



An Experimental Study on Polymer Impregnated Concrete with GGBS.

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Article History: Received: 03.11.2022

Revised: 15.12.2022

Accepted: 1.01.2023

Abstract

Ground granulated blast-furnace slag, commonly known as GGBS, is a material that possesses characteristics akin to cement. It is a substance that is derived as a by-product from the blast furnaces used to produce iron. GGBS is used widely to enhance the quality of concrete by increasing strength, improving durability, providing resistance to sulfate and chloride attacks. In this exploratory research, 20% of the total cement for three grades of concrete, namely, M20, M40 and M60 are replaced with GGBS. The moulds used for this research are cube, beam and cylinder. They are cast in the moulds, allowed to sit for 24 hours and then removed. The concrete specimens are then cured for 7 and 28 days. Furthermore, after the completion of curing, they are made to undergo partial polymer impregnation of concrete. The polymer used for this process is polyester and styrene. Upon the completion of polymer impregnation, the cast moulds are tested for their compressive strength, flexural strength and split tensile strength. The results are then compared with conventional concrete. This research aims to study the contribution of GGBS concrete along with polymer impregnation to the strength characteristics.

Keywords: GGBS, compressive strength, flexural strength, split tensile strength, polymer impregnation.

DOI: 10.31838/ecb/2023.12.1.014

1. Introduction

Throughout history, concrete has been the most prominent material used in the construction industry. It is preferred for its strength, durability, longevity and resistance, among other characteristics. Cement constitutes a significant part of the manufacturing process of concrete. The manufacturing of cement is a tedious process that consumes an extravagant amount of resources. Due to its soaring demand in the establishment of buildings, bridges, airports, roads, structures, etc., various materials are used to substitute the cement while maintaining the performance of concrete. Different materials are used to replace cement to decrease the usage of resources and conserve energy. Ground Granulated Blast furnace Slag abbreviated as GGBS is one among the various materials used to replace cement in varying percentages [1]. This substance is obtained as a by-product from blast furnaces that are used in the process of producing iron. It has low embodied energy, is readily available and

economical. It is highly cementitious and contains calcium silicate hydrates which makes it suitable as a pozzolanic material [2]. This material also has low reactivity and can be used in combination with other pozzolanic materials to substitute or replace ordinary portland cement. In this paper GGBS is used to replace 20% of the total constituents of cement and tested for its strength characteristics.

GGBS mixed along with ordinary portland cement, aggregates and water can produce durable concrete [3]. The strength and performance of the concrete depend on the grade of concrete, type of cement used, type of aggregates, water-cement ratio and the percentage of GGBS replacing cement. Through the literature review conducted, it is deduced that GGBS contributes to the lifespan of the concrete. This property increases the durability of the structures [4]. GGBS also enhances the strength of the concrete by reducing cracking induced by the thermal reaction, providing resistance to chloride and sulphate attacks, providing higher electrical resistivity and preventing the occurrence of microcracks [5]. Due to its low embodied energy, it consumes only 20% of the resources in comparison with the resources consumed in the manufacturing process of cement. This property of GGBS makes it a sustainable and eco-friendly alternative to ordinary portland cement [6]. Commercially, GGBS replacement of cement is anywhere between 20% - 70%. Studies have shown that by replacement of up to 50% the durability of the structures and concrete can be significantly improved. Complete replacement of portland cement by GGBS mixed with aggregates and water to form concrete is known as geo-polymer concrete. The use of GGBS also contributes to a better aesthetic appeal as it is light in colour when compared with cement which enhances the reflectivity of the finished material. GGBS has finer particles than cement which occupies voids and prevents crystalline deposits from occurring on the surface of the completed structure. Due to its numerous benefits, GGBS is chosen to experiment with and tested for its strength characteristics.

In this laboratory investigation, 20% of cement is replaced by GGBS for M20, M40 and M60 grades of concrete. They have undergone curing for 7 and 28 days for the testing of compressive and split tensile strength. In the case of flexural strength, they have undergone curing for 14 and 28 days. After the completion of curing and before the testing process, the specimens are partially impregnated with the polymer polyester and styrene. After the finishing of partial impregnation, they are dried and tested for their strong results. The second section of this paper constitutes the materials used, design mix ratio and the testing process. The results follow this section, which is presented in a tabulated form. The final section of this paper is the conclusion where the inference derived from the results are shown.

2. Experiment Procedure

2.1. Procurement of Materials:

Cement:

For the carrying out of this investigation, OPC 53-grade cement is used to manufacture concrete. It is a high strength cement with numerous benefits. It has a designed strength of 28 days, being at least 53 MPa. This grade of cement is more substantial than other grades of cement and is more durable.

