# The Use of Granite Industry Waste as a Cement Substitute

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**Abstract:**

Granite industry generates huge amount of waste, during the process of sawing. Current research intended to mix granite saw powder waste in Ordinary Portland Cement (OPC) to get compatible quality cement, in lines with Portland Pozzolana Cement (PPC) where a maximum of 35% of fly ash is mixed in OPC. The granite saw dust waste has been collected from three different locations of Divya Shakti Granites Ltd., Medak, AP, India. All samples were mixed with OPC in different proportions ranging from 20 - 35%.

Using these proportions several experiments were conducted to assess compressive strength, physical properties as well as chemical properties. The results indicate compatibility of granite powder waste as a perfect cementing material, which can be added up to 35% without hampering the quality parameters like compressive strength.

**Keywords:**

Granite industry waste, Granite saw dust, alternative cements, compressive strength, solid waste management, powder.



## Introduction:

Ordinary Portland Cement (OPC) is commonly used as a best means of cementing material for construction, with different grades including 33, 43 and 53 grade, available in the market as per Bureau of Indian Standards (IS: 12269: IS 1489:2005). OPC consists of calcium silicates, aluminates, and iron. Calcium carbonate is first dissociated at around 900$^{o}$C to produce calcium oxide and carbon dioxide, further it is heated at around 1400$^{o}$C and made to react with silica, alumina and iron, to form small pebbles called clinker, which is then grinded to approximately 100 micrometer size to produce OPC cement. An amount of approximately 5% gypsum is added to retard setting time, which serves as a buffer time during construction.

Portland Pozzolana Cement (PPC) is produced by mixing a maximum of 35% (BIS: IS 1489: 1991) of fly ash in OPC cement. Fly ash is produced at thermal power stations as a waste material, when huge volumes of coal are burnt in boilers. The flu gas is made to pass through electrostatic precipitators, and the fine dust (fly ash) is collected. Fly ash consists of silica, calcium oxide, and traces of alumina as well as iron, which is cementing compatible material. The present line of work is to replace fly ash with granite waste, in OPC cement. Earlier fly ash was considered as waste and was used for land filling, similarly granite waste, is presently used in land filling.

In India about 960 million tones of solid waste is generated annually as bi-product from different industrial processes out of which approximately 350 million tones are from organic agricultural sources, 290 million tones inorganic wastage from industrial mining and 4.5 million tones are hazardous waste. Part of the waste from different industries has been recycled in construction industry as well as other industries [Ashokan et al., 2007]. The granite saw dust comprises of calcium and iron which has the compatibility to acid soils, granite waste powder is used as a suitable means to neutralize acid soils [Barral et al., 2005]. Use of granite and marble rock waste found to be effective in the production of concrete for civil construction [Hanifi et al., 2008]. Use of municipal solid waste incinerated fly ash is found to be effective up to 20%, as cement substitute [Lin et al., 2003].

Muscovite granite waste has the ability to produce ceramic tiles by adding 20-30 % [Mirabbos et al., 2011].

In Brazil, granite waste powder has been effectively studied and proved compatible for making ceramic bricks and tiles, the results have been acknowledged by Brazil standardization for ceramic bricks and tiles [Romualdo et al., 2005]. Granite sludge waste is found to be effective filler for pozzolanic motors, where a reddish pigment is produced by calcining at lower temperature (700-900$^0$C) for short time, therefore granite sludge can be an effective additive in the preparation of colored motor (Marmol et al., 2010). The sludge produced from granite cutting polish industries is also found to be effective up to 10 % mixing to produce roof tiles with enhance properties [Monteiro et al., 2004 &Torres et al., 2009]. Granite waste is also found to be effective up to 40 % (Mg by weight) in producing fly ash magnesium oxy chloride cement [Ying et al., 2013]. Granite waste is currently used for land filling at most of the industries in India. A maximum of 35% fly ash is being added to OPC, and available in market as PPC [Ozlem Celik et al., 2008]. Current research is intended to mix different proportions of granite saw dust collected from different locations of granite industry and study for the compatibility with OPC.

