

A STUDY ON CONCRETE CONTAINING THE SANDSTONE SLURRY AND FLY ASH PARTIALLY REPLACED WITH SAND AND CEMENT

Leevesh Kumar^{1,*}, Sitesh Kumar Singh², Woyesa Ararsa¹, Dumesa Gudissa¹, and Jifara Chimdi¹

Received: September 17, 2021; Revised: June 16, 2023; Accepted: June 20, 2023

Abstract

Now a day's the waste is produced in immense amounts during construction and coal burning, this study mainly focused on the utilization of sandstone slurry produced during sandstone cutting and Class-F fly ash produced by coal-burning. In this study a deep analysis is taken after 28 days' testing, six concrete mixes were prepared one is conventional as M₂₀, and trial mix batches are a total of five, three specimens were taken from each concrete mix separately to determine the engineering properties of the prepared specimen. Fly ash partly replaced with the cement in % of 5%, 10%, 15%, 20%, 25% and Sandstone slurry partially replaced with sand in % of 10%, 20%, 30%, 40%, 50%. Water cement ration took. 4-7%, after 28 days specimens were tested of water curing at ± 2 , 27°C. Sulfate bath is prepared for durability test with 5% Na₂SO₄ and prepared specimen left for 28 days curing in prepared sulfate bath after completion of 28 days' normal water curing, the specimen was tested after 56 day curing, acidic nature was maintained for prepared bath, on daily basis pH value has been noted if found more than 6.9 pH than sulphuric acid is added to keep the acidic nature of prepared bath. Only 5% FA and 10% SSS specimen show strength increment up to 14.477% and after sulfate bath, no change was found in specimen's volume. In compressive strength maximum strength increased up to 19.39%, from 5% FA and 10% SSS replacement. In splitting tensile strength maximum strength increased 11.37% with 10% FA and 20% SSS. In Flexural strength, no increment was noticed.

Keywords: Compressive strength; Durability Properties; Flexural Strength; Fly Ash; Sand Stone Slurry; Sulfate bath etc.

¹ School of Civil and Environmental Engineering, Ambo University, Ambo - 19, Ethiopia, E-mail: leevesh.amou@gmail.com; wfekensa@yahoo.com, dumesagudissa@gmail.com, and jifarachimdi@gmail.com

² Department of Civil Engineering, Wollega University, Nekemte - 395, Ethiopia, E-mail: Siteshlp@gmail.com

* Corresponding Author

DOI: <https://doi.org/10.55766/sujst-2023-04-e0927>

Suranaree J. Sci. Technol. 30(4):010242(1-8)

Introduction

At present time, concrete doesn't need any introduction, globally, it is a very important material used in construction. Wherever development is required concrete is the first material which is mainly required, due to the excess use of concrete raw material sources cause of depletion. So now a day this is a major concern and an interesting area for industries and young researchers to find and give new alternatives for concrete-making materials. In the past eras, many researchers find suitable alternatives to silica fume, marble dust, fly ash, rice husk ash, coffee husk ash, etc. but still, research is going on, to utilize the waste materials as an alternative in concrete production, so the current study focused on the utilization of sandstone slurry (SSS) and Fly ash (FA) in concrete production because this both products are waste in nature. Presently FA and SSS have been utilized in cement production and as a filler material in road pavement construction. This study mainly focused on the effect on the engineering properties of concrete with partial replacement of cement and sand by (FA) and (SSS) in incremental replacement within five different trial batches (TB). TB-1 contains 5% FA and 10% SSS, TB-2 contains 10% FA and 20 % SSS, TB-3 contains 15 % FA and 30 % SSS, TB-4 contains 20% FA and 40% SSS, and TB-5 contains 25% FA and 50% SSS. To assess the engineering properties of the prepared specimen compressive strength test, splitting tensile strength test, and flexural strength test conducted as per Indian standard 516: 1969, and the durability of concrete cubes found by sulfate bath (Quadir *et al.*, 2016).

