Research Article

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Utilization of granite sludge in the preparation of durable compressed stabilized earth blocks

Abstract

Granite sludge (GS) is a by–product obtained in the process of cutting and polishing dimension stones. This study presents the attempts done to utilize GS collected from Jigani Industrial area as a partial to total replacement for sand used in the re–grading of soil to make it suitable in the preparation of Compressed Stabilized Earth Blocks (CSEBs). Three series of CSEBs were prepared with 0%, 30 % and 60 % granite sludge, which was used as a replacement of sand present in soil. All the blocks were tested for evaluating their engineering properties with ageing up to 5 years. The properties evaluated were wet compressive strength, water absorption and durability (through 12 cycles of alternate wetting and drying). Test results indicate that it possible to utilize granite sludge in the preparations of CSEBs as they have better engineering properties than the blocks without granite sludge. The blocks with granite sludge have an early wet compressive strength of more than 3.5 MPa and long–term strength nearing 7.8 MPa; with values of water absorption of blocks being less than 10 %. They are also found to be quite durable and can be rated as good quality building blocks suitable for load bearing walls. Test results indicate that the sludge derived from the granite cutting and polishing industries can be effectively used in the preparation of CSEBs. Large scale utilization of granite sludge in making blocks would contribute not only to replace natural river sand used in re–grading the soil used in preparing CSEBs, but also reducing the quantity of soil required in their preparation. Sustainable recycling of granite sludge by its application in the construction industry would not only solve the problem of disposal of huge quantities of granite sludge, but also lead to a cleaner environment that society desires.

Keywords: environmental impact, granite sludge, slurry waste, soil blocks, cleaner production, sustainability

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Introduction

For a sustainable development and a need to address environmental concerns, utilization of by–products from productive sectors has become a necessity. One such issue is utilizing granite sludge obtained as a by–product from the cutting and polishing of granite dimension stones. Granite, a natural igneous rock, because of its fine finish on polishing has very important application in the construction industry in the form of flooring slabs in residential and office buildings. To cater the needs of increased construction activity in metropolis and urban centres, many granite cutting and polishing units have mushroomed in those areas. Bangalore being a very important metropolitan city in India has more than one hundred and seventeen units in Jigani Industrial area alone of Bangalore metropolitan city. Here, huge quantity of stone slurry waste is being produced during the cutting and polishing of thin slices from the big size granite stone blocks obtained from quarries (Plate 1). The slurry is sedimented to separate the granite cutting dust from water to obtain sludge. The size of particles contained in the granite sludge is finer than 425 µm. This sludge is being unscientifically disposed off on vacant lands, unused open areas, tank bed areas (Plate 2) and along the sides of roads in the vicinity of stone cutting and processing units. This has been a serious environmental concern in and around Jigani industrial area of Bangalore city. On drying, granite sludge becomes air borne, and has been a cause of air pollution, leading to health hazards and also loss of vegetation of the land on which it is being deposited. The impact on the environment due to such activity elsewhere has been reported in the literature.[1–5] Many attempts have been made in the past by various researchers to utilize the stone cutting sludge in various industrial applications including, ceramic roof tiles, flooring tiles, as alternative ceramic raw materials;[4,6–9] concrete as a source of water;[8] as partial replacement to sand or as a filler material in concrete[10,11] in concrete brick making.[12] Weng et al.,[13] Menezes et. al.;[14] Dhanapandian et al.[15,16] have investigated the possibility of producing burnt bricks from dried sludge, and they have found that the sludge proportion and firing temperature were the two key factors determining the brick quality. Similar type of waste is generated from marble cutting and polishing units and its utilization in various industrial applications has been reported in the literature.[16,17–19] Utilizing granite sludge in many of the industrial applications is justifiable from both sustainable development, and also, to protect the environment from health hazards. However, utilizing the same in the formulation of burnt bricks as reported by Dhanapandian et al.,[16] has an impact on the environment in the form of burning fuel needed for making bricks, and a consequent release of carbon dioxide. As an alternative to the conventional burnt bricks, many attempts have been continuously made by various researchers in India and elsewhere to produce Compressed Stabilized Earth Blocks (CSEBs) and also popularize their use in construction industry as summarized by Nagaraj et al.,[20,21] Recently, attempts have been made by researchers to utilize granite sludge to prepare concrete bricks[12] to prepare cylindrical blocks[22] or prismoidal blocks similar to the size of burnt clay bricks[23,24] to explore the possibility of utilizing granite sludge for applications in the construction industry. The experimental findings presented in this paper are based on a comprehensive and long–term study started in 2011, and a patent filed in 2012.[25]

