CHAPTER 2

LITERATURE REVIEW

2.1 GENERAL

This chapter presents an overview of literature on the various experiments conducted by many authors on the replacement of fine aggregate by quarry dust, manufactured sand and the results thereof highlighting the significance of using the manufactured sand for replacing the natural sand in concrete. It includes the literature about mix design, fresh concrete properties, strength, durability aspects, micro structures and the structural behaviour of concrete with the replacement of fine aggregate by manufactured sand.

2.2 QUARRY FINES FROM VARIOUS ROCKS

Evertsson (2000) reported that knowledge gained from research should be used by quarry operators to optimize the performance of their equipment and to achieve lower quantities of quarry fines.

Jeffrey et al (2003) found that the generation of quarry fines is due to the extraction and processing operations in a quarry. There are several parameters that influence the production of fines, which are relevant to the rock characteristics and the involved processes. However, careful design and optimization of extraction and processing could minimize the fines production.

British Geological Survey (2003) reported that the fines produced depend on the type of the crusher and the parent rock. Primary crusher produced 1- 10% fines, secondary crusher produced 5 – 25% fines and tertiary crusher produced 5 – 30% fines. Similarly Limestone contains 20 – 25% fines; sandstone contains 35 – 40% fines and igneous and metamorphic rocks contain 10 – 30% fines. Table 2.1 shows the production of fines in quarry.

Table 2.1 Production of quarry fines

Production Stage	**Type of rock**	**Percentage of quarry fines produced in quarries (Crusher type)**
Primary crusher	Igneous Limestone Sandstone	3 – 6% (Jaw) to 10-15% (Gyratory) 6 – 7% (Jaw) to 20% (Impact) 1 – 2% (Jaw) to 15 – 20% (Gyratory)
Secondary crusher	Igneous Limestone Sandstone	10 – 23% (Cone) < 10% (Cone) to < 20% (Impact) 4 – 5% (Jaw and Cone)
Tertiary crusher & further	Igneous Limestone Sandstone	5 – 30% (Cone) to 40% (Impact) < 20% (Impact) to 40% (Hammer mill) ~15% (Cone) to 40% (Impact)

Petavratzi (2006) investigated that the large amount of dust fraction below 75μm generated from various ores and found that the different types of rock produced different amounts of fines with different physical properties.

Mitchell and Benn (2007) replaced a HSI with a cone crusher. For 20mm aggregate size, the production increased from 250 to 300 tonnes per hour for the same feed rate i.e. 20% increase in production and the proportion of fines have been decreased from 38 to 30% i.e. 21% decrease in fines.

Mitchell (2007a) suggested that the quarrying sector would consider using new technologies, which reduce the fines production and that further research work is required in identifying the capital and operational costs associated with quarry fines.

The University of Leeds (2007c) explored that the quarry fines are produced from various activities, but the stages of blasting are considered as the most liable in generating such fines. The amount of dust produced during blasting is estimated to be as high as 20%.

Chris Hartwiger and Patrick O'Brien (2008) found that the manufactured sand is extremely angular and has a wide particle distribution curve. These are characteristics of sand that sets up quickly and this is what happens with the manufactured sand. Companies that manufacture sand should screen out fine and very fine particles. Seven factors need to be evaluated in the sand selection process. They are particle size, shape, crushing potential, chemical reaction, hardness, infiltration rate, color, and overall playing quality.

Sven-Henrik Norman (2008) discussed the merits of manufactured sand from crushed rock. He emphasized that the crusher selection is based on the abrasiveness of the source rock, feed fraction to the circuit and the nature of the sand required and also concluded that the VSI crushing is the preferred method for crushing.

2.3 CHARACTERIZATION OF MANUFACTURED SAND

The International Centre for Aggregate Research (ICAR: 101-2F) has made efforts to develop a framework in regards to the classification procedure for the use of aggregate fines in concrete. The focus of this project was to examine the methods and test procedures used in the past to characterize the properties of fines, and to develop, on a preliminary basis, a framework to characterize and catalogue the properties of aggregate fines. Additionally, new methods and test procedures were proposed that would eventually complement a set of guidelines for the use of aggregate fines in Portland cement concrete.