In concrete major components are cement, sand, and aggregate, now a day it's very difficult to find easily by natural resources. All components are manufactured artificially in different places like cement manufactured in industries, big plants, sand, and aggregate will have extracted from different quarries and crushed in the required size. To fulfill the requirement of concrete materials young researchers are finding alternatives for these materials and research on waste utilization in concrete like silica fume (SF) replacing glass fume (GF) in high-performance concrete (HPC) which shows positive effects, at an early age it increases the compressive strength due to nucleation effect and hydration process activated by alkali contents. Also, no change be located in the compressive strength of prepared concrete specimens containing GF and SF after 91 days of curing. However, at a later stage, the pozzolanic reaction and the alkali reaction of GF influence the durability properties of HPC (Harbec *et al.*, 2017).

On the usage of industrial waste including granite and marble waste vast research has been carried out over the past several decades and found as an alternative material for fine aggregate (Binici, *et al.*, 2008; Topcu, *et al.*, 2009; Kala and Partheeban, 2010; Hebhou, *et al.*, 2011; Uysal, *et al.*, 2012; Vijayalakshmi, *et al.*, 2013), tire waste, palm oil ash (Tangchirapat *et al.*, 2007), timber waste (Elinwa and Mahmood, 2002), and marine sand (Limeira *et al.*, 2011). The research outcomes suggested that the concrete structural properties and sustainable concrete development can improve by the replacement of industrial waste as an alternative material in concrete making. Foundry sand (FS) is high in silica content sand material (Siddique and Noumowe, 2008). In foundries, for the material molding and casting process superior silica sands are used bonded with clay or chemicals. Foundries reprocess the sand up to when the sand is no longer reprocessed, then it is predisposed of, this is named FS (Siddique *et al.*, 2009; Vefago and Avellaneda, 2013; Prabhu, *et al.*, 2015). Million tons of FS have been disposed of by foundry industries, in casting production only about 15% of the sand is utilized. In India, many environmental problems occur due to dumping waste in nearby vacant areas by the foundry industries. In Coimbatore, Tamil Nadu, India, many housing zones are established over landfills, which are composed of FS from ferrous and nonferrous industries. Due to the embodied energy in FS, it will create soil contamination so using FS as a landfill is not suggested (Prabhu, *et al.*, 2015).

The practice of the utilization of FA and SSS waste materials has not been carried out together in concrete making. So, in this study initiative has been taken by the researcher to utilize the waste material FA and SSS in concrete together as a partial replacement of Cement and Sand. Also determining the influence of dosage of FA and SSS on concrete engineering properties after 28 days and 56 days of curing on the prepared concrete specimen as per Indian Standard.

Materials and Methods

The ingredients used in the current study for the preparation of test specimens are shown in the picture below Figure 1, and the chemical composition is shown in Table 1. (Kumar *et al.* 2021)



Figure 1. Shows material used in this study

Cement

In the current study, the specification of Ordinary Portland Cement (OPC) 43 grade was taken as per IS 8112: 2013. Before using the cement for the quality assurance basic test has been carried out and the results are in Table 2, below. The procedure for the testing on the cement sample followed by IS-4031 (Part-II, III, IV, V) 1988.

Sand: River sand is sieved through standard sieves (maximum sieve size 4.75mm and minimum sieve size 300 μ) to remove any particles greater than 4.75mm and smaller than 300 μ . The physical properties of the river sand used in the present study are examined and given in Table 3. The sand was sieved through a set of sieves to obtain sieve analysis and the same is presented in Table 4, Figure 1, shows the sand used in this study. The specification and procedure for testing on sand samples followed by IS 383-1970, 2386 (Part I)-1963.

Aggregate: The aggregates which are retained on a 4.75mm sieve are named as coarse aggregate (CA) as per IS: 383- 1970. In this study, maximum of 20mm size aggregate was used. The aggregate was stored in a shaded area and used in dry conditions. The aggregates were tested as per IS: 2386 (Part III) 1963. The test results of CA are shown in Table 5 and Table 6 shows the sieve analysis results. Figure 1, shows the aggregate used in the present study.

Fly Ash: Class-F Fly ash (FA) was used in the current work, it was collected from a precipitator. The percentage of FA in six different concrete mixes is, in the conventional mix 0%, in other five mixes range is 5%, 10%,15%, 20%, and 25%. Figure 1, shows the FA used in the present study.