GGBS:

GGBS is the Ground Granulated blast furnace slag used to replace 20% of cement. This material is present in a powder form with particles more refined than that of cement. It is almost white, which results in the concrete having a lighter appearance and finish. This material enhances the durability and strength of concrete.

Table 1: Properties of GGBS

Property	GGBS
Colour	Off-White
Specific Gravity	2.9

Silica Fumes:

This is a pozzolanic material used to complete the requirement to design M60 grade of concrete as per IS code rules and regulations. For the M-60 grade of concrete 5% of cement is replaced with silica fumes apart from the 15% of cement replacement by GGBS.

Super Plasticizer:

Tech Mix – 550 is used in the M60 grade of concrete to increase the workability of the concrete. 1.5% of this chemical mixture is added along with the water-cement ratio. This superplasticizer enhances the flow of concrete, which in turn eases compaction of concrete.

Fine aggregates:

For this laboratory investigation manufactured sand (M-Sand) is used as the fine aggregate. It is easily available and preliminary tests were conducted as per IS code. The aggregates belong to Zone-III area.

Coarse aggregate:

12.5 mm size of coarse aggregate is used to carry out this investigation.

Table 2: Properties of Coarse Aggregate

Properties	Coarse Aggregate
Specific Gravity	2.7
Fineness Modulus	7.39
Water Absorption (%)	1.41

Polyester and Styrene:

In this investigation, for the partial impregnation of polymer, a combination of polyester and styrene are used to achieve results. Polyester is a violet coloured resin that has a high viscosity, to reduce its viscosity for impregnation, styrene is added. After the cubes, prism and cylinders mould are cast and hardened, they are made to undergo partial impregnation before testing. The process is done by immersing the specimens in the polymer for a minimum of 8 hours. Through partial impregnation, an impregnation of up to 5mm can be

achieved. Whereas in the case of full impregnation, an impregnation up to 15mm can be achieved.

2.2.Design Mix Ratio

Table 3: Design Mix Ratios

Grade	Mix Ratio	Replacement	Water-Cement Ratio	Admixture
M20	1:2.17:2.35	20% GGBS	0.5	-
M40	1:1.58:1.86	20% GGBS	0.4	-
M60	1:1.59:2.11	20% GGBS	0.3	5% silica fumes and 1.5% super plasticizer

The ratios are calculated as per the IS codes and presented in a tabulated form. Each grade of concrete is replaced with 20% of GGBS. In the case of M-60 grade of concrete to adhere to the IS regulations, further 5% of cement is replaced with silica fumes, and 1.5% of superplasticizer is added to the water-cement ratio. No chemical admixture is added to M20 and M40 grade of concrete.

2.3.Testing

Cubes of dimension 15cmX15cmX15cm, prism of size 50cmX10cmX10cm and cylinders of size dia-10cm and height-20 cm are used for this investigation. After the components are mixed as per the design mix ratio, they are put into the moulds and allowed to sit for a day. After the specimens are hardened, they undergo a curing process. In the case of compressive and split tensile strength, the specimens have undergone curing for 7 and 28 days. Whereas, for the determination of flexural strength, the specimens undergo curing for 14 and 28 days. After the curing process, the specimens are dried and exhibited to partial impregnation of a polymer. The specimens are immersed and soaked in a solution of polyester and styrene polymer for a minimum of 8 hours. After which, they are tested for their strength characteristics. Then, the results are tabulated and compared with conventional concrete. The conventional concrete has undergone the same curing process but has no traces of GGBS and has not undergone any polymer impregnation. The results are compared, and graphs are drawn to depict the difference in strength.

3. Results

3.1. Slump Cone test

Table 4: Slump of Concrete and GGBS

Grade of Concrete	M20	M40	M60
Slump of	51	46	77

conventional concrete (mm)			
The slump of GGBS replaced concrete.	54	50	81

The slump test is conducted to test the workability of the concrete. The approximate slump value is determined as per IS code 1199:1959. The slump cone test for all three grades of concrete M20, M40, and M60 is performed.