Marek (1995) described a method to quantify the particle shape, surface texture and grading by measuring the uncompacted voids.

Persson (1998), Fletcher et al (2002) described an image analysis technique for determining the grain size and shape distributions of fine aggregate. This is a potentially useful method of classifying quarry products in order to determine their suitability for various applications including concrete.

Garboczi et al (2001) depicted how a combination of X-Ray tomography, image analysis-type techniques, and spherical harmonic analysis can give a complete 3-D mathematical characterization of an aggregate particle. Databases of 3-dimensional aggregate shape can be constructed and characterizing various aggregate sources is possible.

Kim et al (2001) described a prototype laser scanner for characterizing the size and shape parameters of aggregate. The Laser Based Aggregate Scanning System (LASS) is being developed at the University of Texas at Austin to characterize rapidly the various properties of construction aggregate. The LASS is expected to provide the characteristics including angularity and particle texture. This ability to analyze the multiple characteristics of aggregate automatically will enable the aggregate producers to monitor the various quality aspects of the products while they are being produced, so that instant process adjustments can be made to ensure better quality products.

Quiroga (2003) recommended a methodology for concrete proportioning based on ASTM C 211, modified for high fines Manufactured Fine Aggregate (MFA). The methodology was adopted based on the test results of Methylene Blue Value (MBV), wet packing density, Blaine fineness and size distribution test (either laser or hydrometer) conducted on microfines.

Gerry Huber and Bob McGennis (2008) reported that the mix design mainly depends upon the surface texture, shape and gradation. If manufactured sand and natural sand are being used together in a mix design, the manufactured sand portion can be increased to improve the surface texture. The additional fine aggregate, blending the aggregates and lowering the dust content in a mixture will increase the voids in mineral aggregate. Switching out 20% natural sand for washed manufactured sand will increase the voids in mineral aggregate by 2%.

2.4 SAND ALTERNATIVES IN CONCRETE

Çelik and Marar (1996) used rock dust (limestone < 75 mm) to replace the sand in concrete for proportions up to 30%, with all other ingredients and proportions constant. They concluded that the slump and air content of fresh concrete decreased, as the percentage of dust content increased. While considering the mechanical properties, the dust content up to 10% improved the compressive strength and flexural strength of the concrete and observed that the concrete with dust content up to 5% improved the impact resistance. Dust contents higher than 15% increased the water absorption of the concrete. Water permeability of the concrete is decreased as the percentage of dust content increased. When the dust content exceeds the value of 10%, the drying shrinkage strain decreased.

Jackson and Brown (1996) stated that the percentage of fines ranging from 5% to 15% can be used in concrete.

Smith and Slaughter (1996) suggested that the quarries certified by the US Department of Transportation are required to maintain the grading target values of 0 to 7% passing the #100 (150mm) sieve and 0 to 2% passing the #200 (75mm) sieve. As a result users have been adding fines to improve the workability.

Babu (1996), Ilangovan (2000) reported that quarry waste could be used as fine aggregate in concrete and also found that quarry dust reduces the cost without affecting the strength of concrete.

Hiroshi Uchikawa (1996) studied the influence of microstructure on the physical properties of concrete prepared by substituting mineral powder for part of fine aggregate. The hydration reaction of cement, hardened structure and pore structure in concrete prepared by substituting a large quantity of mineral powder including fly ash, slag, limestone and silicious stone for part of fine aggregate in concrete have been studied. Likewise, the relationships between the substitutions of those mineral powders and the physical properties of concrete have been investigated. They found that the increase in viscosity and decrease in fluidity of concrete by the substitution of mineral powders for part of fine aggregate were mainly caused by the increase of the fine particles. Higher strength was achieved for concrete with mineral powder than that of concrete without substitution. There is a reduction in dynamic modulus of elasticity that may be caused by the increased quantity of cement paste. They reported the slight increase in the creep of the concrete with fly ash as part of fine aggregate.

