CHAPTER 1

INTRODUCTION

1.1 CONCRETE

Continuous research efforts have established concrete as a versatile material. Concrete required for extensive construction activity can be made available since all the ingredients of concrete are of geological origin. The most widely used construction material is concrete, commonly made by mixing Portland cement with sand, crushed rock and water. The world consumption of concrete is estimated at ten billion tonnes every year or one tonne for every human being.

1.2 AGGREGATE

Aggregate is defined as mineral constituents of concrete in granular or particular form, usually comprising both coarse and fine fraction. About 70 to 80 percent of the volume of concrete is occupied by aggregate. The properties of aggregate influence the characteristic on its fresh state, strength, durability and structural performance on its hardened state. It is not surprising that aggregate quality is important. Aggregate is cheaper than cement and it is therefore economical by mixing the large quantities of the former and small quantities of the latter. Using aggregate is not only for economical reason but also it has certain technical advantages over concrete, which has higher volume stability and better durability than hydrated cement paste (Nevelie 1995).
1.3 AGGREGATE CLASSIFICATION

Aggregates are classified into two major types: fine and coarse. Fine aggregate, often called sand (BS 882: 1992), is not larger than 5 mm in size and coarse aggregate comprises material at least with a size of 5 mm. In the United States, the division of aggregate made at No.4 ASTM sieve is 4.75 mm in size (Neville 2003).

1.4 ORIGINS AND PRODUCTION OF FINE AGGREGATES

Fine aggregates are obtained from a variety of sources. The sources of aggregate are invariably close to their demand locality; it is difficult to transport the large quantity of aggregate (in tonnes) and there will be high cost of transportation. They can be sourced from pits, riverbanks and beds, the seabed, gravelly or sandy terraces, beaches and dunes. The other deposits that provide granular materials can be processed with minimal extra effort or cost. Sand and gravel, which are unconsolidated sedimentary materials, are important sources of natural aggregate. The occurrence of high quality natural sands and gravels with in economic distance of major urban areas may be critical for viable concrete construction in those areas.

1.5 FINE AGGREGATE (NATURAL SAND)

In concrete 30-40% of the volume is occupied by fine aggregate. Aggregate passes through 9.5 mm sieve and almost passes through the 4.75 mm sieve and predominantly retains on the 75-micron sieve. Most of the fine aggregate passes 4.75 mm IS sieve and contains a huge amount of coarser materials. Fine aggregate is generally considered to have a lower size limit of 0.07 mm or 0.06 mm (Nataraja 2001).
Originally, all natural aggregate particles are a part of larger mass. This may have been fragmented by natural process of weathering and abrasion or artificially by crushing. Thus many properties of the fine aggregate depend entirely on the properties of the parent rock. Properties of fine aggregate may have a considerable influence on the quality of the concrete, either fresh or hardened.

1.6 FINE AGGREGATE SUBSTITUTES

Several challenging issues present themselves in the future. These issues will require sustained attention to research, development and appropriate usage of concrete aggregates. Possibly the most important issue is the environmental impact of aggregate production.

Large scale of sand quarrying from riverbeds creates environmental problems such as shortage of ground water and changing watercourses. Farmers’ organizations, environmental managers and the public have expressed concern over the indiscriminate quarrying in violation against the river environmental conservation principles. Riverbeds, which supply water to cities and villages, suffer extensive damage owing to excessive sand mining. River sand acts as excellent filter system to ground water. The infrastructure developments such as express highway projects, power projects and industrial developments have started now. Natural sand is getting depleted resulting in high cost of sand.

Fine aggregate is obtained from natural rivers, crushing stone sand and industrial waste. Other substitutes are obtained from coal ash, foundry sand, ponded fly ash and quarry rock dust, etc.
1.7 QUARRY ROCK DUST

Concreting the natural stone extraction and processing industries, generate huge amount of waste which is continuously accumulated in open-air dumpsites and constitutes unsolved environmental problems. Worldwide natural stone industry offers an output of 68 million tonnes of the processed product (dust or slurry) annually. In 2006, the European Union alone accounted for 39.2% of total amount, assuming the leadership of the sector, followed by Asia, which owed its comfortable share of 37% contributed by China and India.