3.2.Compressive strength test

Table 5. Comparison of compression strength for GGBS with PIC and conventional concrete

Grade of Concrete	S.no.	Compression strength in (N/mm ²)		Average Compression strength in (N/mm ²)		Compression strength in (N/mm ²)		Average Compression strength in (N/mm ²)	
		Conventional Concrete		Conventional Concrete		GGBS with PIC		GGBS with PIC	
		7 days	28 days	7 days	28 days	7 days	28 days	7 days	28 days
M20	1	15.6	21.06	15.54	22.38	16.22	30.12	16.77	31.88
	2	15.33	22.35			16.77	31.42		
	3	15.7	23.73			17.33	34.12		
M40	1	23.24	41.24	24.5	40.73	25.76	50.14	25.45	48.97
	2	25.73	41.11			25.66	48.20		
	3	24.53	39.86			24.93	48.57		
M60	1	42.8	61.8	52.8	65.87	55.2	73.88	60.3	74.46
	2	58.93	69.9			58.83	75.15		
	3	56.93	65.93			6.87	74.36		

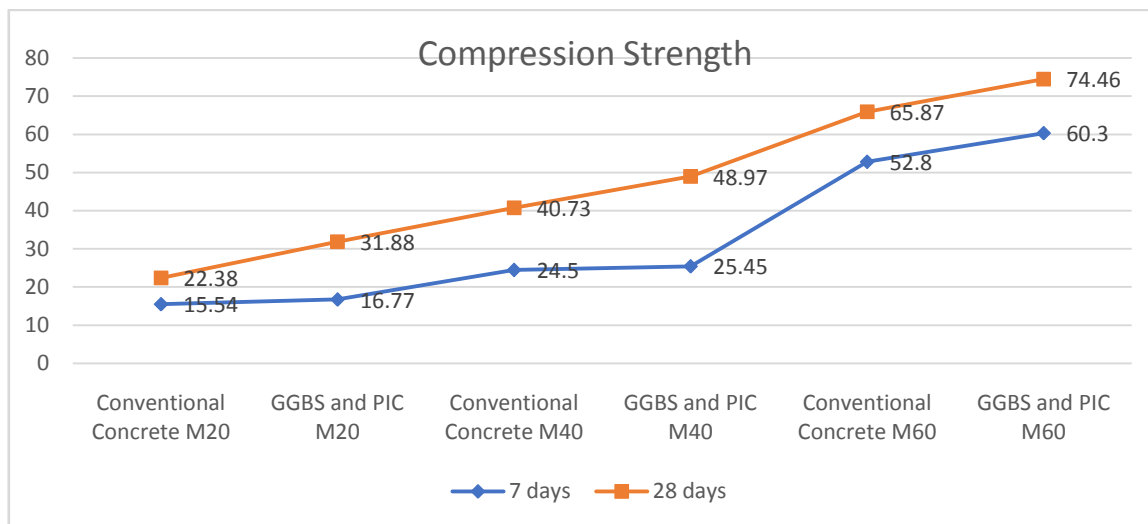


Fig.1.Graph of Conventional concrete and GGBS with Polymer Impregnated Concrete.

3.3.Flexural Strength test

Table 6. Comparison of flexural strength for GGBS with PIC and conventional concrete

Grade of Concrete	S.no.	Flexural strength in (N/mm ²)		Average Flexural strength in (N/mm ²)		Flexural strength in (N/mm ²)		Average Flexural strength in (N/mm ²)	
		Conventional concrete		Conventional Concrete		GGBS with PIC		GGBS with PIC	
		14 days	28 days	14 days	28 days	14days	28 days	14 days	28 days
M20	1	5.5	10	5.75	9.58	7.11	12.66	7.41	12.33
	2	5.75	9.25			7.25	12.12		
	3	6	9.5			7.88	12.22		
M40	1	6.25	9.25	7.41	10.5	9.76	15.22	9.73	16.30
	2	8.25	11.75			9.55	15.12		
	3	7.75	10.5			9.88	15.87		
M60	1	10	16.5	9.16	15.3	11.21	18.66	11.76	19.07
	2	8.5	14.5			12.31	19.12		
	3	9	9			11.78	19.34		