## Materials and Methods:

Granite Samples: Granite industry cuts the granite rock to slabs based on the requirement of the client, using metal saws, and the fine powder is produced during cutting is considered as solid waste and is being sent to dump. During the conveyance from granite cutting zone to waste dump, samples were collected at different intervals. Sample -1 is collected just below the cutting zone and the same is blended with different percentages starting from 20% to 35% in Ordinary Portland Cement (OPC). Similarly Sample -2 is collected from the middle of the path between sawing zone and dumping zone and the same is blended with different percentages starting from 20% to 35% in OPC. Likewise sample-3 is collected from the end point, which is the dumping zone and the same is blended with different percentages starting from 20% to 35% in OPC.



### Preparation of testing specimen:

Aggregates are prepared with reference to the BIS standards by mixing laboratory grade sand (supplied by Tamilanadu minerals Ltd, Innore, Chennai) cement and water, in the ratio of 3:1 (sand: cement-granite mix -mass basis), water is added based on the normal consistency. These composites are thoroughly mixed in pony mixer for 2 minutes, poured into standard mould of 7.5 x 7.5 x 7.5 cm, then subjected to compression in vibrating machine for 2 minutes, and then kept in humidity chamber for 24 hours, maintaining 27 degree centigrade. The specimens are then taken out and cured for 1, 3, 7, and 28 days in curing chambers of same temperature.

## Testing of samples:

1. Compressive Strength: Specimen cubes are subjected to compressive strength test in the standard compressive strength machine, supplied by AIMIL, New Delhi.
2. All the blended samples were analyzed for physical and chemical analysis as per Bureau of Indian Standard norms

## Results and Discussions:

Sample-1, sample-2 and sample-3 of granite are mixed up to 35 % in OPC, and its physical properties measured and are reported in Table-1. It has been observed an increase of bulk density and tapped density as the percentage of granite mix increased [Matthews et al., 2011]; this could be because of variance in particle size and shape of granite waste and OPC cement. When the bulk density increases, the tapped density also found to be increased. Flowability index shows decrease in values which infers increase in flowability, and is in line with porosity values (E.C.Abdullah et al., 1999). The values of true density are decreasing as the percentage of granite waste increases, since the true density of cement is higher to granite waste.

Bulk densities of samples-1 and 3 found to be slightly higher than sample-2, it could be because of morphology of sample and its movement from sawing zone to dumping zone [Xiao-Dong Tong et al., 2002], after sawing operation as well as percentage of iron content, which must have slightly settled more in at starting point 1(sample-1) and ending point 3(sample-3), and there must have been a continuous flow at point 2(sample-2). The results are also matching with the bulk densities, as the one day strength of sample-1 and 3 are slightly more than sample-2, where iron reaction takes place.

The critical quality parameter 'compressive strength' of samples are shown in Table-2. A maximum of 41.71 Mpa for 20% granite mix and minimum of 36.23 Mpa for 35% granite mix is observed for sample-1, similarly for sample-2 maximum of 42.81 Mpa and minimum of 37.12 Mpa is observed, and for sample-3, a maximum of 43.51 Mpa and a minimum of 38.39 is observed, after curing 28 days. The compressive strength is increasing as the number of days of curing increases, in line with the established research [Wig et al., 1915]. The values of compressive strengths of sample-1 and 3 for 1, 3 days compressive strength found to be increasing as the percentage of granite waste increased, this could be because of initial reaction of iron. As the sample-1 is collected right below sawing zone, percentage of iron could be little higher, similarly sample-3 is collected at the dumping zone, where sedimentation takes place there by yielding slight higher percentage of iron, in comparison with sample-2. Iron is present in granite waste as eroded powder of iron saws, during sawing operation. The compressive strengths of 28 days found to be decreasing as the percentage of granite waste increases for all samples.

The compressive strength values obtained after mixing with granite shows the same trend as in case of fly ash mix [Ozlem et al., 2008]; therefore granite waste can be perfect mix as a cementing material.