Quarry rock dust is an industrial by-product. It is formed by screening products of secondary and subsequent stages of crushing igneous rocks, sedimentary rocks or gravel. It can be classified by the size of the particles as 0 to 4.75 mm. Presently a large amount of quarry rock dust is generated in natural stone processing plants.

There are some reports on the usage of vast quantities of waste generated by mixing and quarrying industries. A small amount of these wastes has been utilized in construction and manufacturing of bricks, tiles and autoclaved blocks. Quarry rock dust, which is available abundantly from crusher units at low cost in many areas, provides a viable alternative to river sand in concrete.

Quarry rock dust is cheap and widely available throughout the world. It is formed from waste fines of crushed product of stone (gravel) in crushing plants. The volume of waste at every quarry reached 13-15% of crushed stone by mass based survey taken from 13 locations in Dindigul District, Tamilnadu, India.
Figure 1.1 shows the location of quarries at various places in Dindigul District. Totally thirteen samples were collected from different quarries located throughout the district. All samples were collected within 7 days from the crushing date. Physical and chemical properties of the collected samples were tested. Out of 13 samples, the sample collected from Q1 was used for the entire experimental work, because sieve analysis results and other properties were very close to Zone II of IS 383.

![Figure 1.1 Location of Sample Collected Quarries at Dindigul District (Q1 to Q13)](image)

Figure 1.2 shows the aggregate producing countries that surpassed 1 million tonne, representing 73% of the total production during 2000. As per the expectations from the sector, it is likely that the world interchange of natural stone will quadruplicate in the next 20 years. An experimental programme was undertaken at Anna University in Chennai, India, to evaluate the main mechanical properties of concrete mixtures incorporating quarry rock dust as fine aggregate, namely in concrete mixtures.
The quarry rock dust generated in industrial plants was reused as a component for concrete mix without being submitted to any kind of previous treatment. The quarry rock dust generated in crushing plants was cheap and widely available. It is formed of waste fines of crushed product from stone (gravel) quarries. The volume reached 15-20% of crushed stone mass (Nisnevich et al 2003).

![Figure 1.2](image)

**Figure 1.2  World procedures of processed natural stone during 2000**  
(Nuna Almedia 2006)

Characterization of the quarry rock dust varied from place to place based on crushing methods and machineries. So a detailed study was carried out to ascertain the extent of variability of the physical and chemical properties of the quarry rock dust from thirteen crushing plants in Dindigul district, Tamilnadu state, India.
1.8 PROCESSING METHODS OF QUARRY ROCK DUST

Sources of granular deposit are becoming depleted, particularly in high demand areas such as urban areas. Hence, alternative sources of aggregates must be found. One of the sources is hard rock, which is quarried and crushed. It is possible to produce both coarse and fine aggregates from hard rock quarries. Rock crushing methods and techniques together with the nature of rock itself govern the quality and properties of the product. In particular, particle shape can be beneficially or adversely affected by the crushing and this is more critical for crushed sand due to their strong influence on the plastic properties of concrete. Shapes can generally be reduced by the use of appropriate crushing techniques.

At the time of crushing the chips, fines are removed in the aggregate plants by using circuit feeding, corrugated crushing surfaces and low reduction ratio. However, in impact crushers, good aggregate shapes can be produced even with high reduction ratios. Types of crushing equipment are jaw crushers, roll crushers, disc or gyro sphere crushers, gyratory crushers, cone crushers, rod mills, and impact - type crushers such as horizontal impactors (eg; hammer mill) or vertical impactors. Modern equipment such as gyratory and cone crushers and rod mills tend to produce better particle shapes. Washing and scrubbing may also be required for crushed aggregates. Figures 1.3 to 1.5 show the stone crusher, screen and storage of rock dust in the quarry site (Crushing plant Q1).
Figure 1.3  View of a Stone crusher

Figure 1.4  View of the screen used in the quarry
Table 1.1 shows that totally, 19,71,000 tonnes of coarse aggregates are produced per year from 13 aggregate crushing units in Dindigul district. The screening products of second and subsequent stages and volume of waste at every unit reached upto 15 percent of crushed stone by mass. From this study 22,000 tonnes of quarry rock dust has produced from the 13 units in every month. Approximately, every crushing unit has produced 730 tonnes of quarry rock dust per day.

