compressive strength of concrete when nano silica and nano ferrite was added reaches 21% and 17%, respectively, with respect to the control mixes. With the addition of nano silica and nano ferrite the improving percentage of splitting tensile strength of concrete reaches approximate rate of about 44% and 60%, respectively, with respect to the control mixes. With the addition of nano silica and nano ferrite the improving percentage of flexural strength and modulus of elasticity of concrete reaches approximate rate of about 23% and 25%, respectively, with respect to the control mixes. They concluded that the sample of concrete containing granite was better than similar-containing dolomite and the approximate rate of about 10%. The use of a superplasticizer was necessary in the concrete mixes to improve the workability.
2.3 CONCRETE WITH WASTE MATERIALS

2.3.1 Granite powder

Nuno Almeida et al. (2007) presented the report on High Performance Concrete with stone slurry. Dimension stone industry was responsible for generating about 1 ton of stone slurry (semi-liquid natural stone waste) per 2.5 ton of final product. Besides depleting mineral resources, it causes serious environmental impact regarding water, air, soil, landscape visual aggression, biodiversity and human communities. A research was aiming to evaluate the feasibility of incorporating stone slurry in high-performance concrete mixtures. The results showed that the substitution of 5% of the sand content by stone slurry induced higher compressive strength, higher splitting tensile strength, and higher modulus of elasticity and improvement of properties related to durability. The feasibility of incorporating up to 20% stone slurry in detriment of the respective amount of fine aggregate without prejudicing mechanical properties in a serious manner was also determined. The behaviour of fresh high-performance concrete is enhanced due to the presence of the stone slurry particles and that the performance of hardened concrete can benefit up to 16%.

Felixkala & Partheeban (2010) studied about the properties of Granite Powder Concrete. The performance of concrete made with granite powder as fine aggregate and partial replacement of cement with 7.5% Silica fume, 10% fly ash, 10% slag and 1% superplasticiser subjected to water curing was conducted for finding the characteristic mechanical properties such as compressive strength, split tensile strength, modulus of elasticity for 1, 7, 14, 28, 56 and 90 days of curing for 0.40 water-cement ratio. The test results indicated that granite powder as a partial sand replacement has beneficial effects of the mechanical properties of high performance concrete.
Concrete with 25% of granite powder (GP25) was found to be superior to other mixtures as well as GP0 and NA100 for all operating conditions. Therefore the conclusions were made based on a comparison of GP25 with the conventional concrete with 0% of granite powder, GP0. There was an increase in strength as the days of curing increases and decreases as the curing temperature increases.

In general, the behaviour of granite aggregates with admixtures in concrete possesses the higher properties like concrete made by river sand. Thus granite powder aggregate in concrete was the best choice, where they are available.

Abukersh & Fairfield (2011) reported that the recycled aggregate concrete produced with red granite dust (RGD) as a partial cement replacement. Substantial quantities of RGD, estimated at between 1% and 2% by mass of the total aggregate crushed, are produced in quarries. This RGD is currently disposed of as waste. The mechanical properties of recycled aggregate concretes should be directly measured on representative samples. The results showed that natural aggregate concretes produced with dust, 30% cement replacement level had strengths. Concrete with 30% dust demonstrated better early age strength. Any RGD addition beyond 30% caused a decrease in strength.

Divakar et al. (2012) presented the results on the behaviour of concrete with the use of granite fines. The compressive strength was increased by 22% with the use of 35% replacement of fine aggregates with granite fines. With increase of granite fines up to 50% increasing compressive strength will limit to 4% only. The split tensile strength remains same for 0%, 25% and 35% replacement of fine aggregates with granite fines. For 5% replacement there was an increase of 2.4% of strength and for 15% replacement there was
a reduction of tensile strength by 8%. With the replacement of 35% granite fines the test results shows no decrease in strength compared with the conventional mix using fully sand as fine aggregates. The flexural strength of prism of 10cm x 10cm x 50cm without reinforcement, there was 5.41% increase in flexural strength with 5 % replacement, and there was a small decrease up to 5% in flexural strength at 15%, 25% and 35% replacement with granite fines and further reduction in strength (i.e. 6%) at 50% replacement of granite fines in comparison with test results of nominal concrete mix of 1:1.5:3 (M-20) without granite fines. The water cement ratio has been considered for all the mixers as 0.6. The workability of concrete mixes decreased with the increase in percentage of granite fines as partial replacement of sand. The other strength and durability test conducted shows that the granite fines was fit to be used in concrete mixes. The dimension of the granite fine particles was compatible with the purpose of filing up the transition zone and capillary pores, thus acting as micro filler.