Sandstone slurry: The Paste of the slurry was collected from the cutting plant and left in the open air until it went dry. Then sieved through the standard sieve (maximum sieve size 4.75 mm and minimum sieve size 300 microns). The Slurry collection was very careful at the collection location no external substances will be mixed with the slurry.

Table 1. Chemical Composition of Cement, Fly ash, Sandstone

Composition	Portland Cement %	Fly Ash %	Sand Stone %
SiO ₂	21.82	53.39	93-94
Al ₂ O ₃	6.49	16.07	1.4-1.5
Fe ₂ O ₃	1.93	13.05	1.5-1.6
CaO	60.74	6.33	0.8-0.9
MgO	1.08	5.48	0.2-0.25
SO ₃	2.62	1.06	-
Na ₂ O	0.14	1.59	1.0-1.2
Free CaO	0.84	0.11	-

Table 2. Shows test conducted on Ordinary Portland Cement

S.N	Characteristics	Obt. Value	IS8112 :2013
1	Consistency %	28.2	-
2	Initial Setting time (min)	126	>30 min
3	Final Setting time (min)	190	<600 min
4	Fineness (m ² /kg)	286.3	>225m ² /kg
5	Specific gravity	3.51	-

Table 3. Shows physical properties of sand

S.N.	Properties	Results
1	Specific Gravity	2.567
2	Bulk Density	1.48 g/cc
3	Fineness Modulus	2.465
4	Water Absorption	1.914%
5	Grading Zone	II
6	Silt Content	Below 3%

Table 4. Shows gradation of sand

Sieve Size (mm)	Retained Avg.	% Retained	Zone II	Cam. %
10	15.66	1.57	98.43	1.57
4.75	29.33	2.93	95.47	4.53
2.36	70.33	7.03	88.47	11.53
1.18	143.33	14.33	74.14	25.86
600 μ	210.66	21.07	53.07	46.93
300 μ	418.66	41.87	11.2	88.8
150 μ	85	8.50	2.7	97.3
75 μ	24	2.40	.3	99.7
Pan	0	0	0	100

Table 5. Shows physical properties of Aggregate (20mm sieve passing)

S.N.	Properties	Results
1	Type	Crushed
2	Specific Gravity	2.66
3	Fineness Modulus	6.83
4	Water Absorption	0.56
5	Grading Zone	Single-graded 20 mm

Table 6. Gradation of aggregate

Sieve Size (mm)	Retained Avg.	% Retained	Zone II	Cam. %
20	36.33	1.82	98.18	1.82
16	217.33	10.87	87.31	12.69
12.5	251	12.55	74.76	25.24
10	744	37.2	37.56	62.44
4.75	745.33	37.26	0.3	99.7
Pan	6	0.3	0	100

Table 7. Shows slump value and w/c ratio of concrete freshly mixed

	Conventional	TB1	TB2	TB3	TB4	TB5
Slump Value	47	47	48	46	44	42
w/c %	0.4	0.5	0.55	0.6	0.7	0.7

Table 8. Shows compressive strength tests N/MM²

Conventional	TB1	TB2	TB3	TB4	TB5
28.66	34.22	30.22	23.33	21.11	16

Table 9. Shows flexural strength tests Kg/Cm²

Conventional	TB1	TB2	TB3	TB4	TB5
918.36	867.34	790.81	739.79	663.26	484.69

All the concrete mixes were prepared after replacing sand with 10%, 20%, 30%, 40%, and 50% sandstone slurry except conventional. Figure 1 shows the sandstone slurry used in the current work.

Methodology

In General, preparing the concrete specimen for the required test and testing will be followed by the Indian standards. For the quality insurance of collected material, the specimen casting will be highly taken into the measure. All apparatus and equipment used in this current study are as per Indian Standards.

Mix Proportion and Curing: In this study, six different M20 (1:1.5:3) grade concrete mix was prepared in which one is conventional M20 and the other five were trial mix with partial replacement of cement by fly ash and sand by sandstone slurry by weight percentage of 5%-25% and 10%-50% FA, SSS respectively. For each mix, three specimens were prepared and tested after 28 days of curing at the temperature of 27°C, ± 2 of water and for durability test, sulfate bath was prepared with 5% Na₂SO₄ of required water to submerge the prepared specimen after that specimen was left for another 28 days curing in sulfate bath. After observing the pH value every day of the prepared bath sulphuric acid was added to maintain the acidic nature of the prepared sulfate bath.