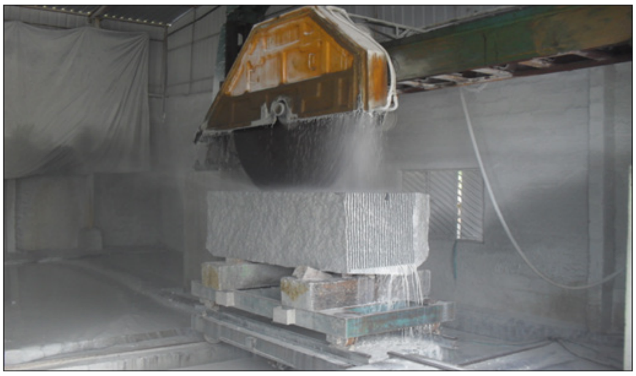

Plate 1 View of granite slurry being formed while slicing granite stone block.

Plate 2 Unscientific dumping of granite sludge obtained from granite cutting and polishing units along one of the tank bed area in Bangalore region, India.

Materials and methods

A locally available red earth from Bangalore area was selected for the preparation of CSEBs. The selected soil was characterized for its physical properties namely, specific gravity, liquid limit, plastic limit, shrinkage limit, and particle size distribution using the standard procedures as specified by SP–36 (Part1)–1987.[26] The particle size distribution is shown in Figure 1 and the properties are tabulated in Table 1. The mineralogical analysis of the soil was performed using an X–ray diffract meter with Cu–kα radiation (45 kV/30 mA). The principal clay mineral present in the soil is found to be kaolinite. Figure 2 shows the x–ray diffraction pattern of the soil used in this study. Granite sludge used in the present study was obtained from one of the granite cutting and polishing units situated in Jigani Industrial area, Bangalore, India. The granite sludge was air dried and stored in bins before being used for making CSEBs. Ordinary Portland cement was used for making blocks. It was tested for fineness, normal consistency, initial setting time and specific surface area according to IS: 12269–1987.[27] The properties are reported in Table 2. CSEBs were prepared with freshly prepared lime powder processed from quick lime obtained from Bijapur, Karnataka, India. Sufficient water was sprayed on the surface of quicklime to blossom into powder form. The powdered lime was sieved through 425μm sieve and immediately stored in airtight polyethylene bags, to prevent reaction with moisture present in air.

Table 1 Physical properties of soil sand and granite dust used in the present study

Sl. no.	Soil description	Gs	Atterberg limits			Ip	Grain size distribution			
			w_L	w_P	w_S		Gravel (%)	Sand (%)	Silt (size) (%)	Clay (size) (%)
1	Red Earth (Bangalore)	2.77	54.2	28.4	22.6	24.96	0	52	38	10
2	Sand	2.62	NP#	NP	NP	NP	0	97	3	0
3	Granite sludge	2.58	NP	NP	NP	NP	0	75	25	0

Note # NP- Non-Plastic

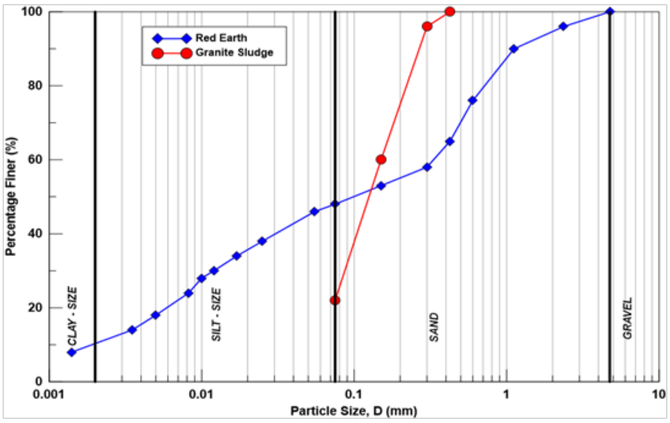

Figure 1 Particle size distribution curve of Red Earth and granite sludge used in the present study.