Vijayalakshmi et al. (2013) presented the results on Strength and durability properties of concrete made with granite industry waste. The mechanical and durability property of the GP concrete was studied to ensure the reliability of its usage in aggressive environments. Based on the extensive experimental test results of six mixtures the following conclusion can be made. The high surface specific area and rough and angular texture of the GP waste, have led to the significant losses in slump in addition the workability of the concrete decreases with the increases in the substitution rate. The early age (i.e. 7 days) compressive strength of the mixtures CGP 5%, CGP 10%, CGP 15% showed better gain in strength when compared to the CM. The reason may be attributed to the denser matrix of the GP by-product and the better dispersion of the cement grains. The split tensile and flexural strength of the concrete mixtures CGP 5%, CGP 10%, CGP 15% were somewhat equal or little lower than the control mixture however significant losses in
tensile and flexural strength was observed beyond the substitution rate of 15%.

Chloride penetration values of the mixtures CGP 5%, CGP 10% and CGP 15% were almost equivalent to the penetration value of the CM. However mixtures CGP 20% and CGP 25% were showed highest permeability value. The chloride penetration rate of the concrete was increased when increasing the GP waste substitution rate. The GP waste should be subjected to chemical bleaching or oil separation process using petroleum ether (Hydro carbons), prior to blend in the concrete in order to remove the oil traces present in the GP. It was recommended that the replacement of natural sand by GP waste up to 15% of any formulation is favourable for the concrete making without adversely affecting the strength and durability criteria.

Kanmalai Williams et al. (2008) studied and presented the behaviour of high performance concrete incorporating granite powder as fine aggregate. The granite powder as a partial sand replacement has beneficial effects of the mechanical properties of high performance concrete. Of all the five mixtures considered, GP25 was found to be superior to other mixtures as well as GP0 for all operating conditions. Compressive strength, Split tensile strength, modulus of elasticity for G25, particularly in all the ages higher than that of the reference mix (GP0). There was an increase in strength as the days of curing increases.

The behaviour of granite aggregates with admixtures in concrete possesses the higher properties like concrete made by river sand. The strength properties of the concrete could enhance the effect of utilization of granite powder obtained from the crusher units in the place of river sand both granite stone and granite powder in concrete are the best choice, where they are
available. Hence the granite aggregates was considered as equivalent or alternative coarse and fine aggregates for blue metal and river sand.

Nagabhushana & Sharada Bai (2011) published their research paper on Use of crushed rock powder as replacement of fine aggregate in mortar and concrete. The natural sand can be replaced by Crushed Rock Powder (CRP) in case of cement mortars. The strength of mortar containing 40% CRP was much higher than normal mortar containing only sand as fine aggregate. Though the trend in variation of compressive strength with percentage of CCRP was found to be similar to that of CRP mortar, the strength of CCRP mortar was less than that of CRP mortars. It was better to use CRP without removing the finer particles. For lean mortar mixes, CRP can be replaced up to 100%. For rich mortar mixes, CRP can be replaced up to 40%. It was concluded that the compressive strength, split tensile strength and flexural strengths of concrete are not affected with the replacement of sand by CRP as fine aggregate up to 40%. Hence, CRP can be effectively used to replace natural sand, without reduction in the strength of concrete with CRP replacement level up to 40%.

Felixkala & Sethuraman (2013) had published the results on Shrinkage Properties of concrete using Granite Powder as Fine Aggregate. Experimental investigation on the high performance concrete made with granite powder as fine aggregate and partial replacement of cement with 7.5 % silica fume, 10% fly ash, 10% slag and 1% superplasticiser was conducted for finding the shrinkage parameters for 0.35 water-cement ratio. The test results concluded that granite powder as a partial sand replacement and partial replacement of cement with admixtures has beneficial effects of the shrinkage properties of high performance concrete. Of all the three mixtures considered, concrete with 25% of granite powder (GP25) was found to be superior to other mixtures for all operating conditions. The combination
of admixtures with granite powder can produce a concrete of lower shrinkage parameters as compared to conventional concrete. The behaviour of granite aggregate with admixtures in concrete possesses the higher properties like concrete made by river sand.

Rubaninbacheran & Ganesan (2014) conducted tests on Durability of Fibre Concrete Using Partial Replacement of Cement by Granite. 25%, 30%, 35% granite powder specimen having chloride ion permeability in low range proves to be more economical than all other specimen. 25% granite powder specimen having highest residual compressive strength was the most durability against fire. 25% granite powder specimen having the least sulphate deterioration factor, was the most economical of the specimen.

FelixKala (2013) investigated the effect of Granite Powder on Strength Properties of Concrete. An experimental study on the high performance concrete made with granite powder as fine aggregate and partial replacement of cement with 7.5 % Silica fume, 10% fly ash and 10% slag subjected to water curing was conducted for finding the mechanical properties such as compressive strength, split tensile strength, modulus of elasticity, flexural strength and water absorption characteristics of concrete mixtures. Concrete specimens were prepared with w/c ratio of 0.25, 0.30, and 0.35 for M60 grade concrete mix. The test results show clearly that granite powder as a partial sand replacement has beneficial effects of the mechanical properties of high performance concrete. Of all the six mixtures considered, concrete with 25% of granite powder (GP25) was found to be superior to other percentages of granite powder concrete as well as conventional concrete and no admixtures concrete for all operating conditions. The mechanical properties like the compressive strength, split tensile strength, modulus of elasticity and flexural strength particularly for all ages higher than that of the reference mix, CC as mentioned below. The strength properties of the
concrete could enhance the effect of utilization of granite powder obtained from the crusher units in place of river sand in concrete. In general, the behaviour of granite aggregates with admixtures in concrete possesses the higher properties like concrete made by river sand.