Table-1: Physical properties of sample-1, 2 and 3

| Granite % | BULK DENSITY (gm/cc) | | | TAPPED DENSITY (gm/cc) | | | TRUE DENSITY (gm/cc) | | | FLOWABILITY INDEX | | | POROSITY | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | S - 1 | S - 2 | S - 3 | S - 1 | S - 2 | S - 3 | S - 1 | S - 2 | S - 3 | S - 1 | S – 2 | S - 3 | S - 1 | S - 2 | S - 3 |
| **20** | 0.79 | 0.78 | 0.87 | 1.25 | 1.19 | 1.28 | 2.77 | 2.77 | 2.77 | 1.58 | 1.53 | 1.47 | 0.54 | 0.57 | 0.53 |
| **25** | 0.87 | 0.83 | 0.88 | 1.31 | 1.27 | 1.28 | 2.63 | 2.76 | 2.77 | 1.50 | 1.53 | 1.45 | 0.50 | 0.53 | 0.53 |
| **30** | 0.88 | 0.84 | 0.89 | 1.31 | 1.31 | 1.29 | 2.5 | 2.63 | 2.65 | 1.48 | 1.50 | 1.45 | 0.47 | 0.50 | 0.50 |
| **35** | 0.89 | 0.86 | 0.91 | 1.32 | 1.34 | 1.28 | 2.4 | 2.61 | 2.60 | 1.46 | 1.50 | 1.40 | 0.45 | 0.50 | 0.48 |

Table 2: Compressive strength of Sample-1, 2 and 3, at different ages of curing and different percentages of granite saw waste mix.

| Granite % | Day/Compressive strength (MPa) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Sample – 1 | | | | Sample - 2 | | | | Sample - 3 | | | |
| | 1 | 3 | 7 | 28 | 1 | 3 | 7 | 28 | 1 | 3 | 7 | 28 |
| **20** | 12.54 | 18.79 | 31.27 | 41.71 | 4.88 | 18.95 | 25.55 | 37.15 | 9.17 | 25.93 | 34.14 | 43.51 |
| **25** | 13.13 | 22.02 | 30.28 | 40.57 | 12.23 | 27.71 | 26.32 | 42.04 | 11.24 | 25.99 | 35.23 | 42.32 |
| **30** | 13.75 | 23.09 | 31.58 | 37.22 | 12.76 | 23.85 | 28.59 | 42.81 | 11.26 | 26.17 | 30.04 | 39.39 |
| **35** | 14.15 | 23.79 | 30.21 | 36.23 | 12.34 | 22.84 | 37.94 | 39.56 | 15.53 | 26.87 | 29.35 | 38.39 |

Various chemical properties like, insoluble residue, loss on ignition and $SO_3$ is measured for all the samples and obtained results are shown in Table.7. The values of insoluble residue found to be increasing, as the percentage of granite increases, this could be because of nature of granite material. The range of values is similar with PPC cement [BIS: IS 1489: 1991]. The other chemical property 'loss on ignition' found to be approximately 1 % which infers organic material, which is similar in case of OPC as well as PPC. Percentage of gypsum as indicated by $SO_3$ found to be slightly decreasing as the percentage of granite increases. The normal percentage of gypsum in OPC and PPC as $SO_3$ should be less than 5%, which is added to clinker externally, for retarding setting time. There has been a slight increment $SO_3$, values for all samples of granite mix, which could be because of the nature of granite.

Table 3: Chemical properties of samples

| Samples | Granite% | Loss on Ignition% | Insoluble Residue% | $SO_3$% |
|---|---|---|---|---|
| Sample-1 | 20 | 1 | 20 | 6 |
| | 25 | 1 | 21 | 6 |
| | 30 | 1 | 25 | 5 |
| | 35 | 1 | 27 | 5 |
| Sample-2 | 20 | 1 | 20 | 6 |
| | 25 | 1 | 23 | 6 |
| | 30 | 1 | 30 | 5 |
| | 35 | 1 | 32 | 5 |
| Sample-3 | 20 | 1 | 33 | 6 |
| | 25 | 1 | 33 | 6 |
| | 30 | 1 | 33 | 5 |
| | 35 | 1 | 33 | 5 |

## Conclusions:

The objective of present work is to study the compatibility of granite saw waste as a cementing material, and the results found are encouraging. The compressive strength is decreasing as the percentage of granite waste is increasing. It is found that maximum amount of 35% granite waste that may mix with OPC without compromising quality parameters like compressive strength. Further, as expected it is found that as curing time increases the compressive strength is increasing. The granite waste collected from any corner/zone is not effecting physical and chemical parameters.



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