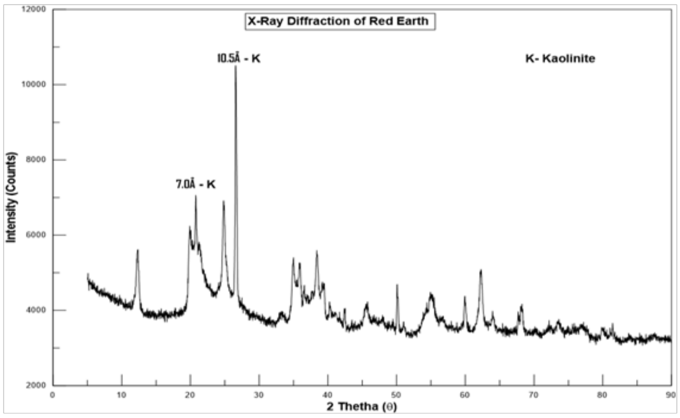

Figure 2 X-ray diffraction pattern for the red earth used in the present study.

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Table 2 Physical properties of cement used in the present study

Fineness (%)	Normal consistency (%)	Initial setting time (min)	Specific surface of cement (m^2/kg)
6.2	28	52	215

Characterization of granite sludge

Chemical composition of granite sludge used in the present study was obtained from Essen and co., analytical testing and analysis laboratory, Bangalore. Table 3 shows the average chemical composition of sludge sample of two samples used in the present study. The results of both the samples were observed to be almost identical. Dried sludge was found to have high quantity of silica (SiO_2 = 73 %), and some amount of alumina (Al_2O_3 = 17%). In addition, small amount of ferric oxide, sodium oxide, calcium oxide, potash as well as traces of titanium oxide and manganese oxide have also been found. The mineralogical analysis of the granite sludge used in this study was also performed using an x–ray diffract meter and Cu–kα radiation. Figure 3 shows the x–ray diffraction pattern of the granite sludge. The mineralogical content present in granite sludge obtained through x–ray diffraction indicates the presence of Oligoclase [$(Na,Ca)Al_{1-2}Si_{3-2}O_8$], Microcline [$KAlSi_3O_8$] and Melilite [$(Ca,Na)_2(Al,Mg,Fe^{2+})$ [$(Al,Si)SiO_7$]]. This matches with the chemical composition obtained through analytically obtained results as reported in Table 3.

Table 3 Chemical composition of granite sludge used in the present study

Sl. No.	Parameter	Quantity (%)
1	Silica (SiO_2)	72.67
2	Alumina (Al_2O_3)	16.78
3	Ferric oxide (Fe_2O_3)	2.49
4	Titanium dioxide (TiO_2)	0.08
5	Calcium oxide (CaO)	1.4
6	Magnesium oxide (MgO)	0
7	Sodium oxide (Na_2O)	3.17
8	Potash (K_2O)	2.32
9	Manganese oxide (MnO)	0.05
10	Loss on Ignition (LOI)	0.97

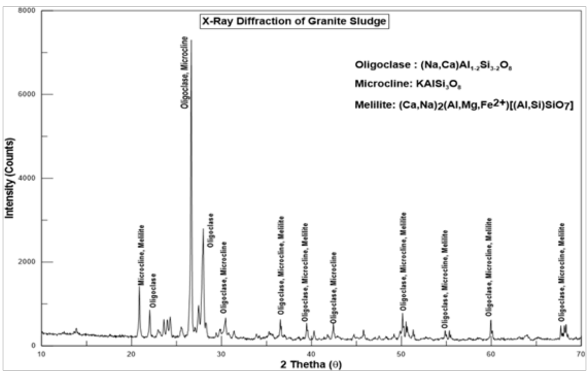

Figure 3 X-ray diffraction pattern for the granite sludge used in the present study.

Sieve analysis of granite sludge

Mechanical sieve analysis was carried on the granite sludge as per Indian standards.[26] The test was carried out on three samples of granite sludge to obtain the average particle size distribution. Figure 1 shows the plot of particle size distribution for the dried granite sludge, indicating that it is silty sand, with the sand portion being fine (75 to 425µm).