Talah et al. (2015) have presented the effect of Marble Powder on High Performance Concrete Behaviour. Marble powder could be used as partial replacement of Portland cement up to 15% in composite cement. The durability test on the concrete containing Marble powder consisted of immersion in running water, chloride solution, in all cases, structural changes to the samples were noted. In all cases the addition had improved the physical characteristics of concrete relatively to the reference concrete sample. The addition of Marble powder contributes to the reduction of chloride ion penetration and oxygen permeability and increase the durability of concrete. They concluded that Marble powder had positive influence on the properties of concrete under hydrochloric mediums.

Bacarji et al. (2013) investigated the effect of marble residue and granite residue as filler in concrete. The replacement of Portland cement by marble and granite residues was studied. Experimental research has been conducted where 5%, 10% and 20% of the cement was replaced by residues and the mechanical performance was determined by means of compressive strength tests, elastic modulus tests and water adsorption tests. They concluded that the X-ray diffraction analysis shows a crystalline nature and due to its non-reactive nature, in general, adding residue as a cement replacement leads to a relative reduction of the compressive strength.

Gameiro et al. (2014) studied the durability performance of structural concrete containing fine aggregates from waste generated by marble quarrying industry. The workability of fresh concrete tends to decrease as the
replacement ratio increases except for the river sand specimens. Water absorption by immersion, it can be concluded that incorporating marble improved the permeability of the granite specimens, which is beneficial for durability. Concerning carbonation resistance, granite sand mixes improved with the incorporation of marble sand. The chloride migration coefficient decreased in the granite and basalt concrete mixes as the fine marble waste aggregates replacement ratio increased.

Huajian Li et al. (2016) studied the effect of granite dust on mechanical and durability properties of manufactured sand concrete for the replacement of fly ash. When granite dust is utilized, a lower superplasticizer dosage is needed to obtain the same slumps. Concrete early strengths are reduced by introducing granite dust. When the replacement ratio is controlled within 20%, the manufactured sand concrete possesses higher long term compressive strengths, bending strengths and elastic moduli.

The chloride penetration of the concrete with granite dust is better than that of pure cement concrete. The workability, mechanical property, durability and shrinkage performance, the optimum dosage of granite dust is 20% of the total cementitious materials.

Marmol et al. (2010) presented the use of granite sludge wastes for the production of coloured cement-based mortars. The composition of granite sludge wastes, the main components of which are SiO₂, Al₂O₃, CaO and Fe₂O₃ based compounds, together with their small particle size. The compressive strength was increased gradually replacing CaCO₃ filler with GS. Conversely, 10% cement can be replaced with GS without loss of 28 day compressive strength. GS can be readily converted into reddish pigments simply by calcination.
Telma Ramos et al. (2013) reported the effect of Granite quarry sludge waste in mortar. Quarry granitic sludge waste studied is mainly composed of silica and alumina. Particles observed in SEM showed to be more angular and elongated compared to cement. Mortars Strength at 28 days for coarser (PG) and finer (PGS) granitic sludge waste used at 10% cement replacement was lower than control mortar but strength loss was marginal for PGS. They concluded that, the granitic quarry sludge waste, if ground to sufficient fineness, produces a denser matrix promoting up to 38% reduction in expansion due to ASR and almost 70% improvement in resistance to chlorides (higher than SF mortar).

2.3.2 Bottom Ash

Aggarwal et al. (2007) presented the properties of bottom ash as replacement of fine aggregate in concrete. The workability of concrete decreased with the increase in bottom ash content due to the increase in water demand, which was incorporated by increasing the content of superplasticizer. The density of concrete decreased with the increase in bottom ash content due to the low specific gravity of bottom ash as compared to fine aggregates. Compressive strength, Splitting tensile strength and Flexural strength of fine aggregates replaced bottom ash concrete specimens were lower than control concrete specimens at all the ages. The strength difference between bottom ash concrete specimens and control concrete specimens became less distinct after 28 days. Compressive strength, Splitting tensile strength and Flexural strength of fine aggregate replaced bottom ash concrete continue to increase with age for all the bottom ash contents. Mix containing 30% and 40% bottom ash, at 90 days, attains the compressive strength equivalent to 108% and 105% of compressive strength of normal concrete at 28 days and attains flexural strength in the range of 113-118% at 90 days of flexural strength of normal concrete at 28 days. The time required to attain the required strength
was more for bottom ash concrete. Bottom ash concrete attains splitting tensile strength in the range of 121-126% at 90 days of splitting tensile strength of normal concrete at 28 days. Compressive strength of bottom ash concrete containing 50% bottom ash was acceptable for most structural applications since the observed compressive strength was more than 20 MPa at 28 days. Even though the strength development was less for bottom ash concrete, it can be equated to lower grade of normal concrete and making utilization of waste material justifies the concrete mix-development. Bottom ash used as fine aggregates replacement enables the large utilization of waste product.