Fowler (1997), Machemal (1997), Watson (1999) concluded that more fines can be used in concrete than are typically permitted (in the US). However, the actual percentage depends on end use and fines properties.

Baguant (1999) found that the slump of the fresh concrete decreased significantly from 90mm to 25mm with the increase in rock dust content and water demand increased correspondingly when slump was maintained constant. Bleeding of free water decreased from 9% to 3% as rock dust increased from 0 to 20%. In hardened concrete, the presence of rock dust did not significantly impair the compressive strength of specimens stored in air and in water up to a period of 1 year. There was no negative effect on the modulus of elasticity too. The drying shrinkage was increased by about 40%, when dust content increased from 0 to 20%. Initial surface absorption and water permeability, both indicated the significant improvements, while increasing the rock dust content.

Hudson (1999) concluded that due to irregular particles of manufactured sand, the workability is very poor in concrete. Due to the high void space in manufactured sand, the water requirement is also high, which reduces the strength of the concrete.

Chan and Wu (2000) investigated the use of silt and clays of grain size < 150 μm obtained from crushed granite stone as cement substitutes and it was found that upto 25% of cement replacement could be achieved without affecting the workability, strength and durability of concrete. Silt and clays showed reactive properties and they could be used as reactive minerals. Although the inclusion of silt and clay increased the w/c ratio, it was thought that the problem could be solved by using high specific surface area material with a superplasticizer admixture.

Ilangovan (2000), Ilangovan and Nagamani (2002), Ilangovan et al (2008) reported that natural sand with quarry dust as full replacement in concrete is possible with proper treatment of quarry dust before utilization and also found that the compressive, flexural, split tensile strengths and durability properties of concrete made of quarry rock dust are nearly 10% more than the conventional concrete.

Shukla et al (2000) confirmed that the replacement of sand by stone dust reduces the workability of the concrete, whereas the compressive strength and split tensile strength of concrete mixes increase up to 40% replacement of sand by stone dust.

Ahn et al (2001), Ahn and Fowler (2002) asserted that the mortar compressive strength was decreased as the MBV increased. Mortar drying shrinkage showed a similar trend for correlation among test results as compressive strength and also it is increased as absorption capacity increased. It was confirmed that good quality concrete can be made with manufactured fines contents up to 17% without using admixtures. Compared with concrete made of natural sand, high fines concrete generally had higher unit weight, higher flexural strength, improved abrasion resistance, and lower permeability.

Sahu et al (2003) found that the concrete made with the replacement of natural river sand by crushed stone dust waste can attain the same compressive strength, comparable tensile strength and modulus of rupture as the control concrete. Concrete made with this replacement can attain lower degree of shrinkage as that of control concrete.

Topçu et al (2003) evolved that the compressive strength and flexural strength were increased when replacing the sand by limestone of less than 2mm grain size. The durability properties such as permeability, absorption and porosity were decreased when the filler was 7 to 10%. In excess of this, no changes or detrimental effects were observed.

Mark James Krinke (2004) studied the effect of admixtures in concrete containing manufactured sand. He found that the addition of superplasticizer into a concrete mix improves the workability and strength of the concrete mix. When large amounts of plasticizer are added, the strength improved by around 30 percent on the mix without plasticizer. However, the rate of strength gain of the concrete mix is lowered considerably when the plasticizer is added. In order to maintain the manufactured sand mix as cheaper than the natural sand concrete mix, the amount of superplasticizer added should not exceed 1.5 percent.

Lamb (2005) confirmed that the Sandstone Quarry Sand (SQS) can be used as a cement substitute, subject to the end user requirements and material's availability. The leachate results showed a significant increase in lime, when SQS was added to the mortar, which might cause efflorescence on concrete products. Even though the pozzolanicity results were positive, it was found that this material contains a very high insoluble residue, which limits its use in cement only as filler.