Experimental methods

Proportioning of the soil–admixtures for preparing CSEBs

The various proportions of sand, silt, clay, granite sludge and stabilizers used for preparing blocks of different series in the present study have been tabulated in Table 4. The portion of the sand available in the red earth was also accounted for while proportioning the mixes, and the remaining amount of sand required to meet the graduation requirement for preparing a good and durable block was made up by using sand from external source. In order to explore the possibility of optimising the utilization of granite sludge in making blocks as a replacement to sand, two variations of granite sludge were used, namely 30 % and 60 %, so that it would respectively amount to 50 % and 100% replacement of sand. The admixture content was maintained constant at 10% for blocks of all the three series used in this study. However, instead of using cement alone as the admixture as hitherto being a recommended practice in the manufacture of blocks at the time of initiation of this study, lime (6%) was used in combination with cement (4%) to take the advantage of its beneficial effect to effectively stabilize the fines present in the mix. This was based on the results available from another study initiated earlier by the author and reported in 2014.[24]

Table 4 Proportions and combination of various ingredients used in the preparation of different series CSEBs

Series	Sand (%)	Red earth fines (%)		Granite sludge (%)	Cement (%)	Lime (%)
		Silt	Clay			
I	60	24	6	0	4	6
II	30	24	6	30	4	6
III	0	24	6	60	4	6

Preparation of CSEBs

The CSEBs were prepared by using a hand operated soil block making machine known as ASTRAM press, which was developed by the centre for Application of Science and Technology for Rural Areas (ASTRA) in India. The dimensions of the mould used to prepare the soil blocks were 305 mm x140 mm x100 mm. The required quantities (weight basis) of the ingredients namely sand, granite sludge, red earth and the admixtures (lime and cement) as obtained from the calculations depending on the series were weighed and initially mixed in a dry condition. Then the optimum quantity of water needed to mould the bricks and eject them successively as one unit was determined by mixing the dry mix of the ingredients with minimum water to obtain a good intact ball of the mix without sticking to the hand. By conducting few trials, this optimum water content was observed to be around 16 % on weight basis of the mix. For making soil blocks, the proportioned dry mix was spread on a big tray, and the requisite water was sprinkled to the mix. Then the mix was thoroughly worked by hand to have uniform distribution of moisture. Care was taken to use hand gloves while remoulding the mix. The wet mix was then transferred to the mould placed in position on the ASTRAM press.[20,21,28,29] The wet mix was remoulded in the mould using a wooden mallet to give proper hand compaction. Later the stiffened lid of the mould was closed and properly locked at the top. Using the toggle lever mechanism provided in the machine, the mix was pressed to give the requisite compactive effort. This was followed by unlocking and opening of the top lid to eject the compressed soil block. The ejected block (Plate 3) was weighed and serially labelled with date of manufacture, date of testing and a suitable identification number (for the series adopted) for ease of future identification. The prepared CSEBs were stacked in shade for wet curing with gunny bags below and also over the blocks to maintain wetness (Plate 4). Sufficient number of CSEBs were prepared for evaluating their engineering properties, namely, wet compressive strength and water absorption for various ageing periods, namely, 7, 15, 28 days; 2, 4, 6 months; 1, 2 and 5 years from the date of preparation.

Plate 3 Freshly prepared Compressed Stabilized Earth Block (CSEB) utilizing granite sludge being ejected from the ASTRA machine.

Plate 4 CSEBs of different series stacked for curing.

Tests conducted on CSEBs

Wet compressive strength and water absorption

Similar to other masonry units, wet compressive strength is one basic measure of quality and durability of Compressed stabilized blocks. Wet compressive strength and water absorption of the CSEBs for different series was determined as per Indian standards.[30] Both the properties reported here is an average of tests conducted on five CSEBs. To determine the wet compressive strength, the blocks were first immersed in clean water for 24 hours. Later, they were removed from water, and the surfaces were wiped dry and tested for their compressive strength using Universal Testing Machine (UTM) (Plate 5). Plywood sheet of 3 mm thick was placed on either faces of the block before the application of load. The test specimen was loaded at the rate of 14 $N/mm^2/min$ till failure occurred. To determine the water absorption, the blocks were first dried completely in the oven and its mass was recorded accurately. The blocks were then immersed in water for 24 hours at a temperature of 27±2°C. Later, the blocks were weighed again, and the increased mass was noted to determine their water absorption.