Mohd Syahrul Hisyam bin Mohd Sani et al. (2010) represented the results on the properties of special concrete using washed bottom ash as partial sand replacement. Bottom ash of 10% cement replacement by weight was not suitable for concrete because it has produce a lower strength concrete at the early ages which can results in ruptures during construction. 30% WBA replacement for fine aggregate was found to be the optimum amount in order to get a favourable strength and good strength development pattern over the increment ages.

Seung Bum Park et al. (2009) studied about the mechanical properties of porous concrete utilizing coal bottom ash coarse aggregate. The chloride content of the coal bottom ash aggregate satisfied the standard allowable values when it was washed more than twice. The compressive and flexural strength tended to be decreased at all aggregate grading as the coal bottom ash mixing ratio increased. When fly ash and coal bottom ash were mixed together and even though the bottom ash mixing ratio was 20%, the compressive strength increased by approximately 0.5% at the age of 90 days. However, it was decreased to 11.7–27.1% at a mixing ratio of greater than 40%. When the coal bottom ash was not mixed, the specimen fracture
occurred due mostly to aggregate fracture and interface fracture between aggregate and binder. However, as the coal bottom ash mixing ratio increased, the specimen was fractured due to the fracture of the coal bottom ash aggregate itself rather than interface fracture.

Kim & Lee (2011) presented the results of use of power plant bottom ash as fine and coarse aggregates in high-strength concrete. The porosity of the mortar with Fine Bottom Ash (FBA) aggregates was higher than that with Normal Fine aggregates (NF), and the discrepancy between the two values decreased from 6 vol. % to 2 vol. % along with a decrease of W/B from 50% to 20%. Due to the presence of absorbed water in the FBA, the mortar flow was increased by 10–20% with the replacement by FBA aggregates, except in the case of the mortar with W/B = 50%. The W/B of the mortar with FBA aggregates was slightly higher than that of the mortar with NF aggregates, because the water absorbed in FBA aggregates is believed to have been expelled out of the pores during mixing process. The relative values of compressive strength were in a range of 80–95%, while the compressive strength of the reference specimen (the mortar with NF aggregates) was in a range of 40–90 MPa. It was concluded that the higher porosity and higher W/B in the mortar with FBA aggregates resulted in lower compressive strength as compared to the mortar with NF aggregates. The mortar with FBA aggregates showed higher capillary absorption than the mortar with NF aggregates because of the higher porous structure of FBA aggregates.

Kou Shi-Cong & Poon Chi-Sun (2009) reported the Properties of concrete prepared with crushed fine stone, furnace bottom ash and fine recycled aggregate as fine aggregates. When using the same W/C ratio, generally the compressive strength of the FBA and FRA concrete decreased at all the ages with an increase in the FBA and FRA contents. This may be due
to the high initial free water content used in the mixes rendered bleeding and poorer interfacial bonding between the aggregates and the cement pastes. At a fixed W/C, the compressive strength decreased with the increase in the Fine Bottom ash content. Fine Recycled Aggregate decreased the compressive strength of the concrete. At a fixed slump value, the use of FBA and FRA was able to reduce to free water requirement of the concrete mixes. For the mixes prepared with the same slump range and with the use of a lower free W/C ratio, the FBA concrete had the highest compressive strength values. At a fixed slump value, the resistance to chloride-ion penetration of all FBA, FRA and Crushed Fine stone (CFS) concretes was higher than that of the control concrete. It was feasible to use FBA and FRA as fine aggregate in preparing concrete mixes.

Malkit Singh & Rafat Siddique (2013) reported the results of Effect of coal bottom ash as partial replacement of sand on properties of concrete. The published research literature shows that the strength development pattern of bottom ash concrete is similar to that of conventional concrete but there is decrease in strength at all the curing ages. The decrease in strength of concrete is mainly due to higher porosity and higher water demand on use of bottom ash in concrete. The compressive strength can be improved by reducing the water demand by using super plasticizers.

Malkit Singh & Rafat Siddique (2014) discussed the results of Strength properties and micro-structural properties of concrete containing coal bottom ash as partial replacement of fine aggregate. The workability of bottom ash concrete decreased on use of coal bottom ash in partial or full replacement of river sand in concrete. The slump and compaction factor values of bottom ash concrete decreased with the increase in levels of sand replacement by coal bottom ash in concrete. Compared to sand particles, the porous particles of coal bottom ash absorbed more water internally as such
quantity of water available for lubrication of constituent particles of the bottom ash concrete mixture reduced. The complicated shape and texture of particles of coal bottom ash have also contributed towards increasing the interparticle friction and hence lowering the workability of concrete.