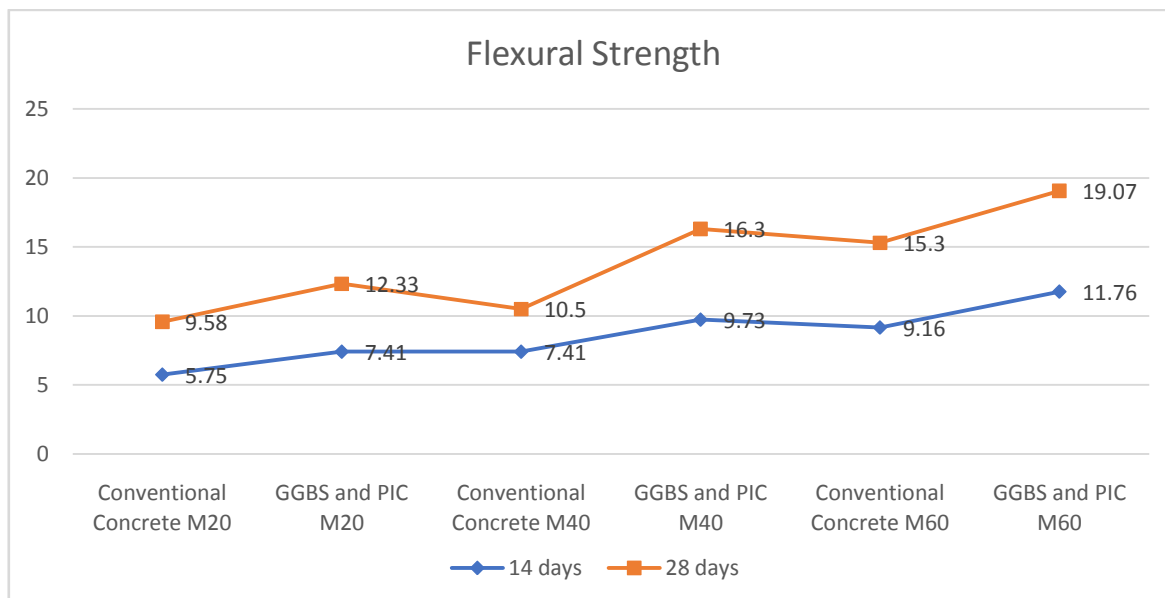


Fig.2. Graph of Conventional concrete and GGBS with Polymer Impregnated Concrete.

3.4. Split tensile strength

Table 7. Comparison of split tensile strength for GGBS with PIC and conventional concrete

Grade of Concrete	S.no.	Split tensile strength in (N/mm ²)		Average Split tensile strength in (N/mm ²)		Split tensile strength in (N/mm ²)		Average Split tensile strength in (N/mm ²)	
		Conventional Concrete		Conventional Concrete		GGBS with PIC		GGBS with PIC	
		7 days	28 days	7 days	28 days	7 days	28 days	7 days	28 days
M20	1	2.1	2.83	2.14	2.82	2.45	3.45	2.61	3.62
	2	2.26	2.73			2.77	3.66		
	3	2.07	2.9			2.62	3.76		
M40	1	2.57	4.58	2.55	4.28	3.66	4.22	3.40	4.28
	2	2.38	4.17			3.44	4.51		
	3	2.7	4.1			3.11	4.12		
M60	1	4.87	6.1	4.53	6.21	5.66	7.21	5.47	7.27
	2	4.14	6.25			5.26	7.33		
	3	4.59	6.3			5.51	7.29		

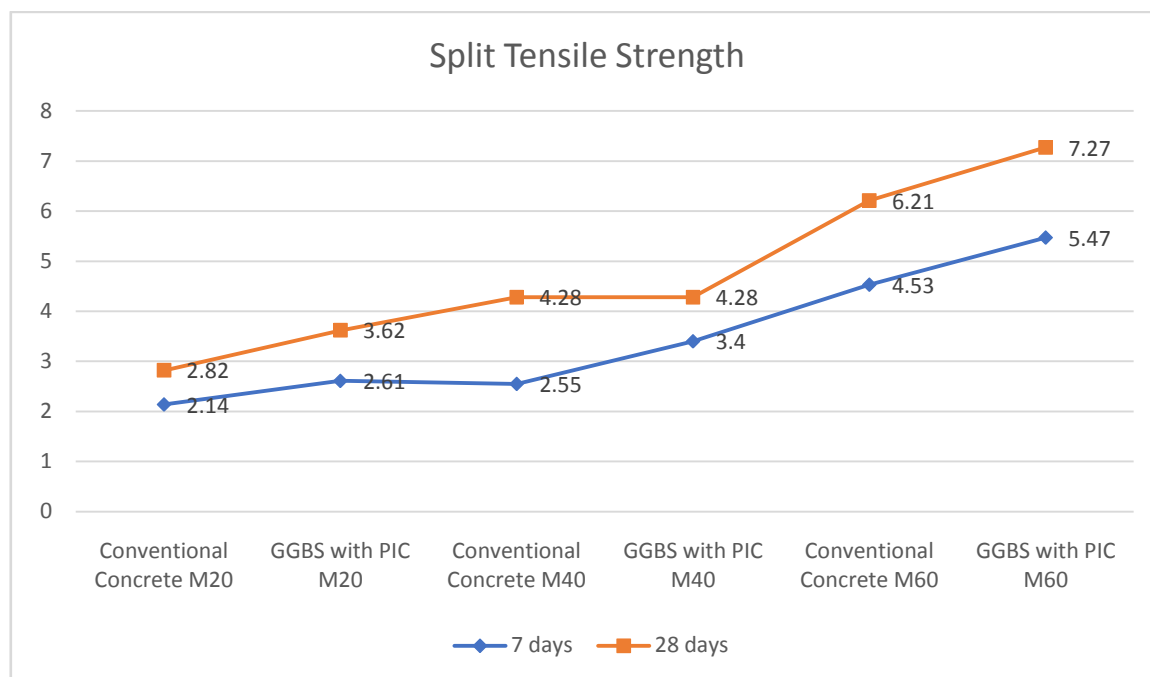


Fig.3. Graph of Conventional concrete and GGBS with Polymer Impregnated Concrete.