Plate 5 View of wet compression test on CSEB.

Alternate wetting and drying

Response of CSEBs to alternate wetting and drying cycles is important from the point of view of long–term performance. In case the admixtures used in the preparation of blocks do not adequately stabilize the fines present in the soil used in the block, it is likely to undergo expansion–contraction sequences with each wetting and drying cycle. This can lead to a gradual disintegration of the internal structure of the block. An accelerated durability test procedure that would reasonably represent the actual field condition of alternate wetting and drying cycle was planned to assess the blocks for their durability when used in construction as masonry units and exposed to nature. Since, in tropical climates like India, approximately two thirds part of the year is dry with an average maximum temperature of 50^0C, and one third part of the year is wet due to rains, it was planned to have an accelerated durability test of alternate wetting and drying cycles (12 cycles in total) by subjecting the blocks to accelerated temperature of 50^0C for nearly 48 hours and immersed in water for approximately 24 hours; each such cycle representing one year of exposure to nature. This procedure is similar to that suggested by Jagadish et al.[28] As a first step, three blocks from each series, which were wet cured for a period of 28 days were placed for 20 hours in an oven maintained at 60^0C to drive out the moisture present, and obtain constant initial mass. The initial dry mass of blocks was noted. The blocks were then immersed completely in water for a period of 22±2 hours ensuring complete saturation, and the wet mass of the blocks recorded (Plate 6). The completely wet CSEBs were subjected to oven drying under controlled temperature of 50^0C for a period of 46±2 hours (Plate 7).

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This constituted one cycle of complete wetting and drying. Similar procedure was repeated for 12 cycles. At the end of 12 cycles (Plate 8), the final dry mass was noted. The difference between the initial dry mass and the final dry mass after 12 cycles of alternate wetting and drying was expressed as a percentage mass loss relative to the initial mass. Finally, the blocks were completely immersed in water for a period of 24 hours, and the wet compressive strength determined. The average percentage loss of mass of blocks of all the three series and their wet compressive strengths were evaluated.

Plate 6 CSEBs being subjected to alternate wetting and drying removed from water and placed in baskets (date of manufacture of blocks can be observed).

Plate 7 CSEBs placed in wire basket and kept in oven for durability study.

Plate 8 CSEBs after completing 12 cycles of alternate wetting and drying.

Results and discussions

Wet compressive strength and water absorption of CSEBs

Figure 4 is the plot of wet compressive strength of CSEBs for the three series (Table 4) versus ageing. It can be observed that, there is a continuous increase in the wet compressive strength of the CSEBs. It is well known that use of stabilizers like cement and lime in the presence of moisture will produce cementitious products, and hence, contribute to the strength of blocks. It is well known that hydration of cement will contribute to early strength gain within the first one month, being around 90 % of its ultimate strength by the end of 28 days, and further increase in strength will be marginal. On the other hand, cementitious reactions lime continues for a long time even up to 2 years, and hence contributes to the long term strength.[20,29] Since lime has been used in the preparation of blocks, continuous strength gain can be seen with time even beyond one year. At any ageing period, the blocks with granite sludge (GS) have shown higher wet compressive strength than blocks without granite sludge; series–III blocks with 60 % GS have shown maximum strength as compared to blocks of other two series. This may be due to the better interaction of the admixtures with the fine particles of granite sludge. As per IS: 1077–1992,[31] the minimum wet compressive strength of blocks to be suitable for ordinary masonry construction is 3.5 MPa. Wet compressive strength is one of the basic requirements of any masonry unit to be suitable for building construction. From the test results of blocks of all the series prepared in the present study, the minimum wet compressive strength is near to 3.5 MPa after 60 days of ageing and have further gained strength with ageing leading to a strength ranging between 5 to 7.5 MPa depending on the composition of the blocks. It should be understood that the block units used in load bearing masonry construction with cement motor prepared with Ordinary Portland Cement for residential houses not exceeding two stories, will not be subjected to compressive stress not exceeding 1.5 MPa. From this point of view, the CSEBs prepared with granite sludge are quite suitable for masonry construction. Figure 5 presents the water absorption of the CSEBs versus curing period for all the three series adopted in this study. It was observed that water absorption has kept on reducing with ageing. Initially the blocks prepared with GS have shown to have higher water absorption. However, after 15 days of ageing, their values are less than blocks without GS. These changes may be attributed to the micro–level changes taking place due to the interactions of cement and lime with the silicates of granite sludge and soil, and aluminates of granite sludge, to form cementations products. As a result of the cementations reactions, the interconnectivity between the pores may be getting reduced, and hence, reduction in water absorption of the CSEBs. Except after 1 week of ageing, the water absorption of blocks of all the three series are quite below the upper limit of 15% for standard bricks as suggested by IS: 1725–1982.[32]