Density of concrete decreased linearly on use of coal bottom ash in concrete. The decrease in density of bottom ash concrete was apparently due to low specific gravity of coal bottom ash and increased pore space. At the early age, compressive strength reduced marginally on the inclusion of coal bottom ash in concrete. However, 28 days compressive strength of concrete was not found to be significantly affected by replacing river sand with coal bottom ash. After 28 days of curing age, compressive strength of bottom ash concrete mixtures improved and surpassed the compressive strength of the control concrete mixture.

The pozzolanic activity of coal bottom ash was slow up to 14 days and starts after 28 days of curing age. It was believed that after 28 days of curing age, the pozzolanic activity of coal bottom ash have helped in improving the compressive strength of bottom ash concrete mixtures over that of control concrete. The reduced free water cement ratio also played its role in improving the compressive strength of bottom ash concrete mixtures.

Splitting tensile strength of concrete improved at all the curing ages on use of coal bottom ash as fine aggregate in partial or full replacement of river sand. With the progress of curing age, the effect of inclusion of coal bottom ash in concrete on splitting tensile strength and compressive strength ratio was not so predominant. Similar to the conventional concrete, compressive strength of bottom ash concrete with the progress of curing age improved at a faster rate than the splitting tensile strength.
Modulus of elasticity of concrete mixture containing coal bottom ash as fine aggregate in partial or full replacement of river sand was lower than that of control concrete. Modulus of elasticity decreased linearly with the increase in levels of river sand replacement by coal bottom ash in the concrete.

Andrade et al. (2009) reported the Influence of coal bottom ash as fine aggregate on fresh properties of concrete. The high porosity of the bottom ash means that the w/c ratio of the concrete cannot be taken as exact. The water absorbed internally by the bottom ash was released to the concrete over time, being part of the production process with the concrete still in the fresh state. The presence of bottom ash increased the quantity of water loss by bleeding, the bleeding time and also the water release rate, and the higher the bottom ash content of the concrete the greater this effect.

The reference concrete showed a lower quantity of heat evolution as well as a lower heat evolution rate in relation to the concretes with bottom ash. The two ways to add bottom ash in the concrete mixes influenced significantly the mechanical behaviour. The CRT3 type concrete, due to the high w/c ratios, showed very significant losses in compressive strength. The CRT4 type concretes, which were manufactured with the aim of maintaining the mechanical properties, gave similar results to those of the reference concrete.

Nader Ghafoori & Jeffrey Bucholc (1996) submitted the results on an Investigation of lignite based bottom ash for structural concrete. Due to the high absorption rate, angular shape, and very porous surface of the bottom ash, higher water content was required to achieve the degree of lubrication needed for a workable mix. When a water reducing admixture was incorporated into the mixture, the setting time remains unaffected in the
mixtures of low cement content [297 kg/m$^3$ or less] and decreases slightly in the high cement content concretes [416 kg/m$^3$ or more]. Due to the higher water-cement ratio, the strength properties of the bottom ash mixtures without admixture are slightly lower than those of the control samples. Inclusion of the bottom ash has a more pronounced influence on tensile resistance than on compressive strength. When a water-reducing admixture was used, splitting-tensile resistance of the bottom ash concretes was superior to that of the control mixtures at all levels of cement content and curing age. Bottom ash mixtures display a lower modulus of elasticity than the control mixes. The chloride permeability of the bottom ash concrete was considered high by the AASHTO T 277 specification. The permeation of chloride ions into the bottom ash concrete decreases drastically when a low dosage of superplasticizer was used. As a result, the difference in conductivity between the bottom ash and control concretes was cut in half. Bottom ash and natural sand concretes exhibit similar expansion characteristics under external sulfate attack.

Kim et al. (2012) reported the mechanical characteristics of normal and high-strength mortar incorporating fine bottom ash aggregates. The mortar with Fine Bottom Ash aggregates was lighter than the mortar with Natural Fine aggregates regardless of the W/B because of the lighter specific gravity and porous structures of the FBA aggregates. The porosity of the mortar with FBA aggregates was higher than that with NF aggregates. The relative values of compressive strength were in a range of 80–95%, while the compressive strength of the reference specimen (the mortar with NF aggregates) was in a range of 40–90 MPa. It can be said that the higher porosity and higher W/B in the mortar with FBA aggregates resulted in lower compressive strength as compared to the mortar with NF aggregates.

Turhan Bilir (2012) submitted the report on the Effects of non-ground slag and bottom ash as fine aggregate on concrete permeability.
properties. Concretes having 10%, 20% and 30% replacement ratios have lower strength losses than reference one. All groups are durable against chloride permeability. Non Ground Coal Bottom Ash can be used at 30% ratio, to produce very low permeable concrete.

Ashis Kumar Bera et al. (2007) had reported about the compaction characteristics of pond Ash. Three types of pond ash have been chosen to investigate the effects of compaction energy, moisture content, and specific gravity. Dry density of pond ash increases up to a certain limit of thickness, beyond which no significant change of dry density is observed. Specific gravity significantly affects the dry density of pondash. The relationship between dry density and moisture content for a particular pond ash is linear. Based on the experimental results, a linear relationship has been developed between dry density, specific gravity and moisture content.

