Study on cement paste blended with calcined granite powder

Rajendra Prasad Singh\textsuperscript{1,2}, K Rajasekhar\textsuperscript{3}, S Adiseshu\textsuperscript{3}

\textsuperscript{1}Research Scholar, Department of Civil Engineering, College of Engineering (Autonomous), Andhra University Visakhapatnam, India
\textsuperscript{2}Assistant Professor, Department of Civil Engineering, MVGR College of Engineering (Autonomous), Vizianagaram, Andhra Pradesh 535005 India
\textsuperscript{3}Professor, Department of Civil Engineering, College of Engineering (Autonomous), Andhra University Visakhapatnam, India

Email: rp.singh130@gmail.com

Abstract. Granite in India is famous for flooring and also used as concrete aggregate. Granite mineral is processed in the industry and large sheets are made which are used as the flooring of dwelling units. During the processing of granite, the mineral is cut into suitable pieces and polished which produces very fine powder. The fine granite powder is a by-product of the granite industry and which is often used for landfill. On the other hand, the granite crushers industries break the granite to suitable sizes to make concrete aggregates also have this fine granite powder as its by-product. Granite is a hard mineral-rich in silica. The silica-rich mineral can be used in concrete as a mineral additive. The hydration compounds of cement in concrete have free lime and mineral admixtures rich in silica are useful in secondary reacting with the excess lime to form C-S-H gel. In the present study, experimental results are discussed for the suitability of granite powder in concrete manufacturing. In the present work, the cement by partial replacement with granite powder in normal state and calcined state up to 50% and the compressive strength of cement paste is found at 28 days. The results indicate that the partial replacement of cement with granite powder results in only a 10% decrease in strength when cement is replaced up to 30% with granite powder.

1. Introduction

With increasing environmental awareness, it is essential to explore alternatives to waste disposal. Similarly, the production of cement requires the processing of various raw materials for which natural minerals are being exploited. On the other hand, the by-products that have been produced from various industries such as Fly ash, granite powder, ground granulated blast furnace, rice husk ash, rock dust, quarry waste, marble powder etc. are used as landfilling materials. The by-products consist of various mineral and chemical compositions that are not advised to be disposed of openly as they may cause pollution. Disposal of such industrial by-products is a challenge.

Many studies are being carried out to find the suitability of various industrial by-products into the cement to minimize the consumption of minerals required for the production of cement and safe disposal of industrial by-products. The chemical reaction when cement is mixed with water is already understood and the formation of secondary products such as free lime is undesired for obvious reasons. Because of this, the by-products from industry are utilized to make secondary reactions of minerals added with the existing free lime to form a desirable product in the concrete.

1.1 Granite Powder

Granite is an igneous rock formed from cooled magma. The major chemical composition of the granite is silica and alumina with traces of sodium and potassium. Granite powder is a grey fine powder. The
granite powder is formed due to cutting or polishing of granite slabs used for flooring. The granite powder is initially wet and is available in the form of sludge. This sludge upon drying is formed into a fine powder. The product being fine, it is difficult to handle and dispose of.

1.2 Calcined Granite Powder
The free lime formed due to the reaction of cement and water. The excess free lime is an undesirable product and over some time will leach out of the concrete and make very huge pores in concrete causing reduction in strength. Reactive silica added to concrete will react with this free lime and forms C-S-H gel which improves not only strength but also prevents leaching in concrete. Granite powder consists of silica which is inert in nature. Upon burning the granite powder to 800°C, it is observed that the colour changes to light pink. Figure 1 shows Unburnt and burnt granite powder.

![Unburnt and Burnt Granite Powder](a) and (b)

Figure 1. (a) Un-Burnt Granite powder and (b) Burnt Granite powder

1.3 Inert and reactive fillers in concrete.
The concrete is a matrix consisting of particles of various shapes and sizes. Larger particles being coarse aggregate and packing of coarse aggregate cause voids, the voids caused by coarse aggregates are filled by fine aggregates and further, the voids caused by fine aggregates are occupied by cement. Cement acts as binding materials and binds aggregates and makes stiff and rigid matrices. The voids further caused by the cement can be occupied by the smaller filler material which can be either inert or reactive in nature.