Alternate wetting and drying

The test results on blocks subjected to 12 cycles of alternate wetting and drying at the end of 1 month and 1 year of ageing have been tabulated in Table 5. It can be observed that the loss of mass of blocks prepared with GS after 12 cycles of alternate wetting and drying is slightly less than for the blocks prepared without GS. However, the values of loss of mass due to weathering are within 5 %, which the upper limit permitted as is suggested by IS: 1725–1982.[32] Further, the maximum water absorbed after the last cycle i.e., 12th cycle varied between 7.3 % to 8.5 % after 1 month of ageing and 7.0 % to 8.0 % after 1 year of ageing. These values are slightly less than that the values of water absorption of blocks stored under normal laboratory air–dried conditions at the respective ageing period, being 10.1 % to 10.5 %. The average wet compressive strength of the CSEBs after 12 cycles of alternate wetting and drying was found to be 6.5 and 9.0 MPa respectively for series–II and series–III respectively, being more than the series–I blocks prepared without GS. These values are more than the strength of air–dried blocks (preserved under laboratory temperature after curing for 28 days) at the respective ageing period. The possible reasons for the increase in wet compressive strength, and lower value of water absorption of CSEBs subjected to alternate wetting and drying as compared to that of air dried CSEBs at the similar period of ageing, may be possibly due to blocks being subjected to slightly elevated temperature of 50°C as compared to the maximum laboratory temperature of 30°C in peak summer when the testing of blocks was carried out, which might have accelerated the cementitious reactions, leading to increased bonding at the points of contacts, and thereby, reduced the inter connectivity of pores in the matrix of blocks. Based on these results, it can be inferred that the blocks may have better properties when actually used as masonry units in the construction of structures due to exposure to heat from the sun.[33,34].

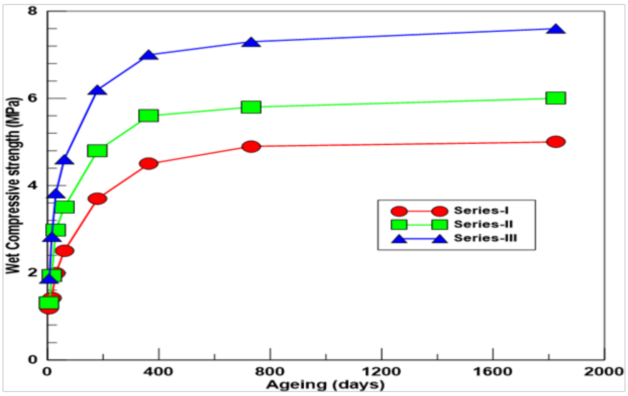

Figure 4 Comparative plots of wet compressive strength of CSEBs of different series versus ageing.

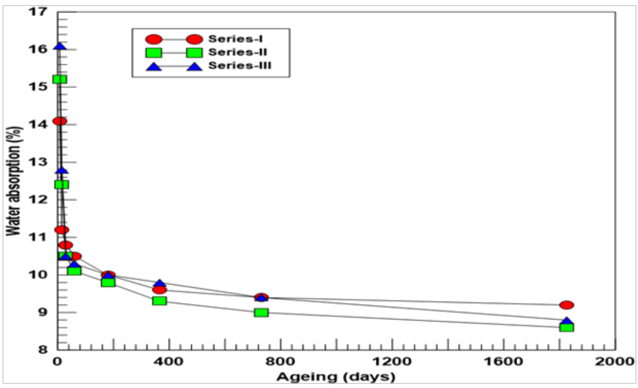

Figure 5 Comparative plots of water absorption of CSEBs of different series versus ageing.