Haldun Kurama & Mine Kaya (2008) studied the usage of coal combustion bottom ash in concrete mixture. In concrete tests, although the compressive and flexural strengths of specimens cured at 56 day increase with increasing amount of ash replacement up to 15%, the maximum substitution rate of CBA was determined as 10%. When 10% of CBA is replaced by cement, the compressive strength of CBA-concrete increases from 42.65 N/mm² to 45.1 N/mm². The observed C–S–H fibres or elongated particles on the SEM micrograph of BC10 clearly indicate the pozzolanic effect of CBA substitution on improving the strength of concrete.

Hyeong-Ki Kim (2015) discussed about the utilization of sieved and ground coal bottom ash powders as a coarse binder in high-strength mortar to improve workability. The larger particle size of bottom ash powder compared to cement and fly ash, the workability of the high-strength paste and mortar mixtures with bottom ash powder were significantly higher. In general,
pozzolanic reactivity of coal ash is directly related to its fineness. Thus, the bottom ash powder, having coarser particle size distribution than fly ash, is not effective in terms of pozzolanic reactivity. The hydration heat and the rate of heat evolution of cement only were decreased by about 25% through the incorporation of a pozzolanic binder with 30% by volume of cement. The effects of bottom ash powder on these results were the same as those of fly ash.

Isa Yuksel et al. (2007) showed the durability of concrete incorporating non-ground blast furnace slag and bottom ash as fine aggregate. The effects of BA and GBFS, as fine aggregate in concrete durability were investigated. As a general result, GBFS and BA affects durability properties of concrete positively when it is used as fine aggregate.

Compressive strength loss due to freezing–thawing effect decreases for low replacement ratio (10–30%). GBFS or BA replaced concretes have better durability than reference concrete. BA, used as fine aggregate, increases the degree of porosity of concrete. GBFS also increases porosity but this increment occurs less than BA.

The comparison of the SEM images and test results show that chemical and physical properties of GBFS and BA as fine aggregate single or mutually are the main factors affecting the concrete durability. It is possible to produce durable concrete by using GBFS and BA as fine aggregate.

Omer Ozkan et al. (2007) submitted their research report on strength properties of concrete incorporating coal bottom ash and granulated blast furnace slag. GBFS and CBA are used as a partial replacement for aggregate, and then FA is partially substituted with cement in addition to these materials. They concluded that the workability of fresh concrete
decreases as (GBFS + CBA) content increases. Replacement of GBFS and CBA as fine aggregate in concrete generally decreases the compressive strength. Production of concretes by utilizing by-products instead of fine aggregate will generate savings of about 20% of the sand.

Geetha & Ramamurthy (2010) submitted their research on reuse potential of low-calcium bottom ash as aggregate through palletization. Binder content, moisture requirements and their interaction effect are the significant factors for achieving maximum palletization efficiency. They suggested that instead of using commercially available clays like bentonite and metakaolin, normal clay with plasticity index greater than 75 can be used as a binder for the production of low-calcium bottom ash aggregate.

Bai et al. (2005) found the Strength and drying shrinkage properties of concrete containing furnace bottom ash as fine aggregate. At fixed W/C, both the compressive strength and the drying shrinkage decreased with the increase of the FBA sand content. At fixed slump, the compressive strength was comparable with that of the control concrete, while the drying shrinkage increased with the increase of the FBA sand content beyond 30% replacement level. They conclude that FBA sand used to produce concrete in the compressive strength range from 40 to 60 N/mm².

Yogesh Aggarwal & Rafat Siddique (2014) studied the microstructure and properties of concrete using bottom ash and waste foundry sand as partial replacement of fine aggregates. Waste from the foundry industry and bottom ash from electrostatic precipitators as recycled fine aggregates in the production of concrete for structural purposes. The mechanical behaviour of the concrete with waste foundry sand and bottom ash showed strengths comparable to that of conventional concrete. The greatest increase in compressive, splitting tensile strength and flexural
strength was achieved by substituting 30% of the natural fine aggregate with industrial by-product aggregate in replaced mixes. The inclusion of waste foundry sand and bottom ash as fine aggregate does not affect the strength properties negatively as the strength remains within limits.

Arumugam et al. (2011) submitted the report on characterization and use of Pond Ash as fine aggregate in Concrete. The density of concrete was reduced with increase in percentage of pond ash. The compressive strength of concrete was increased as the percentage of pond ash increases with increase in curing period. The split tensile strength and flexural strength of concrete increased with pond ash replacement up to 20%. The workability of concrete was reduced with pond ash. For obtaining the required workability, super plasticizers were added while preparing the concrete. With increasing replacement of fine aggregate with pond ash the average density of concrete shows linear reduction due to lower specific gravity.