2. Literature Review
Many researchers have worked on partial replacement of cement and fine aggregate with granite dust. A few works have been presented here. Zhang and Liu [1] indicated in his study that the effect of substituting the cement with granite powder by 5% to 30% at every 5% interval and has observed that the compressive strength reduces beyond 10%. The microstructure study indicates that the pore diameter and throat formation are small for a lower percentage of cement replacement. Nithya Nairet et al. [2] reported the rheological qualities of cementitious materials made with Limestone - Calcined Clay Cement, in correlation with conventional Portland concrete and Portland - Fly Ash concrete. It is seen that the calcined clay has increased the plasticizers dosage. Sing et al. [3] reported the study on strength of M30 grade concrete by substituting cement with fly ash and fine aggregate with granite powder. It is observed that the strength of concrete has improved by 15% when there is the replacement of cement up to 20% with fly ash along with fine aggregate being replaced up to 20%. Manpreet et al. [4] observed
that the strength of concrete on partial replacement of cement with dried waste marble powder slurry. Four distinctive substitution rates (0, 10, 15, and 20 and 25%) and three water-binder proportions (0.35, 0.40 and 0.45) have been tried. The tests suggest that the replacement of 15% has increased the strength and durability of concrete. Yaswanth Kumar et al. [5] explains that the Granite Slurry (GS) utilized as a partial substitute in percentages from 5% to 20% by weight to cement in concrete and found its compressive, tensile and flexural strength. It was seen that replacement of 10% of concrete with GS in concrete brought about an increase in compressive strength to 48 N/mm$^2$ contrasted with 35 N/mm$^2$ of ordinary cement. To accomplish a similar quality of conventional cement, a 20% replacement with GS is effective.

3. Objectives
The objectives of the present study are as follows
1. To understand the suitability of granite powder to be an inert filler by partial substitution in cement.
2. To determine the effectiveness of using calcined granite powder as partial substitution in cement.
3. To study the variations in the compressive strength of cement mortar by partial substitution of cement with granite powder.

4. Scope
The scope of the work is as follows
1. To burn the part of granite powder to 800°C and air cool the material to get calcined granite powder.
2. To perform SEM and EDAX tests on normal granite powder and calcined granite powder to study the microstructure.
3. To prepare a mix by partial replacement of cement at 0%, 30% and 50% with normal granite powder and cast 7.06cm cube specimens with 1:3 proportions (Cement: Sand) for determining its compressive strength at 7 days, 14 days and 28 days.
4. Similarly, a mix is prepared by partial replacement of cement at 0%, 30% and 50% with calcined granite powder and cast 7.06cm cube specimens with 1:3 proportions (Cement: Sand) for determining its compressive strength at 7 days, 14 days and 28 days.

5. Methodology
The granite powder (GP) and the calcined granite powder (CGP) is sieved over a 90 microns sieve and is used a blending material in cement for the proportions mentioned below. SEM and EDX tests are performed on granite powder and calcined granite powder to understand its properties.

The proportions for which the cement compressive strength is tested to know the suitability of inert filler in concrete is done by casting and testing the samples at 7, 14 and 28 days. The mix proportions are presented in table 1.

| Nomenclature | Cement (\%) | Granite powder (\%) | Burnt Granite powder (\%) |
|--------------|-------------|---------------------|---------------------------|
| 100C         | 100         | 0                   | 0                         |
| 70C-30CGP    | 70          | 0                   | 30                        |
| 70C-30GP     | 70          | 30                  | 0                         |
| 50C-50CGP    | 50          | 0                   | 50                        |
| 50C-50GP     | 50          | 50                  | 0                         |

6. Results
With the above-mentioned mixes, the 7.06cm cube specimens are cast with 1: 3 (Cement blend: Sand) cured and tested at 7, 14 and 28 days.
6.1 Physical properties of cement, granite powder and calcined granite powder
The physical properties of the cement, granite powder and calcined granite powder are determined in the laboratory and the results are mentioned in table 2.

| Property                                | Cement (in % Passing on 90 microns sieve) | Granite powder | Calcined Granite powder |
|------------------------------------------|------------------------------------------|----------------|-------------------------|
| Fineness (Dry Sieving)                   | 96 %                                     | 76%            | 80%                     |
| Specific gravity                         | 2.95                                     | 2.21           | 2.56                    |
| Normal Consistency                       | 32%                                      | -              | -                       |
| Initial setting time                     | 36 min.                                  | -              | -                       |
| Final setting time                       | 565 min.                                 | -              | -                       |