Test Setup: In the present study to evaluate the engineering properties the specimen size was used for Compressive strength 15×15×15 cm³ cube, for split tensile strength 15 cm dia. × 30 cm height cylindrical, for flexural strength 10×10×50 cm beam was tested. For durability 15×15×15 cm³ cube were prepared and cured in sulfate bath for another 28 days curing and tested after 56 days curing. The specimen preparation for compressive and flexural strength test according to IS: 516-1959 and split tensile strength according to IS: 5816-1999. The

durability test has been carried out by (Quadir *et al.*, 2016).

Experimental Investigation

Fresh Concrete Properties: In respect to carried out the workability test of prepared fresh concrete slump cone test has been used as per IS 1199-1959. The required water-cement ratio and slump value has been shown in Table 7 below. Water quantity is taken by the weight of cement. Trial Batch represented by TB in tables.

Compressive Strength: A compressive strength test has been carried out on prepared six batches, different specimens after 28 days of curing as per IS 516-1959. Compressive strength has been calculated after dividing the maximum load applied to the failure of the specimen during the test by the measured cross-sectional area of the specimen. The result of each concrete batch specimen strength variation has been shown in Table 8 below.

Flexural Strength: Flexural strength is the ability of a slab or beam to resist failure in bending. The Flexural strength test has been carried out by loading the unreinforced 10 × 10 × 50 cm concrete beam for aggregate size less than 20 mm after 28 days of curing as per IS: 516-1959. It is also expressed as the Modulus of rupture in N/MM². The result of six concrete batch specimen's strength variations has been shown in Table 9 below. The Flexural strength of the prepared specimen is determined by the following formula:

$$f_b = Pl/bd^2$$

Where P = load applied (kg).
b = width of specimen (cm).
d = measured depth of specimen at the place of failure (cm).
l = length of specimen (cm).

We are using this formula because the failure in the section occurs not greater than 13.3 distances from the nearest support for a 10 cm specimen. The distance between nearest support and failure is denoted by 'a'.

Split Tensile Strength: Split tensile strength is one of the most important properties of the concrete, it is required to design the structural elements, it can be determined by the cylindrical specimen which split across the vertical diameter. Its value is also used in the design of roadways and runway slabs, pre-stressed concrete structures, and liquid retaining structures. Direct tensile strength is difficult to determine. In this, study we are using an indirect tensile strength test on the prepared

specimens from six different batches as per IS 5816-1999. The result of six concrete batch specimen's strength variations has been shown in Table 10 below.

The measured split tensile strength f_{ct} of the specimen was calculated to the nearest 0.05 N/MM² using the following expression:

$$f_{ct} = 2P / \pi ld$$

Where, P = load applied to the specimen (N)
l = specimen length (mm)
d = cross sectional area of the specimen

Table 10. Shows split tensile strength tests N/MM²

Conventional	TB1	TB2	TB3	TB4	TB5
3.11	3.21	3.46	2.97	2.33	1.98

Sulfate Test: The Durability of preparing six batches of concrete was tested by compressive strength test after 56-day curing, test was performed after 28 days of normal water curing after that a sulfate bath was prepared with 5% Na₂SO₄ then the specimen was cured for the next 28 days of curing. Sulphuric acid was added timely to maintain the bath pH of 6.5-7. The specimen size was kept 15×15×15cm³. Six different concrete mixes were prepared. Three Specimens from each combination are prepared and tested. Test results of the cube specimen are shown in Table 11, below.

Table 11. Shows compressive strength tests N/MM²

Conventional	TB1	TB2	TB3	TB4	TB5
37.30	42.70	34.58	28.49	24.88	23.84

Results and Discussion

Fresh Concrete Properties

Workability is the most important property of newly mixed concrete its' directly affected by a water-cement ratio as we increase the water-cement ratio the concrete workability is increased but a higher w/c ratio leads to decreasing the strength of concrete due to bleeding. In this study, we are maintaining the slump approx. 40-50 mm which is good for the mass concrete lightly reinforced section in a slab, beam, wall slabs, column, floors, hand placed pavement, canal lining, strip footing, etc. It gives good workable concrete. The slump value of newly mixed concrete is shown in Table 6, from the table it is observed that the slump value remains the same as for the conventional mix for up to 5% FA and 10% SSS. The slump value was found to be increasing as we increasing the percentage of FA and SSS. Since the w/c ratio is fixed for all the

mixes. We are increasing the w/c ratio up to .7% by weight of cement to maintain the slump between 40-50mm.