Figure 1.5 Various sizes of aggregate and quarry dust
Table 1.1  Production details in aggregate crushing plants  
(10 mm to 40 mm)

<table>
<thead>
<tr>
<th>Sl.No</th>
<th>Production details per month</th>
<th>Production in tonnes (Per year)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Effective hours</td>
<td>Production in tonnes</td>
</tr>
<tr>
<td>Q1 –Q5</td>
<td>370</td>
<td>83125</td>
</tr>
<tr>
<td>Q6 –Q10</td>
<td>360</td>
<td>74625</td>
</tr>
<tr>
<td>Q11 –Q13</td>
<td>350</td>
<td>65000</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td></td>
</tr>
</tbody>
</table>

* Q1 to Q13 data collected from 13 quarries in the year 2002-2003 (one year) located in Dindigul District (Figure 1.1)

1.9  EXPERIMENTAL PROGRAMME

Firstly, the physical and chemical characterizations of samples were tested. The characterization consists of physical properties, namely specific gravity, water absorption, sieve analysis, bulk density, etc. Chemical analysis consists of oxide composition of silica content and other oxide content.

Based on the above properties, the mix design has been developed for various grades with different sizes of aggregate and with various workability factors. Trial cubes are cast and confirmed with mix design approaches of the Indian standard, ACI, USBR, Road Note No.4, and British method.
The properties of fresh concrete with full replacement of quarry rock dust as a fine aggregate were examined through slump test, compacting factor test and Vebe test.

The engineering properties were examined with compressive strength, flexural strength, split tensile test and RC beam test.

The durability parameters such as drying shrinkage, deterioration, permeability, and water absorption on quarry rock dust concrete were compared with natural sand concrete.

1.10 ORGANISATION OF THE THESIS

This thesis has been organized into six chapters with three appendix.

The first chapter presents a general introduction to quarry rock dust and quarry rock dust-replaced concrete.

The second chapter gives a glimpse of the background of quarry rock dust and its applications in the concrete technology field. This chapter also presents a comprehensive literature review and research programs conducted by various investigators on the characteristics of quarry rock dust, fly ash, bottom ash and other substitute materials in concrete. Also it describes their mechanisms and methods of evaluation, properties of above material influences, namely workability, compressive strength, shrinkage, creep and modulus of elasticity.
The third chapter describes the overall methodology of materials and methods such as physical and chemical properties of quarry rock dust and its relationship with conventional river sand. This chapter also describes mix proportion (mix design) by Indian Standard and foreign standards incorporating quarry rock dust as fine aggregate.

The fourth chapter deals with the experimental investigation of fresh concrete, hard concrete and durability studies on quarry rock dust concrete.

The fifth chapter presents the results of slump test, compacting factor test, vebe test, compressive strength, flexural strength, spilt tensile strength and RC beam of hardened concrete made by both quarry rock dust and natural sand. This chapter describes how quarry rock dust influences the durability properties of hardened concrete.

The concluding chapter provides the summary of the entire work and suggests the scope for further work in this area of study.

Appendix 1 describes the details of mixture design approaches by using quarry rock dust as fine aggregate through Indian, ACI, USBR Road Note No 4 and British methods.

Appendix 2 compares the cost analysis of quarry rock dust concrete and conventional concrete.

Appendix 3 explains the washing techniques of quarry rock dust.
The objectives of this research study are:

- to study the quarry rock dust source and production
- to examine the properties and characterization of quarry rock dust
- to investigate the quarry rock dust in fresh concrete: workability studies.
- to develop the Mix design approach to quarry rock dust with international codal provision
- to study the quarry rock dust in hardened concrete: physical and mechanical properties and effect of aggregate size in hardened concrete.
- to examine quarry rock dust in hardened concrete: durability and transport properties.
- to study the cost analysis of quarry rock dust concrete with conventional concrete.
- to explain the quarry rock dust washing plant - properties of washed quarry rock dust.