6.2 Average compressive strength of cement blends
The samples cast are cured for the desired days and the compressive strength is determined as per IS 4031 (Part 6) 1988 [6]. The results obtained are as presented in table 3 and figure 2.

| Sample  | Compressive strength (MPa) |
|---------|----------------------------|
|         | 7 day | 14 day | 28 day |
| 100C    | 41.73 | 45.13  | 61.93  |
| 70C-30CGP | 36.90 | 45.73  | 52.03  |
| 70C-30GP | 25.57 | 38.43  | 45.70  |
| 50C-50CGP | 16.13 | 22.77  | 29.10  |
| 50C-50GP | 15.77 | 19.50  | 20.23  |

Figure 2. Variation of compressive strength of cement blends at 7, 14 and 28 days
From results presented in figure 2, it can be observed that the Cement blended with 30% of calcined granite powder the 28days average compressive strength is reduced up to only 16%. For the same
percentage replacement of normal granite powder, the average compressive strength is reduced up to 27% when compared with no replacement in cement.

6.3 Comparison of compressive strength results obtained for 30% substitution of cement with granite powder and calcined granite powder

The results obtained for 30% replacement of cement with granite powder and calcined granite powder is discussed below.

Table 4. Average compressive strengths for 30% replacement of cement with granite powder and calcined granite powder

| Age of testing | Average compressive strength of 30% replacement of CGP in cement (in MPa) | Average compressive strength of 30% replacement of GP in cement (in MPa) | Average compressive strength of cement alone (in MPa) |
|----------------|-------------------------------------------------------------------------------|--------------------------------------------------------------------------|---------------------------------------------------|
| 7 days         | 36.90                                                                        | 25.57                                                                    | 41.73                                             |
| 14 days        | 45.73                                                                        | 38.43                                                                    | 45.13                                             |
| 28 days        | 52.03                                                                        | 45.70                                                                    | 61.93                                             |

Figure 3. Variation of compressive strength of partial replacement of 30% cement with granite powder and calcined granite powder at 7, 14 and 28 days

From the above results, it can be understood that the reduction of strength happens upon partial replacement of cement with granite powder and calcined granite powder. However, calcination of granite powder is observed to have a positive influence on strength when compared with the usage of normal granite powder. The strength of the calcined granite powder sample is 12% more than normal granite powder replacement of up to 30% with cement.

6.4 Comparison of compressive strength results obtained for 50% replacement of cement with granite powder and calcined granite powder

The results obtained for 50% substitute for cement with granite powder and calcined granite powder are presented in table 5 and figure 4.
Table 5. Average compressive strengths for 50% replacement of cement with granite powder and calcined granite powder

| Age of testing | Average Compressive strength (in MPa) |
|----------------|---------------------------------------|
|                | 50% replacement of CGP in cement | 50% replacement of GP in cement | Cement alone |
| 7 days         | 16.13                                | 15.77                             | 41.73         |
| 14 days        | 22.77                                | 19.50                             | 45.13         |
| 28 days        | 29.10                                | 20.23                             | 61.93         |

Figure 4. Variation of compressive strength of partial replacement of 50% cement with granite powder and calcined granite powder at 7, 14 and 28 days

Similarly, the replacement of cement up to 50% with granite powder has drastically reduced the strength of 67%. Eventually, the reduction of strength is only 53% for the same replacement with calcined granite powder. Further, it is also observed that the calcined granite powder replacement has 30% more strength normal granite powder.

6.5 Microstructure study of granite powder and calcined granite powder:
The Microstructure analysis of granite powder and calcined granite powder presented in table 6, table 7, figure 5, figure 6, figure 7 and figure 8.