Compressive strength

Only trial batch 1 and 2 shows the increment in prepared specimen strength by 19.39%, and 5.44% as compared with conventional M20 prepared concrete specimen. After that increasing % of FA and SSS in trial batches 3, 4, and 5 reduced the prepared specimen strength by 18.59%, 26.24%, and 44.173, specimen test results shown in table-7. So only trial batch-1,2 only exceed the target M20 grade strength and the other three batches show decrement. The variation in compressive strength is shown in Figure 2, with different dosages of FA and SSS.

Flexural Strength

The test result of the flexural strength specimen of trial batches-1, 2, 3, 4, and 5 shows a decrement in strength as compared with conventional concrete mix specimens by the % of

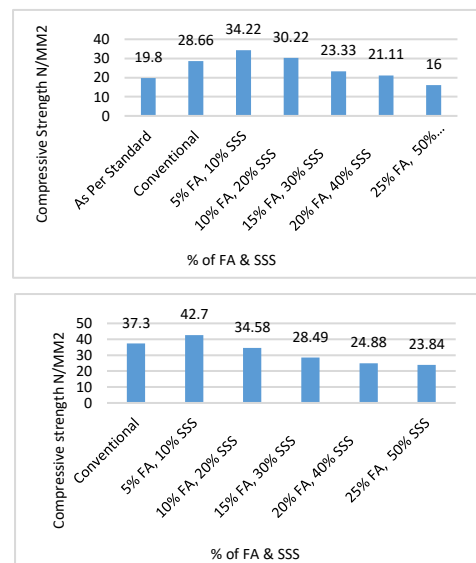


Figure 2. Shows compressive strength

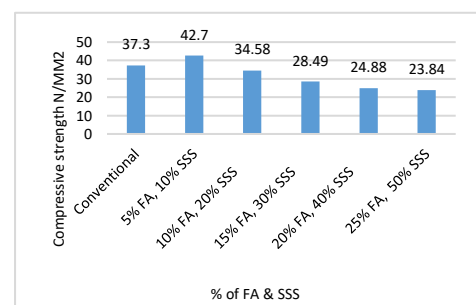


Figure 3. Shows flexural strength

5.55%, 13.88%, 19.44%, 27.73%, and 47.22% respectively. Specimen test results are shown in Table 8. The variation in flexural strength is shown in Figure 3, with different dosages of FA and SSS.

Split tensile strength

Only trial batch 1 and 2 shows the increment in prepared specimen strength by 3.27%, and 11.37% as compared with conventional M20 prepared concrete specimen. After that increasing % of FA and SSS in trial batches 3, 4, and 5 reduced the prepared specimen strength by 4.56%, 25%, and 36.37%, specimen test results shown in Table 9. So only trial batch-1,2 only exceeds the target M20 grade strength and the other three batches show decrement. The variation in compressive strength is shown in Figure 4, with different dosages of FA and SSS.

Sulfate test

Trial batch 1 shows the increment in prepared specimen strength by 14.477%, other trial batches 2, 3, 4, and 5 shows the decrement in strength by 7.292%, 23.61%, 33.29%, 36.08% respectively as compared with conventional concrete specimen after testing. Specimen test results are shown in Table 9. After Sulfate bath curing of 28 days on the prepared specimen, no change has been noticed in specimen volume. The variation in compressive strength is shown in Figure 5, with different dosages of FA and SSS. The variation in compressive strength is shown in Figure 5, with different dosages of FA and SSS. Figure 5 (a, b, c, d, and e.) shows the fracture pattern of the tested specimen.