Conclusion

This experimental study clearly brings out the role of granite sludge, a by–product of granite cutting and polishing units, as a replacement to sand in the preparation of good quality, volumetrically stable and durable CSEBs. The wet compressive strength of blocks prepared with granite sludge (GS) as a partial or complete replacement to sand have more than 3.5 MPa at one month of ageing and are also better than the blocks prepared without GS. The values of wet compressive strength have more than doubled with further ageing as observed up to 5 years from the date of preparation. The blocks with GS are also observed to be better with respect to water absorption values as compared to blocks without GS. Further, the blocks have performed well when subjected to 12 cycles of alternate wetting and drying at two ageing periods indicating that they are quite durable. Thus the blocks prepared with GS can be rated as very good quality masonry units suitable for any load bearing masonry structures. The results from this study are quite encouraging, indicating that it is possible to utilize granite sludge in the large scale manufacture of blocks, and thereby promote sustainability. As a continuation to this work, many more research works taken up to utilize granite sludge in preparing various types of CSEBs (both solid and hollow) and paver blocks, have shown distinctive advantages of using granite sludge in preparation of alternate building blocks. More importantly it would address the problem of disposal of huge quantities of granite sludge, the unscientific disposal of which has been a serious environmental hazard. Sustainable recycling of granite sludge by its application in the construction industry would also lead to a cleaner environment that society desires.

Acknowledgements

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Conflict of interest

There is no conflict of interest whatsoever from the direct application of this research.

References

1. Satish Kumar MR, Kadhirvelan B, Sudhir Kumar MR. *Utilisation of granite industry waste as a low cost building material*. Journal of the Institution of Engineers. India. *Civil Engineering Division*. 1997;78(5):27–28.
2. El Haggar S. Sustainable Industrial Design and Waste Management: Cradle– to– Cradle for Sustainable Development. *Elsevier Academic Press*. 2007;10:346–350.
3. APTDC (2008–2009). *Annual report of Andhra Pradesh Technology Development & Promotion Centre*, Hyderabad, India.
4. Torres P, Fernandes HR, Olhero S, et al. Incorporation of wastes from granite rock cutting and polishing industries to produce roof tiles. *Journal of the European Ceramic Society*. 2009;29(1):23–30.