Salvador Villalobos et al (2005) described that the optimum percentage of crushed sand to natural sand is either 1 : 1.5 or 1.5 : 1 and reported that the volume of voids is reduced as 41 to 46% when it is blended with natural sand. So the cement content and water content can be reduced while blending with the natural sand.

Pedro Quiroga et al (2006) investigated the concrete mixtures with high microfines and found that concrete was stiffer and less workable than concrete with natural sand. When microfines are > 15%, the flow decreases by 60%, also requires high range water reducing admixtures. Hence microfines should be limited to 15% and to increase the flow, proper grading, plasticizers or fly ash (as replacement of cement) need to be used. They found that concrete with MFA resulted in higher compressive and flexural strengths. They also found that concrete with MFA resulted in higher resistance to abrasion and chloride penetration.

Prachoom Khamput (2006) studied the properties of concrete using quarry dust as fine aggregate and mixing with admixture type E". The admixture type E is added for increasing the workability of concrete. The admixture will adjust the electric charges of electron on the particle surface into the same type in such a way that the particles will push each other. This results in decreasing the viscosity of the cement paste and increasing the slump of concrete. The results of compressive strength of concrete at 28 days are nearly the same as that of conventional concrete and the addition of admixture type E increases the compressive strength. Because of polymer in the admixture, the w/c ratio is reduced. Besides the effect of polymer, the effect of calcium in the admixture, leads rapidly to develop the compressive strength at an early stage.

Justin Norvell (2007) studied the influence of clays and clay-sized particles on concrete performance. They found that non clay ultra fine particles are not harmful to the workability, compressive strength and drying shrinkage of the concrete and thus they need not be restricted in use with ordinary concrete. Kaolinite and illite clay minerals only minimally affect the performance. Smectite should be identified in aggregates and prohibited. When the exclusion of clay minerals in aggregates is not possible, it may be feasible to mitigate their effects, by means of a chemical admixture designed to avoid the reaction of clay.

Nataraja and Nalanda (2007) investigated the use of fly ash, rice husk ash and quarry dust as potential by-products in Controlled Low Strength

Materials (CLSM). The results suggested that the engineering properties of flowability and density of CLSM can be achieved satisfactorily using a very small amount of cement and a large amount of quarry fines. When the by-product content increased, the w/c ratio also increased linearly to get a specific flow. Mechanical properties such as the uniaxial compressive strength test results were acceptable and the stress- strain behaviour results suggested that quarry fines could be used for producing controlled low strength materials (CLSM).

Safiuddin et al (2007) inferred that quarry waste fine aggregate enhanced the slump and slump flow of the fresh concrete. The unit weight and air content of the concrete were not affected. In hardened concrete, the compressive strength was decreased. The dynamic modulus of elasticity was marginally increased. But the Ultrasonic Pulse velocity was not affected. They also concluded that the initial surface absorption was marginally increased.

Cortes et al (2008) studied the rheological and mechanical properties of mortar prepared with natural and manufactured sand. The results showed that adequate flow and compressive strength could be attained when the volume of paste exceeded the volume of voids in the loosely packed aggregate, i.e. just above the maximum void ratio e_{max} of the fine aggregate.

Zhou Mingkai et al (2008) stated the influence of natural sand, MS and Stone-Dust (SD) on workability and strength properties of High Strength Concrete (HSC). They found that the workability and the compressive strength of the concrete are improved when the stone dust content is less than 7% and found that the elastic modulus is almost equal to the natural sand HSC when the dust content is less than 7%. Beyond that, it is reduced. The results showed that the shrinkage rate of MS-HSC in 7 days age is higher than that of the natural sand HSC, but the difference of the shrinkage rate in the later age is not marked. Meanwhile, the shrinkage rate reduces as the fly ash is added; the specific creep and creep coefficient of MS-HSC with 7% stone dust are close to those of the natural sand HSC.