SEM and XRD

The material of the structure can be analysed by Scanning electron microscopy (SEM). The SEM analysis is characterized with easy preparation of samples, variety of accessible knowledge, good resolution about the high depth of field and ever-expanding. The crystal structure can be analysed by X-ray diffraction method Temiz and Karakeci, (2002). We know that with proper percentage of fly ash can increased the mechanical properties. Fly ash shows pozzolanic properties by reacting with Ca(OH)_2 which is a Portland cement hydration product. FA increases the CH as compared to Portland cement. JSM5600 scanning electron microscope (SEM) with 30kV has been used in this study The X-Ray diffraction method shows that the amount of hydration products vary with different ages. This method also shows the existence of mineral compounds that contribute to an increase and development of hydration products. The result of the specimen analysed with SEM and XRD shown in Figure 6 (a, b, c, d, and e) (Uzbas *et al.*,

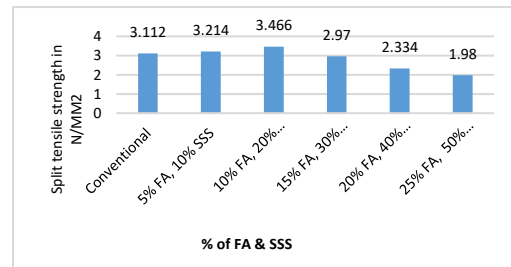


Figure 4. Shows split tensile strength



Figure 5. Shows flexural strength

2019). The XRD analysis of sandstone reveals that significant amount of silica in sandstones. The result of XRD and SEM analysis shows that Si, Al, and Fe are the main components Figure 6 (f and g) shows the analysis results (Mukuna, 2013).

Conclusions

Based on the result of all prepared trial mix batches and conventional mix batch specimen testing the following conclusion can be drawn:

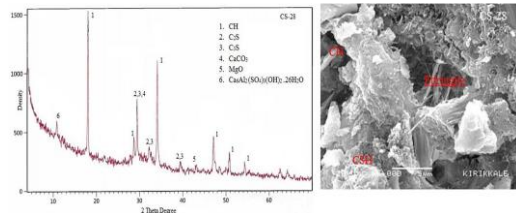
The key finding of this research is that 5 % FA and 10% SSS can be replaced with cement and sand, the concrete made with this replacement percentage shows good mechanical and durability properties as compared with conventional concrete. The FA and SSS chemical composition and particle size have maximum similarity with cement and sand. It will produce denser concrete and improve its sulfate

resistance and corrosion. After observing the fracture pattern of the specimen, it shows a more brittle nature with increasing the dosage of FA and SSS. Concrete preparation with FA and SSS shows higher water demand.

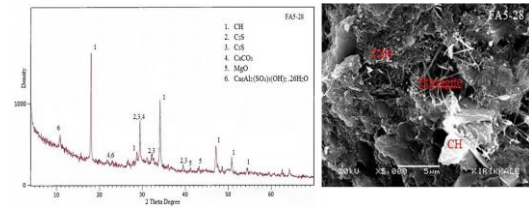
In sustainable development, the contribution is possible with the dosage of 5% FA and 10% SSS replaced with cement and sand in concrete, It also

conserves the natural resources and improves the properties of the concrete component. It will also help in the economic production of cement and reduce carbon footprint during production.

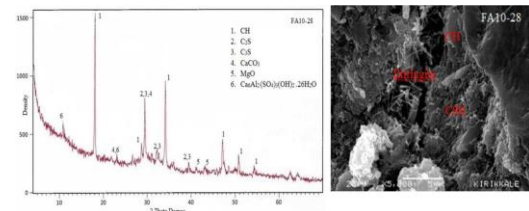
In XRD and SEM analyses portlandite peaks observed decreased after hydration increased. The $\text{Ca}(\text{OH})_2$ increased by fly ash addition which results in cement hydration and leads the increase in C-S-H



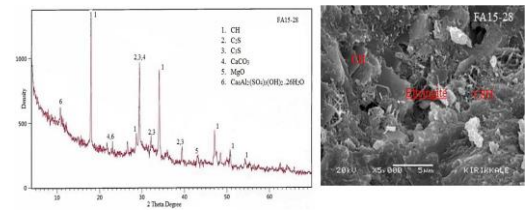
(a) Shows CH (Portlandite), C-S-H gels and large as of ettringite are seen in the analysis of the CS sample. A found gap is larger than the other trial mix prepared.