2.4 STRUCTURAL BEHAVIOUR

Sagar Patel & Balakrishna (2014) have reported the results on Flexural Behaviour of Reinforced Concrete Beams Replacing GGBS as Cement and Slag Sand as Fine Aggregate. The fresh concrete property (slump) varied from 100mm to 140mm and all the concrete mixes were homogeneous and cohesive in nature with no segregation and bleeding in any of the mixes. The slump was improved as the GGBS content was increased with shear type of failure compared to the control mix. The results of the hardened concrete properties such as Compressive strength, split tensile strength and the flexural tensile strength of all the concrete mixes concluded that the mix having 40% GGBS (i.e. MIX- 2) was optimum and equal to the control mix for 28 days of curing period. All the beams were designed as an under reinforced section such that it fails in the flexural zone and evidently all
the beams were failed as such. The flexural crack propagated from the tension fiber to the compression fiber with crushing of concrete at the top surface with no horizontal cracks at the level of the reinforcement, indicating no bonding failure. The flexural results show that there was increase in cracking moment by 23.38% for 0.72% tensile reinforcement and 34.90% for 1.03% tensile reinforcement. The experimental ultimate moment of the test beams are greater than the theoretical ultimate moment by 36.82%. The deflection was increased as the tensile reinforcement was increased by 0.72% to 1.03% due to increase in load carrying capacity of beams. The deflection was increased for the beams containing GGBS and Slag sand by 3.74% compared to the control beams. Also, the deflections at mid span at service load obtained during the testing of beams are within the prescribed limits as per codal provisions.

Mahdi Arezoumandi et al. (2015) had presented the paper on an experimental study on flexural strength of reinforced concrete beams with 100% recycled concrete aggregate. The RCA beams the cracks are spaced closer compared to the CC beams. The RCA beams showed lower cracking moment (around 7%) compared to the CC beams, but no significant difference observed between yielding moments of the RCA and CC beams. The RCA beams showed lower stiffness after the cracking moments compared with the CC. The RCA beams showed comparable results in terms of flexural strength and existing codes can be used to design the RCA beams. It means RCA (sustainable and environmentally friendly concrete) can be used instead of CC that uses significant amount of non-renewable resources.

Luaay Hussein & Lamya Amleh (2015) reported the Structural behaviour of ultra-high performance fiber reinforced concrete. The addition of a UHPFRC layer with 1.5% and 2% fibers volume content at the bottom of the NSC prism significantly enhanced the flexural capacity by 54%, and 90%
respectively. The bond strength between the UHPFRC and NSC/HSC layers was significantly higher and the percentage of steel fibers in the UHPFRC layer did not control the strength at the composite interface. The initial crack appeared diagonally in the mid depth of the shear span of the NSC/HSC layer. Additional diagonal cracks formed within the shear span as the applied load increased. Failure occurred when the concrete crushed in the NSC/HSC layer.

Sofi & Phanikumar (2015) have presented the results on an experimental investigation on flexural behaviour of fibre-reinforced pond ash-modified concrete. When pond ash content increased for a given steel fibre content in the beams, ultimate load increased. When the pond ash content increased to 30%, for 1% fibre content, the increment was 43% when compared to 0% pond ash + 1% steel fibre. Similarly, for a given pond ash content in beams, when steel fibre increased, ultimate load increased. The use of pond ash and steel fibres in careful quantities in combination with traditional steel reinforcement increases the performance of beams in comparison with the conventionally reinforced beams.

Saaid I Zaki et al. (2011) submitted the report on Flexural Behaviour of Reinforced High-Performance Concrete Beams made with Steel Slag Coarse Aggregate. HPC-containing steel slag coarse aggregate attained super improvement in mechanical properties (compressive strength, tensile strength, and static modulus of elasticity) compared with dolomite aggregate concrete. Steel slag waste was used in the production of green concrete with high performance. Both steel slag concrete beams and dolomite concrete beams showed typical structural behavior in flexure. At both the service and ultimate states, the flexural performance of reinforced steel slag concrete beams can be comparable or even superior to that of concrete made entirely with natural aggregates. All beams exhibited considerable amount of deflection, which provided sufficient warning to the nearness of failure. The
tests of both high-performance concrete beams containing dolomite and steel slag as coarse aggregates reported that, for concrete strengths approximately equal. The concrete incorporating steel slag coarse aggregate was able to achieve its full strain capacity under flexural loading.

Deepak Gowda & Balakrishna (2014) have presented the results of Experimental Study on Flexural Behaviour of Reinforced Concrete Beams by replacing Copper Slag as Fine aggregate. The properties of copper slag are similar to that of natural sand and can be used as natural sand. The control mix for M30 grade and the replacement of copper slag by 0%, 35%, 40% and 45% by weight of natural sand were designed. The optimum level of replacement of copper slag was found to be 40% and the results were better than that of control mix. The workability of fresh concrete increases with increase in the replacement of copper slag content for the same dosage of super-plasticizer. The compressive strength gradually increases from 0%, 35%, 40% replacement of copper slag and decreases for 45% replacement of copper slag. The deflection of the test beams was increased as the tensile reinforcement was increased by 0.62% to 0.89% due to increase in the load capacity of the test beams. The flexural results indicate that there was an increase in cracking moment by 31.84% for 0.62% tensile reinforcement and 41.01% for 0.89% tensile reinforcement.

