Construction and Building Materials 46 (2013) 1–7

Contents lists available at SciVerse ScienceDirect

Construction and Building Materials

journal homepage: www.elsevier.com/locate/conbuildmat

Strength and durability properties of concrete made with granite industry waste

M. Vijayalakshmi [a], A.S.S. Sekar [b], G. Ganesh prabhu [c,*]

[a] Dept. of Civil Engineering, Fatima Micheal College of Engineering, Tamil Nadu, India
[b] Dept. of Civil Engineering, Alagappa Chettiar College of Engineering, Tamil Nadu, India
[c] Dept. of Civil Engineering, Sethu Institute of Technology, Tamil Nadu, India

HIGHLIGHTS

- Utilization of granite industry waste in concrete production was carried out.
- Effect of GP waste on mechanical and durability properties of concrete was evaluated.
- Inclusion rate up to 15% does not affect the strength and durability properties.
- Optimum inclusion rate of GP waste was recommended for concrete production.

ARTICLE INFO

Article history:
Received 26 February 2013
Received in revised form 3 April 2013
Accepted 5 April 2013
Available online 10 May 2013

Keywords:
Concrete
Granite powder
Waste
Compressive strength
Durability
Carbonation
Chloride
Sulphate

ABSTRACT

Granite stones processing industry from Tamilnadu state produces tons of non-biodegradable fine powder wastes and utilization of that hazardous waste in concrete production will lead to green environment and sustainable concrete technology. The main objective of this study is to experimentally investigate the suitability of granite powder (GP) waste as a substitute material for fine/natural aggregate in concrete production. The experimental parameter was percentage of granite powder substitution. Concrete mixtures were prepared by 0%, 5%, 10%, 15%, 20% and 25% of fine/natural aggregate substituted by GP waste. Various mechanical properties such as compressive strength, split tensile strength, flexural strength; ultrasonic pulse velocity (UPV) and elastic modulus were evaluated. To ensure the reliability of its usage in aggressive environments, the durability properties such as water permeability, rapid chloride penetration (RCPT), carbonation depth, sulphate resistance and electrical resistivity was also determined. The obtained test results were indicated that the replacement of natural sand by GP waste up to 15% of any formulation is favorable for the concrete making without adversely affecting the strength and durability criteria however it is recommended that the GP waste should be subjected to a chemical bleaching process prior to blend in the concrete to increase the sulphate resistance.

1. Introduction

Among the 32 states in India, Tamilnadu state has the 45% of total granite reserve. Using different types of cutting method, granite stones are machined from the quarries and that blocks are transported to the nearby processing plants. Then the stones are industrially processed such as sawing and polishing, finally the processed stones are used for decorative purposes. During this industrial process, the fine granite particle and the water mixed together and become a granite colloidal waste. When the stone slurry is disposed in landfills, its water content is drastically reduced and the waste becomes a dry mud consisting of very fine powder that can be easily inhaled by human being and animals. In addition to that, it is a non-biodegradable waste that causes pollution and environmental damage. The data available from the literature, the amount of wastes in the different production stages of the granite industry reaches some 20–25% of its global production, meaning millions of tons of colloidal waste per year and disposal of those fine wastes is one of the environmental problems worldwide today. With increasing restrictions on landfills in nearby area, the cost of deposition also become increase and the industries are forced to find ways for reusing that wastes. Even though the reutilization of granite wastes has been practiced, the quantity of wastes reutilized in that way is still negligible. Hence, the need for its application in other industries is become very imperative. Past few decades, the construction industry especially the concrete industry has utilized almost all stone industrial waste to resolve

* Corresponding author. Address: Department of Civil Engineering, Sethu Institute of Technology, Kariapatti, Virudhunagar 626 115, Tamil Nadu, India. Tel.: +91 989451881.
E-mail address: gganeshprabhu@gmail.com (G. Ganesh prabhu).