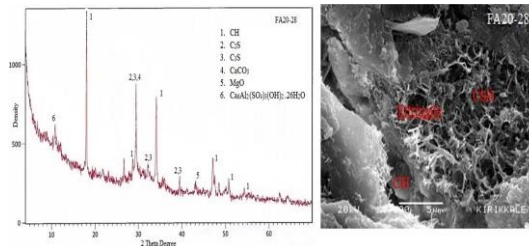
(b) Shows CH (Portlandite), C-S-H gels and ettringite are seen in analysis of TB1 sample. Gap between particle is similar with CS.



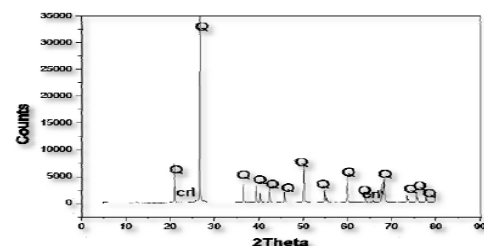
(c) Shows CH (Portlandite), C-S-H gels and ettringite are seen in the analysis of the TB2 sample. gaps decrease and denser structure is obtained.



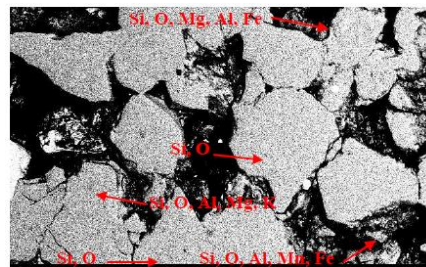
(d) Shows CH (Portlandite), C-S-H gels and a small amount of ettringite are seen in the analysis of the TB3 sample. It can be seen that the gaps between phases are lesser.



(e) Shows CH (Portlandit), C-S-H gels and a small amount of ettringite are seen in the analysis of the TB4 sample. it can be seen that the gaps between phases are lesser and a small .



(f) XRD sandstone graph showing the identified minerals (Q= Quartz, crl= Crysobilite).



(g) SEM combined with EDS micrograph of the sandstone showing the surface morphology and the chemical composition

Figure 6. SEM and XRD analysis

and density increased by 33.99% Therefore, using 10% fly ash instead of cement in situations that do not require early age resistance will provide many advantages over unplasticized concrete. The XRD diffractograms confirmed that the sandstones are quartz-based minerals along with traces of Kaolinite, Illite, and Albite. Optical microscopy analyses revealed that the sandstones had grain sizes ranging from fine to coarse grains size. The result shows Silicon as the highest chemical element in the sandstones.