5. Shirazi EK. Reusing of stone waste in various industrial activities. 2nd Int. Conf. on Env. Sc. and Dev. *IPCBEE*. 2011;l(4):217–219.
6. Torres P, Fernandes HR, Agathopoulos S. Incorporation of granite cutting sludge in industrial porcelain tile formulations. *J of the European Ceramic Soc*. 2004;24(10–11):3177–3185.
7. Segadães AM, Carvalho MA, Acchar W. Using marble and granite rejects to enhance the processing of clay products. *Applied Clay Science*. 2005;30(1):42–52.
8. Alzboon KK, Mahasneh KN. Effect of using stone cutting waste on the compression strength and slump characteristics of concrete. *International Journal of Environmental Science and Engineering*. 2009;1(4):167–172.
9. Hojamberdiev M, Eminov A, Xu Y. Utilization of muscovite granite waste in the manufacture of ceramic tiles. *Ceramics International*. 2011;37(3):871–876.
10. Almeida N, Branco F, de Brito J. et al. High– performance concrete with recycled stone slurry. *Cement and Concrete Research*. 2007a;37(2):210–220.
11. Almeida N, Branco F, Santos JR. Recycling of stone slurry in industrial activities: Application to concrete mixtures. *Building and Environment.* 2007b;42(2):810–819.
12. Hamza RA, El– Haggar S, Khedr S. Marble and granite waste: characterization and utilization in concrete bricks. *International Journal of Bioscience, Biochemistry and Bioinformatics.* 2011;1(4):286.
13. Weng CH, Lin DF, Chiang PC. Utilization of sludge as brick materials. *Advances in environmental research*. 2003;7(3):679–685.
14. Menezes RR, Ferreira HS, Neves GA, et al. Use of granite sawing wastes in the production of ceramic bricks and tiles. *Journal of the European Ceramic Society*. 2005;25(7):1149–1158.
15. Dhanapandian S, Gnanavel B. An investigation on the effect of incorporation of granite and marble wastes in the production of bricks. *ARPN J Eng Appl Sci*. 2009;4(9):46–50.
16. Dhanapandian S, Gnanavel B. Using granite and marble sawing power wastes in the production of bricks: spectroscopic and mechanical analysis. *Research Journal of Applied Sciences, Engineering and Technology*. 2010;2(1):73–86.
17. Aukour FJ. Incorporation of marble sludge in industrial building eco–blocks or cement bricks formulation. *Jordan Journal of Civil Engineering*. 2009;3(1):58–65.
18. Demirel B. The effect of the using waste marble dust as fine sand on the mechanical properties of the concrete. *International journal of physical sciences*. 2010;5(9):1372–1380.
19. Marras G, Siotto G, Parra JL. *Potential applications of waste material deriving from marble processing plants*. In Proceedings of 7th international marble and natural stones congress of Turkey (Mersem VII), 2010;14–15.
20. Nagaraj HB, Sravan MV, Arun TG, et al. Role of lime with cement in long– term strength of Compressed Stabilized Earth Blocks. *International Journal of Sustainable Built Environment*. 2014;3(1):54–61.
21. Nagaraj HB, Rajesh A, Sravan MV. Influence of soil gradation, proportion and combination of admixtures on the properties and durability of CSEBs. *Construction and Building Materials*. 2016;110:135–144.
22. Ribeiroa SV, Holandaa JNF. Soil– Cement Bricks Incorporated with Granite Cutting Sludge. *International Journal of Engineering Science and Innovative Technology (IJESIT)*. 2014;3(2).
23. Rajgor M, Pitroda J. Stone sludge: Economical solution for manufacturing of bricks. *International Journal of Innovative Technology and Exploring Engineering (IJITEE*). 2013;2:16–20.
24. Shabarinath N, Virendra Kumara KN, Anadinni SB. Experimental study on Granite sludge blocks. *International Journal of Information and futuristic Research*. 2015;2(10):3773–3781.
25. BMS College of Engineering. *2012–Indian Patent No. 576/CHE/2012–Compositions for Compressed Stabilized Earth Blocks (CSEBs), Methods therefor, and CSEBs Therefrom*, India.
26. SP–36 (Part1)–1987. Compendium of Indian Standards on Soil Engineering: Lab Testing of soils for Civil Engineering purposes. Bureau of Indian Standards, India.
27. IS:12269–1987. *Specification for 53 Grade Ordinary Portland Cement*. Bureau of Indian Standards New Delhi, India.
28. Jagadish KS, Venkataramana Reddy BV, Nanjunda Rao K. *Alternative Building Materials and Technologies*. New Age International, India; 2007.
29. Sravan MV, Nagaraj HB. *Effectiveness of Lime as a Stabilizer along with Cement in CSEBs*. 4th Indian Young Geotechnical Engineers Conference. 2013;51–55.
30. IS: 3495 (Part 1)–1976. *Methods of Tests of Burnt Clay Building Bricks–Determination of Compressive Strength*. Bureau of Indian Standards, New Delhi, India.
31. IS: 1077–1992 (Reaffirmed 2005). *Common Burnt Clay Building Bricks–specification*. Bureau of Indian Standards, New Delhi, India.
32. IS: 1725– 1982. *Specification for soil based blocks used in general building construction*. Bureau of Indian Standards, New Delhi, India.
33. Al–Zboon K, Tahat M, Abu–Hamatteh ZS, et al. Recycling of stone cutting sludge in formulations of bricks and terrazzo tiles. *Waste Manag Res*. 2010;28(6):568–574.
34. Salah M. El– Haggar. Industrial solid wastes utilization and disposal.In: Nemerow NL, editor. Environmental Health and Safety for Municipal Infrastructure, Land Use and Planning, and Industry, John Wiley & Sons, New York. *Environmental Engineering.* 2009.