Table 6. Chemical composition of Granite powder

| Element | Wt. % | At. % |
|---------|-------|-------|
| O       | 28.70 | 46.63 |
| Na      | 00.18 | 00.20 |
| Mg      | 08.65 | 09.25 |
| Al      | 01.34 | 01.30 |
| Si      | 30.10 | 27.86 |
| P       | 00.29 | 00.24 |
| K       | 00.34 | 00.23 |
| Ca      | 00.72 | 00.47 |
| Ti      | 00.21 | 00.11 |
| Mn      | 00.93 | 00.44 |
| Fe      | 28.54 | 13.28 |
Figure 5. EDX Results of granite powder

Figure 6. SEM image showing the microstructure of granite powder

Figure 7. EDX Results of calcined granite powder

Figure 8. SEM image showing the microstructure of calcined granite powder

Table 7. Chemical composition of Calcined granite powder

| Element | Wt. % | At. % |
|---------|-------|-------|
| O       | 37.56 | 51.60 |
| Na      | 00.18 | 00.17 |
| Mg      | 00.13 | 00.12 |
| Al      | 00.65 | 00.53 |
| Si      | 59.78 | 46.78 |
| P       | 00.23 | 00.16 |
| K       | 00.31 | 00.17 |
| Ca      | 00.00 | 00.00 |
| Ti      | 00.09 | 00.04 |
| Mn      | 00.50 | 00.20 |
| Fe      | 00.57 | 00.22 |

From the chemical composition obtained for the granite powder and calcined granite powder, it can be understood that the silica composition is about 30% in normal granite powder and the same granite powder upon burning up to 800 degrees, the silica content is observed to be about 60%. This can be the
reason for improved compressive strength. The microstructure of the calcined granite powder has smaller particles compared to normal granite powder, hence can have a much higher void filling ability.

7. Conclusion
The cement when fractional substitution with inert filler material like granite powder shows appreciable suitability.
1. Compressive strength of 7.06 cm cube of cement mortar tested at 07 days is 41.73 Mpa, 14 days is 45.13 MPa and 28 days is 61.93 MPa.
2. When the cement is fractional substituted up to 30% with granite powder shows that there is a decrease of 25% of strength. For the similar replacement of calcined granite, powder shows only a 10% decrease in strength at 28 days.
3. Later, when the cement is fractional substituted up to 50% with granite powder shows that there is a decrease of 65% of strength. But when the same granite powder is replaced in the calcined state shows only a 50% reduction in strength by 28 days.
4. From the experiment, it is understood that, upon burning the silica-rich granite powder, it becomes reactive and reacts with cement compounds to contribute to its strength. The increase in strength could be due to secondary reactions in cement with the free lime and the reactive silica in calcined granite powder.
5. From the microstructure of the calcined granite powder, it can be understood that the silica reactivity increases and more fine particles are observed when compared with normal granite powder.

Hence, studies on partial replacement of cement with calcined and un-calcined granite powder have a great deal of promise in making cement more sustainable (Naga Rajesh et al. 2019 [7]).

References
[1] Zhang, Kunqiang, Fusheng Liu, Qiang Yue, Jianguo Feng 2020 Effect of granite powder on properties of concrete Asia-Pacific Journal of Chemical Engineering e2468
[2] Nair Nithya, K Mohammed Haneefa, Manu Santhanam, Ravindra Gettu 2020 A study on fresh properties of limestone calcined clay blended cementitious systems Construction and Building Materials 254 p 119326.
[3] Singh R P, Rajasekhar K, Adiseshu S 2019 Experimental Study on Performance of M30 Grade Concrete by Partial Replacement with Fly Ash and Granite Powder In: Das B., Neithalath N. (eds) Sustainable Construction and Building Materials. Lecture Notes in Civil Engineering Springer, Singapore 25 p 627-634
[4] Singh Manipreet, Anshuman Srivastava, Dipendu Bhunia 2019 Long term strength and durability parameters of hardened concrete on partially replacing cement by dried waste marble powder slurry Construction and Building Materials 198 p 553-569.
[5] Kumar Y Yashwanth, Vivek Vardhan C M, Anitha A 2015 Use of granite waste as partial substitute to cement in concrete International Journal of Engineering Research and Application 5 (4) p 25-31
[6] IS 4031 (Part 6) 1988 Indian Standard - Methods of physical tests for hydraulic cement Bureau of Indian Standard New Delhi
[7] Naga Rajesh K, Rath M K, Markandeya Raju P 2019 A research on sustainable micro-concrete International Journal of Recent Technology and Engineering 8 (2 Special Issue 3) p 1137-9