References

- Binici, H., Shah, T., Aksogan, O., and Kaplan, H. (2008). Durability of concrete made with granite and marble as recycle aggregates. *Journal of Materials Processing Technology*, 208(1-3):299-308. <https://doi.org/10.1016/j.jmatprotec.2007.12.120>
- Elinwa, A.U., and Mahmood, Y.A. (2002). Ash from timber waste as cement replacement material. *Cement and Concrete Composites*, 24(2):219-222. [https://doi.org/10.1016/S0958-9465\(01\)00039-7](https://doi.org/10.1016/S0958-9465(01)00039-7)
- Harbec, D., Zidol, A., Hamou, A.T., and Gitzhofer, F. (2017). Mechanical and durability properties of high-performance GF concrete and mortar. *Construction and Building Material*, 134:142-156. <https://doi.org/10.1016/j.conbuildmat.2016.12.018>
- Hebhoub, H., Aoun, H., Belachia, M., Houari, H., and Ghorbel, E. (2011). Use of waste marble aggregates in concrete. *Construction and Building Materials*, 25(3):1,167-1,171. <https://doi.org/10.1016/j.conbuildmat.2010.09.037>
- IS 1199-1959 methods of sampling and analysis of concrete.
- IS 2386 (Part-I)-1963 fine aggregate particle size and shape.
- IS 2386 (Part-III)-1963 Methods of test for aggregate for concrete.
- IS 383-1970 Specification for fine and coarse aggregate from natural sources for concrete.
- IS 4031-1988 (Part- II, III, IV, V) Consistency, Setting time, Fineness, Specific gravity test for cement.
- IS 516-1959 methods of test for the strength of concrete.
- IS 5816-1999 splitting tensile strength of concrete method of test.
- IS 8112-2013 Ordinary Portland Cement 43 Grade- specification.
- Kala, F., and Partheeban, P. (2010). Granite powder concrete. *Indian Journal of Science and Technology*, 3(3):311-317. <https://doi.org/10.17485/ijst/2010/v3i3.6>
- Kumar, L., Thanappan, S., Mekonnen, E., Mulugeta, D. and Chala, G. (2021). Effect of fly ash and sandstone slurry on mechanical properties of concrete materials. *Materials today proceedings*, 45(2):2,878-2,882. <https://doi.org/10.1016/j.matpr.2020.11.856>
- Limeira, J., Etxeberria, M., Agullo, L., and Molina, D. (2011). Mechanical and durability properties of concrete made with dredged marine sand. *Construction and Building Materials*, 25(11):4,165-4,174. <https://doi.org/10.1016/j.conbuildmat.2011.04.053>
- Mukuna P. Mubiayi. (2013). Characterisation of sandstone: Mineralogy and Physical Properties, *Proceedings of the World Congress on Engineering*; July 3-5, 2013; London, U.K. Vol. 3.
- Prabhu, G.G., Bang, J.M., Lee, B.J., Hyun, J.H. and Kim, Y.Y. (2015). Mechanical and Durability Properties of Concrete Made with Used Foundry Sand as Fine Aggregate. *Advance in Material Science Engineering*, 2015(ID161753):11. <https://doi.org/10.1155/2015/161753>
- Quadir, U.M., Islam, K., Billah, A.H.M.M., and Alam, M.S. (2016). Mechanical and durability properties of concrete using recycled granulated steel. *Concrete and Building Materials*, 123:174-183. <https://doi.org/10.1016/j.conbuildmat.2016.06.139>
- Siddique, R. and Noumowe, A. (2008). Utilization of spent foundry sand in controlled low-strength materials and concrete. *Resources, Conservation and Recycling*, 53(1-2):27-35. <https://doi.org/10.1016/j.resconrec.2008.09.007>
- Siddique, R., Schutter, G.D., and Noumowe, A. (2009). Effect of used foundry sand on the mechanical properties of concrete. *Construction and Building Materials*, 23(2):976-980. <https://doi.org/10.1016/j.conbuildmat.2008.05.005>
- Tangchirapat, W., Saeting, T., Jaturapitakkul, C., Kiattikomol, K., and Siripanichgorn, A. (2007). Use of waste ash from palm oil industry in concrete. *Waste Management*, 27(1):81-88. <https://doi.org/10.1016/j.wasman.2005.12.014>
- Temiz H., and Karakeçi, A.Y. (2002). An investigation on microstructure of cement paste containing fly ash and silica fume. *Cement and Concrete Research*, 32(7):1,131-1,132. [https://doi.org/10.1016/S0008-8846\(02\)00749-4](https://doi.org/10.1016/S0008-8846(02)00749-4)
- Topcu, I.B., Bilir, T., and Uygunoglu, T. (2009). Effect of waste marble dust content as filler on properties of self-compacting concrete. *Construction and Building Materials*, 23(5):1,947-1,953. <https://doi.org/10.1016/j.conbuildmat.2008.09.007>
- Uysal, M., Yilmaz, K., and Ipek, M. (2012). The effect of mineral admixtures on mechanical properties, chloride ion permeability and impermeability of self-compacting concrete. *Construction and Building Materials*, 27(1):263-270. <https://doi.org/10.1016/j.conbuildmat.2011.07.049>
- Uzbas, B., and Aydin, A.C. (2019). Analysis of Fly Ash Concrete with Scanning Electron Microscopy and X-ray diffraction. *Advances in Science and Technology Research Journal*, 13(4):100-110. <https://doi.org/10.12913/22998624/114178>
- Vefago, L.H.M., and Avellaneda, J. (2013). Recycling concepts and the index of recyclability for building materials. *Resources, Conservation and Recycling*, 72(127):135. <https://doi.org/10.1016/j.resconrec.2012.12.015>
- Vijayalakshmi, M., Sekar, A.S.S., and Prabhu, G.G. (2013). Strength and durability properties of concrete made with granite industry waste. *Construction and Building Materials*, 46:1-7. <https://doi.org/10.1016/j.conbuildmat.2013.04.018>