0950-0618/$ - see front matter © 2013 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.conbuildmat.2013.04.018

the environmental problem. The first known study in this topic involved that utilization of granite dust for making aerated concrete and ceramic production conducted by Beretka and Taylor [1]. Test results of Moreira et al. [2] illustrated that the ceramic bodies containing granite powder waste are adequate for manufacture of structural ceramic and the employed methodology is environmentally correct. Experimental results of Saboya et al. [3], Ilker Bekir et al. [4], Binici et al. [5], Corinaldesi et al. [6] and Hebhoub et al. [7] demonstrated that the waste marble and granite powder can be potentially used as a substitution for fine aggregates in concrete production and the mechanical properties of concrete were found to be conforming to the concrete production standards. Recently Flexikala and Partheeban [8] found that the replacement of sand by granite powder has beneficial effect on the mechanical properties of concrete and the values of both plastic and drying shrinkage of granite powder concrete was nominal than the ordinary concrete.

From the past research, it was observed that there were boundless investigations done with the marble powder by-product as a substitute material in concrete production besides investigations on granite powder (GP) waste as a filler material in concrete production is not widespread. The main objective of this study is to experimentally investigate the suitability of granite industry waste as a substitute material for fine aggregate in concrete production and aimed to study the physical and chemical properties of the GP waste as well. The experimental parameter was percentage of granite powder substitution. The concrete cubes and cylinder specimens were prepared with 0%, 5%, 10%, 15%, 20% and 25% of natural sand is substituted by GP waste. Fresh concrete properties evaluated by slump cone test and the mechanical properties were evaluated through density, split tensile, flexural, compressive strength, UPV and elastic modulus test. Durability tests such as water and chloride permeability test, electrical resistively, carbonation depth and sulphate resistance test were also conducted on granite powder concrete to ensure the reliability of its usage in aggressive environments.

2. Materials

2.1. Portland cement and aggregate

The commercial Portland cement supplied by India cements was used in this study. The specific gravity of the cement was tested according to IS 8112:1989 [9] and the obtained value was about 3.14. Natural sand passing through 4.75 mm sieve and having a specific gravity of 2.48 was used in this study. The maximum size and the specific gravity of the coarse aggregate were 20 mm and 2.67 respectively. According to IS 2386(1):1963 [10], grain size distribution analysis was carried out on both fine and coarse aggregate.

2.2. Granite powder

The granite powder (GP), which is a by-product obtained from granite processing industry was used in this study. To verify the physical and chemical characterization of the granite powder, the following tests were carried out at National Testing House at Chennai, Tamilnadu. The obtained specific gravity and specific surface area value of GP waste was about 2.386 and 351 m^2/kg respectively, which was equivalent to the finesse of the cement. To verify the physical characterization of the GP by-product, its grain size distribution analysis was carried out and it was observed that, 55% of granite powder was less than 150 μm and the 31% of particles were less than 45 μm. The chemical analysis results were shown that the GP waste contains about 72.14% of soluble silica (Sio_2) and 17.13% of alumina (Al_2O_3), indicating very suitable for concrete production. The X-ray diffraction analysis, Fig. 1 shows that the presence of Quartz about 3% and Microcline about 1%. The remaining GP by-product consists of amorphous silica, whose low crystallinity making them mostly undetectable by X-ray diffraction [6].

2.3. Concrete

The concrete mix proportion was designed by IS method [11] to achieve the strength of 30 N/mm^2 and the designed mix proportion was 1:1.39:2.77 by weight. The designed water cement ratio was 0.40 and the formulations of various mixtures proportion were listed in Table 1.