Shahul Hameed and Sekar (2009) deliberated the properties of green concrete containing quarry rock dust and marble sludge powder as fine aggregate. They concluded that the compressive strength, split tensile strength and the durability properties of concrete made of quarry rock dust are nearly 14% more than the conventional concrete.

Tony Thomas opined that manufactured sand is a suitable replacement for increasingly limited sources of natural sand for premixed concrete.

The Cement Concrete and Aggregates Australia, (CCAA) carried out the research and provided data and developed the guidelines to support the replacement of natural sand with manufactured sand. The benefits of fines on concrete have been presented in several ICAR symposium papers, in which the emphasis is usually on concrete made from manufactured sand and not from natural sand.

2.5 EFFECT OF MANUFACTURED SAND IN FRESH CONCRETE

Ahmed et al (1989) considered the influence of natural and crushed stone sand of particle size less than 75 micron on the performance of fresh concrete. The ordinary stone dust obtained from crushers does not comply with IS: 383-1970. The presence of flaky, badly graded and rough textured particles resulted in harsh concrete.

ICAR 102 test results indicated that good quality concrete could be produced using microfine levels up to 18 percent, when the chemical admixtures are used to increase the workability of the concrete at a fixed w/c ratio.

Zain et al (2000) inferred that the partial replacement of sand with quarry dust without the inclusion of other admixtures resulted in enhanced workability of the concrete mixes.

The Cement and Concrete Association of Australia (CCAA)'s guide to Concrete Construction (2002) stated that the shape and texture of aggregate particles have an important influence on the workability of freshly mixed concrete since they affect the water demand and the water cement ratio.

Ghataora et al (2004) used the limestone quarry fines of size below 4mm. They suggested that the quarry fines could be pumped by hydro-transport techniques using water only. Quarry fines could be developed into cementitious pastes and pumped over long distance.

Revathi et al (2009) studied the performance of quarry waste in flow of fly ash - gypsum slurry. The industrial waste materials such as fly ash, gypsum and quarry waste were used in the preparation of flow of slurry. They pointed out that the quarry waste can be effectively used in fly ash gypsum slurry and that addition in quarry waste content increases the water requirement.

2.6 EFFECT OF MANUFACTURED SAND IN MECHANICAL PROPERTIES OF CONCRETE

Carrasquillo (1981) studied the properties of compressive strength, stress - strain behavior, elastic modulus, Poisson's ratio and their relations for normal strength concrete of M 20 grade. They concluded that the concrete with high compressive strength and high modulus of elasticity attains higher stiffness which yields lower ductile property. If strain is low the ductility will be less. From their data for the elastic modulus and modulus of rupture, they proposed the following equations relating these properties to the compressive strength of the concrete for compressive strengths ranging from 21 MPa to 83 MPa:

$$E = 40{,}000\sqrt{f'_c} + 106 \text{ psi} \quad (2.1)$$

$$E = 3{,}320\sqrt{f'_c} + 6{,}900 \text{ MPa} \quad (2.2)$$

$$f_r = 11.7\sqrt{f'_c} \text{ psi} \quad (2.3)$$

$$f_r = 0.94\sqrt{f'_c} \text{ MPa} \quad (2.4)$$

E is the modulus of elasticity.

f_r is the modulus of rupture.

f'_c is the specified compressive strength.

In 1992, these equations were reported in ACI Committee 363's state-of-the-art Report of High-Strength Concrete [ACI 363R-92 1997].

Dukatz (1995) found that the clay minerals present in the natural sand reduces the strength of the concrete, whereas when manufactured sand is used, the fines are typically not clay. He suggested conducting chemical analysis to find out the presence of clay in manufactured sand.

Nagaraj and Zahida Banu (1996) expounded the efficient utilization of rock dust and pebbles as aggregate in Portland cement concrete. They concluded that the rock dust due to its higher surface consumes more cement than sand and the pebbles due to their smooth surface texture reduce the concrete strength.

Pofale et al (1998) explained the strength properties of concrete mixes made by partial or full replacement of natural sand by crushed stone powder and it is reported that the use of crushed stone powder is feasible and practical for plastic and cohesive mixes of normal, medium and high strength.