Arivalagan (2015) studied the flexural behaviour of reinforced fly ash concrete beams. The effect of fly ash reinforced concrete beams with or without reinforcement, were tested. He concluded that fly ash replacement (up to 20%) in concrete had good improvement in flexural strength. The crack width under service load was within the permissible limit as per IS 456:2000. Load deflection study was similar to Control beams (RCC beams). The incorporation of fly ash had a minor effect on the beam stiffness.
Vijay Shankar & Suji (2014) presented their report on static and cyclic behaviour of high performance concrete beams using metakaolin and partial replacement with quarry dust. The possibility of using High performance concrete using (10% of cement with Metakaolin and 30% of sand with Quarry Dust) were studied. The ultimate load carrying capacity of High performance concrete beam using (10% Metakaolin and 30% Quarry Dust) was found to be 26kN, and 38kN, at the age of 28, and 56 days of curing. This shows that there is increase in load carrying capacity by 8.33%, and 26.67%, of Conventional concrete Beam. They concluded that HPC with Metakaolin and sand with Quarry dust produces late appearance of first crack and the presence of smaller deflection compared with Conventional concrete Beam.

Ravikant Shrivastava et al. (2013) presented their research report on the effect of cyclic loading on flexural behaviour of FRP strengthened RC beams. Flexural strengthening of RC Beams using FRP provides additional strength and had highly brittle behaviour. Failure of FRP strengthened under reinforced RC beams initiates with yielding of steel followed by sudden FRP rupture. It was concluded that the maximum load was reduced for cyclic loading.

### 2.5 SUMMARY OF LITERATURE

Cement replacement up to 12% with silica fume leads to increase in compressive strength, splitting tensile strength and flexural strength. Granite crushed sand appears as the most advantageous for producing HSC. With the increase of surface roughness of manufactured sand particles, the compressive and flexural strengths of concrete were increased. Carboxylic based superplasticizer gives a higher decrease of the w/c ratio which is up to 40% in mixtures with crushed aggregates. Compressive strength tested for
normal water exposure, the control Pozzlan Portland cement showed superior to OPC.

The substitution of 5% of the sand content by stone slurry induced higher compressive strength, higher splitting tensile strength, and higher modulus of elasticity and improvement of properties related to durability. The behaviour of granite aggregates with admixtures in concrete possesses the higher properties like concrete made by river sand. With the replacement of 35% granite fines the test results shows no decrease in strength compared with the conventional mix using fully sand as fine aggregates. Chloride penetration values of the mixtures GP 5%, GP 10% and GP 15% were almost equivalent to the penetration value of the Control Mix. The granite aggregates may be considered as equivalent or alternative coarse and fine aggregates for blue metal and river sand.

Compressive strength, Splitting tensile strength and Flexural strength of fine aggregates replaced bottom ash concrete specimens were lower than control concrete specimens at all the ages. The bottom ash concrete gains strength at a slower rate in the initial period and acquires strength at faster rate beyond 28 days, due to pozzolanic action of bottom ash. Even though the strength development was less for bottom ash concrete, it can be equated to lower grade of normal concrete and making utilization of waste material justifies the concrete mix-development. Bottom ash used as fine aggregate replacement enables the large utilization of waste product. The chloride content of the coal bottom ash aggregate satisfied the standard allowable values when it was washed more than twice. Bottom ash and natural sand concretes exhibit similar expansion characteristics under external sulphate attack.
The use of pond ash and steel fibres in careful quantities in combination with traditional steel reinforcement increases the performance of beams in comparison with the conventionally reinforced beams. The flexural performance of reinforced steel slag concrete beams can be comparable or even superior to that of concrete made entirely with natural aggregates. The properties of copper slag are similar to that of natural sand and can be used as natural sand.

2.6 NEED FOR THE PRESENT INVESTIGATION

The various past researches concluded about the importance of manufactured sand in concrete for the partial replacement for river sand. But in the present study, the fine aggregate used was 100% Manufactured sand. The waste materials in the past studies were used as partial replacement only for river sand and also there were no investigations of the long term performance and the structural behaviour of concrete with these industrial wastes in M sand. Hence there is a lot of scope to study the effects of Granite powder and Bottom ash as partial replacement to M-sand on Mechanical, Durability, Structural behaviour and micro structural properties of concrete.

2.7 OBJECTIVE AND SCOPE OF PRESENT WORK

The Primary objective of the present work is to investigate the use of Granite powder and Bottom ash in producing high strength concrete as trial mixes by replacing 0, 10, 20, 30, 40 and 50 percent of the weight of M-sand and replacing 10 percentage of cement by Silica Fume and Super plasticizer at varying dosage for all mixes.

The investigation is aimed at finding out the optimum percentages of M-sand replacement using Granite powder and Bottom ash for strength characteristics.
To achieve the strength properties of combined mix of Granite powder and Bottom ash replacement in M-sand about 60 MPa as Compressive strength.

To study the long term properties like porosity and impermeability for individual and combined mix.

To study the structural behaviour of RC Beam with the combined concrete mix under monotonic and cyclic loading.