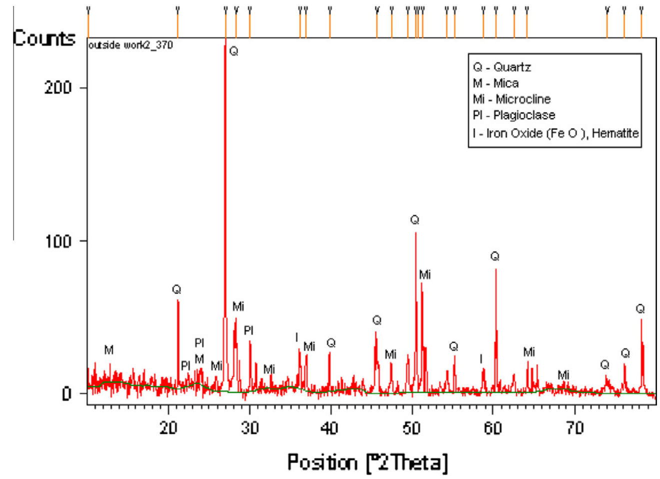

Fig. 1. X-ray diffraction of the GP by-product.

3. Experimental program

3.1. Preparation and testing of specimens

The concrete mixtures were prepared by Portland cement, natural sand, coarse aggregate (Blue metal) and GP by-product. Among the six series of mixtures, one was the control mixture and the remaining five mixtures were containing GP waste substitution in various proportions such as 5%, 10%, 15%, 20% and 25%. For all the mixtures, aggregates were weighed in dry condition and the mixtures were mixed together for 4–5 min in a laboratory counter current mixer. Workability of the fresh concrete was verified by slump test apparatus. Compressive and splitting tensile strength of the concrete was measured using 150 mm × 150 mm × 150 mm cubes and 150 mm × 300 mm cylinders respectively. In addition beams were prepared to determine the flexural strength of the concrete. All the cubes, cylinders and beams were cast in three layers and each layer was fully compacted by using a needle vibrator for beams and a vibrating table for other specimens. After casting, specimens were kept in a room temperature for 24 h, thereafter demoulded and transferred to the curing tank until their testing dates. Compressive strength of the cube was measured by compression testing machine (CTM) having a capacity of 2000 kN at the age of 7, 28 and 90 days. The flexural and splitting tensile strength of the concrete was measured by flexure testing machine (FTM) and by CTM respectively at the age of 28 days. For each mixture three specimens were tested and tests were carried out according to the relevant IS standards.

Chloride permeability of the concrete mixtures was performed according to ASTM C 1202-97 [12] and resistance to the penetration of chloride ions were measured by determining the electrical conductance of concrete. A concrete disc having a diameter and thickness of 102 mm and 51 mm respectively was prepared and allowed to cure for 28 days. Afterwards, both ends of the disc was sealed with cell, one which filled with 3% NaCl solution, the other one filled with 0.3N NaOH solutions. A potential difference of 60 V was maintained across the two cells and the amount of charge passed to the specimen was monitored for the duration of 6 h. The amount of chloride penetration was measured in terms of Coulombs. A concrete permeability test apparatus supplied by AIMIL Ltd., India was used in this study to determine the water permeability of the concrete and the test was performed according to IS 3085:1965 [13]. The water permeability of the cubes was obtained by measuring the water volume that passes through the specimen under constant air pressure 10 kg/cm^2. For carbonation test, cylinders having a dimension of 150 mm × 300 mm were prepared for all mixtures and allowed to cure for 28 days. Later than, all the specimens were air cured for the duration of 90 days and 180 days then they were split. The split surface of the concrete was thoroughly cleaned and the phenolphthalein indicator was uniformly applied along the entire length using brush. The average depth was measured at three points to the nearest 1 mm, from the external surface to the colorless phenolphthalein region. The electrical resistivity of the concrete was determined using concrete electrical resistivity meter supplied by AIMIL Ltd., India under saturated condition.

3.2. Descriptions of mixtures

Among the six mixtures, five mixtures were prepared with natural sand substituted by GP by-product and the remaining one was control mixtures (CM). To identify the mixtures easily, the each mixtures was designated with the names such as CM, CGP 5%, CGP 10%, CGP 15%, CGP 20% and CGP 25%. For example CGP 10% specifies that the concrete mixture made with 10% of natural sand is substituted by GP waste.