Shukla et al (1998) demonstrated the performance of stone dust as fine aggregate for replacement of sand in concrete and mortar. They reported that sand up to 40% can be replaced by stone dust in concrete mixes without affecting the strength.

Ahn (2000) indicated that for fixed water cement ratio, MFA concrete showed higher compressive strength than the control batch. On the other hand, for fixed slump, the compressive strength of the control batch was higher than the MFA concrete. MFA concrete with 13, 17, and 20 percent microfines showed higher flexural strengths than that of the control batch.

Tan et al (2000) investigated the influence of quarry dust and silica fume on the properties of high performance concrete. It was inferred that the partial replacement of sand with quarry dust reduced the compressive strength of the concrete mixes.

Yilmaz Akkaya (2000) ascertained the effect of sand addition on properties of fibre reinforced cement composites. They concluded that the addition of sand increased the strength of the plain cement paste, but decreased the mechanical performance of fibre reinforced cement composites.

Nataraja et al (2001) reported a method of producing concrete of the required strength, by measuring the characteristic strength of the aggregate with marble quarry waste used as aggregate and the necessary proportions of cement and water can be calculated from this method.

Safiuddin et al (2001) investigated the effect of quarry dust and mineral admixtures on the strength and elasticity of concrete. They concluded that quarry dust had been used for different activities in the construction industry such as for road construction and manufacture of building materials such as lightweight aggregates, bricks, tiles and autoclave blocks.

Jaafar (2002) reckoned the strength and durability characteristics of high strength autoclaved stone dust concrete. They concluded that the strength and durability performances of autoclaved stone dust concrete proved superior to that of normal high strength concrete.

Vasumathi (2003) examined the strength of the concrete by partial replacement of cement with fly ash and sand with quarry dust. It is concluded that quarry dust replaces the sand with gain in strength during early period but there is no or less improvement in the strength after 28 days and the workability decreases. If cement is replaced with fly ash, the rate of gain in strength is slightly improved.

Abou-Zeid and Fakhry (2003) reported that hardened concrete properties indicated that there is an increase in compressive strength in concrete mixes incorporating fines, not using admixtures, when keeping a consistent water cement ratio (w/c). When the w/c is increased in order to maintain the workability and slump, the compressive strength predictably decreases. Also, at the same w/c, mixtures incorporating microfines had higher flexural strength than concrete mixtures with no microfines.

Naidu et al (2003) investigated the strength and elasticity of concrete incorporating quarry dust and mineral admixtures. They reported that the compressive strength was reduced while incorporating the quarry dust in concrete mixes.

Nisnevich et al (2003) revealed the light weight concrete containing thermal power station and stone quarry waste. They concluded that the strength increased by a factor of 2 or more, when the crushed sand is close to 50%.

Palani Raj (2003) evaluated the effect of manufactured sand in concrete. He reported that the fine particles below 600 microns must be 35 to 45% for good results. Fine particles below 150 microns which reduce the strength should be removed. He concluded that the manufactured sand can be used successfully for making concrete by replacing the ordinary river sand for desired strength of concrete.

Prakash Rao and Giridhar Kumar (2004) inferred that the concrete cubes with crusher dust developed about 17% higher strength in compression, 7% more split tensile strength and 20% more flexural strength than the concrete cubes and beams with river sand as fine aggregate.

Katz and Baum (2005) reported that most of the improvement in strength attributed to the microfines occurred at a relatively small addition of fines and did not change greatly at higher fines contents.

Logan Andrew Thomas (2005) concluded that at the age of 28 and 56 days, specimen moist cured for 7 days exhibited the highest compressive strength and elastic modulus. Among the three different curing methods, 1-day heat curing generally resulted in the lowest strength. The continually moist-cured specimens which were never allowed to dry out exhibited modulus of rupture values in some cases twice as great as the values attained from the 7-day moist-cured specimens. The equation published in ACI 363R-92 provided a good estimate of the modulus of rupture and the elastic modulus regardless of the curing method or the compressive strength. The average Poisson’s ratio measured from the test specimens was 0.17 which is within the range generally assumed for normal-strength concrete (0.15 - 0.25). This finding suggests that it is adequate to use the same Poisson’s ratio for HSC as that of normal strength concrete.

Shewaferaw Dinku Belay (2006) found that the hardened properties of the concrete mixes with partial replacement of natural sand with manufactured sand achieved higher compressive strength. Using manufactured sand in partial or full replacement to natural sand does not cause any significant cost variation. He also stated that the use of manufactured sand is more suitable for high strength concrete production.

Hailong Wang and Qingbin Li (2007) proposed a model to explain the changes that happened in the wet concrete and to predict the elastic parameters including elastic modulus and Poisson’s ratio of unsaturated concrete. The viscosity of water in pores, micro-cracks and further hydration of cement are taken into account by means of the definition of saturation concept according to the effect of pore water on the modulus of concrete. In this model, both stiff effect of water and soft effect of cracks on the concrete are introduced to describe the bulk modulus. At the same time, the effect of shear rate on the shear modulus is also considered.

Nguyen Thanh Sang and Pham Duy Huu (2008) conducted an experimental research on sand concrete. They examined the mechanical properties of the sand concrete like compressive strength, flexural strength, splitting tensile strength and elastic modulus. The results obtained showed that the sand concrete can be used for different construction projects.

Crouch and Jason Philips (2009) used both river sand and manufactured limestone sand as fine aggregate in concrete mixtures. The mixtures exhibited comparable costs and increased the compressive strength of the concrete.

Felix Kala and Partheeban (2009) scrutinized the utilization of granite powder as fine aggregate in high performance concrete. In their study, the fine aggregate was replaced with the granite powder. Of all the mixtures considered, concrete with 25% Granite Powder (GP25) was found to be superior to other mixtures. Mechanical properties such as compressive strength, split tensile strength and modulus of elasticity in all the ages at both curing temperature of 32^{o}C and 38^{o}C were higher than that of the reference mix. There was an increase in strength as the days of curing increased. The result suggested that the proper use of the granite powder could produce high performance concrete. At any rate both granite stone and granite powder in concrete are the best choice, where they are available.

2.7 EFFECT OF MANUFACTURED SAND IN DURABILITY PROPERTIES OF CONCRETE

Ahmed and El Kourd (1989) indicated that the addition of microfines called “dust” increased the shrinkage properties of concrete. Seven concrete mixes were made and measured over one year. In this regard, an increase in the amount of microfines increased the drying shrinkage.

Celik Ozyildirim (1993) probed the chloride ion penetration, corrosion and rapid permeability properties of concrete. He confirmed that these parameters depended on w/c ratio, cement type and curing temperature.

Sawich and Heng (1995) observed the durability of concrete with the addition of limestone powder. The results showed that a beneficial influence of a powdered limestone on concrete durability was observed when w/c < 0.6. Above this value, the powdered limestone has almost no essential effect.

Ueda et al (1996) pointed out that sulphuric acid is hard to penetrate into hardened cement. The reaction between cement hydrates and sulphuric acid occurs only in the surface portion of specimens. The surface portion, therefore, is a main field of the reaction of sulphuric acid.

St. John (1998) examined the composition of the aggregate, cement type, w/c ratio, air void system, identification of admixtures and surface flaws in the paste. In this study the investigator showed that in concrete that had been attacked by soft water (low pH), the texture of the outer layer would consist of silica gel over a carbonated zone. The outer gelatinous layer may or may not be fully intact because it can easily break off during the transportation and the testing process. This pattern is always observed in concrete that has been attacked by acidic water.

Wilson et al (1998) concluded that the hydraulic property such as sorptivity is related directly to the composition of concrete. The sorptivity decreases systematically with increasing bulk density, cement content and the level of compaction.

Dale Bentz et al (1998) identified that w/c ratio, degree of hydration and aggregate volume fraction are the three major variables influencing the concrete diffusivity in the model. They developed a simple equation for predicting the chloride ion diffusivity in concrete based on these three parameters. It was concluded that higher w/c ratio reduced diffusivity and particles ranged from fine to coarse which reduced diffusivity.

Wissam Elias Touma (2000) examined the alkali – silica reaction in Portland cement concrete. He found that using 10% silica fume to replace the cement by weight was effective in decreasing the 14-day expansion below 0.10% for slowly reactive aggregates. This level of replacement was not effective with highly reactive aggregates even though it caused a decrease in

14-day expansion. Replacing the cement with 55% of granulated slag and 25% of calcined clay became effective in decreasing the 14-day expansion below 0.10% for slowly and highly reactive aggregates.

Kome Shomglin et al (2001) considered the alkali aggregate reaction test on five different types of cement. Type I/II Portland cement, Type III Portland cement, two Calcium Sulfoaluminate cements (CSA I, and CSA II), and Calcium Aluminate cement (CA) with two types of aggregates like granitic and phyllonitic. The results indicated that CA cement showed high resistance to alkali silicate reaction and the other four types of cements pointed out that the expansion was greater than 0.20 percent, 16 days after casting.

Kosmatka (2002) stated that keeping a low w/c would increase the resistance of the concrete deterioration by acid. Low permeability, a result of the low water cement ratio, will help keep the acidic solution out of the concrete pore structure.

Kurashige (2002) described that sulphuric acid penetrating into the mortar or concrete reacts with calcium hydroxide of cement hydrates, which causes expansion resulting in erosion.

Pacheco-Torgal et al (2002) dealt with the durability properties of concrete with different types of aggregates. They found that there was not much difference on concrete durability parameters when produced either with granite, gabbro or calcareous coarse aggregate. The results obtained for vacuum water absorption, oxygen and water permeability of all concrete mixes showed the same order of magnitude. This indicated that the quality of concrete mixes produced with different aggregates looked approximately same, in all cases.

Malathy (2004) concluded that the High Performance Concrete (HPC) mix with 15% silica fume is more impermeable than other concrete mixtures. The addition of mineral admixtures improves the impact strength of the concrete significantly and also the addition of 10% silica fume and metakaolin improves the resistance against corrosion attack. Initiation of corrosion is also delayed when mineral admixtures are added.

Raman et al (2004) investigated the influence of quarry dust and mineral admixtures on the 28^{th} day of the initial surface absorption of concrete. They found that the durability properties are reduced while using the quarry dust in concrete mixes.

Kawai et al (2005) found that the rate of concrete deterioration caused by sulphuric acid attack depended on the pH value of acid solutions and the depth of erosion of concrete. It was nearly proportional to the exposure time of flowing acid solution to which the concrete was exposed.

Keiichi Imamoto et al (2006), Keiichi Imamoto and Masanao Arai (2008) concluded that drying shrinkage of concrete with various kinds of aggregates increased with the increase of the Specific Surface Area (SSA) of the aggregate and suggest that the SSA determined by using H_2O is an effective index for evaluating the influence of the aggregate type on the drying shrinkage properties of concrete.

Karthik Obla and Colin Lobo (2007) established the test set up for Rapid Chloride Permeability Test (RCPT) and compared the compressive strength and RCPT values of concrete.

Crouch and Jason Philips (2009) investigated both river sand and manufactured limestone sand used as fine aggregate in concrete mixtures. The mixtures exhibit comparable cost and enhanced the durability properties.

2.8 NEED FOR THE PRESENT STUDY

The literature survey encompasses many studies with quarry fines used as fine aggregate in concrete. That reflects a growing interest in academic and industrial research in this area. Even though various studies have been conducted on manufactured sand as fine aggregate, there is no in - depth study on the characterization of manufactured sand to optimize their replacement level in concrete. Hence there is a lot of scope to study the effects of manufactured sand on mechanical, durability, structural and micro structural properties of concrete.