4. Conclusion

For this laboratory investigation, three grades, namely M20, M40 and M60, are used to conduct analysis. For each grade, 12 specimens are cast, i.e., 12 cubes, 12 prisms and 12 cylinders. The grades constitute of 6 samples of conventional concrete, out of which three are cured for seven days and the other 3 for 28 days in the case of cubes and cylinder. For prisms, three specimens are cured for 14 days, and the additional three samples are cured for 28 days. A similar curing process is followed for the other six specimens except they contain GGBS replacing 20% of the cement. After curing, they are made to undergo partial polymer impregnation with the polymers polyester and styrene. The polymer impregnation is performed by immersing the specimens in the solution for a minimum of 8 hours. After the impregnation process, they are tested for their compressive, flexural and split tensile strength. The results are tabulated, and the strength of GGBS with PIC and conventional concrete are compared.

From the strength test results obtained, we can infer that the replacement of 20% of cement by ground granulated blast furnace slag, followed by partial polymer impregnation after curing and drying process contributes significantly to increase in compressive, flexural and split tensile strength. M60 grade has achieved the highest increase in strength. This pattern is observed consistently for all the strength parameters. There is a constant increase in strength with the replacement of GGBS along with polymer impregnation for all three grades of concrete. Hence, we can conclude that using GGBS as a replacement and PIC and conserve resources and energy along with enhancing the properties of conventional concrete.

5. ACKNOWLEDGEMENT

We kindly acknowledge the facilities provided by Easwari Engineering college to complete this research work through DRDO-funded equipment and AICTE MODROB-funded equipments for testing and other experimental works. The authors wish to thank the Department of Science & Technology, Government of India, for funding the research infrastructure under the scheme entitled “ Funds for the improvement of S&T Infrastructure (DST-FIST)” Ref.NO.SR/FST/college -2017/110(c).

REFERENCE

- [1] LAVANYA PRABHA, S., GOPALAKRISHNAN, M., NEELAMEGAM, M., : Development of high-strength nano-cementitious composites using copper slag, *ACI Materials Journal*, 117(4), 37–46 (2020).
- [2] S. LAVANAYA PRABHA, A. MOHAN, G. VELRAJKUMAR, A. MOHAMMEDHAROONZUBAIR., Study On Structural Behaviour Of Ductile High-Performance Concrete Under Impact And Penetration Loads ., *Journal of Environmental Protection and Ecology* 23, No 6, 2380–2388 (2022)
- [3] MOHAN, A , VIJAYAN, D.S. , REVATHY, J., PARTHIBAN, D., VARATHARAJAN, R. :Evaluation of the impact of thermal performance on various building bricks and blocks: A review, *Environmental Technology and Innovation*, 23, 101577 (2021).
- [4] M. THOLKAPIYAN, A.MOHAN, VIJAYAN.D.S, :A survey of recent studies on chlorophyll variation in Indian coastal waters, *IOP Conf. Series: Materials Science and Engineering* 993 , 012041, 1-6 (2020).
- [5] GOPALAKRISHNAN, R., MOHAN, A., SANKAR, L. P., & VIJAYAN, D. S. : Characterisation On Toughness Property Of Self-Compacting Fibre Reinforced Concrete. In *Journal of Environmental Protection and Ecology* , 21(6), 2153–2163.
- [6] M. THOLKAPIYAN , A. MOHAN, D. S. VIJAYAN., VARIABILITY OF SEA SURFACE TEMPERATURE IN COASTAL WATERS OF GULF OF MANNER, INDIA, *Oxidation Communications* 45, No 3, 562–569 (2022) .
- [7] MOHAN, A., TABISH HAYAT, M. :Characterization of mechanical properties by preferential supplant of cement with GGBS and silica fume in concrete, *Materials Today: Proceedings*, 43, 1179–1189 (2020).
- [8] DHARMAR, S., GOPALAKRISHNAN, R., MOHAN, A. :Environmental effect of denitrification of structural glass by coating TiO₂, *Materials Today: Proceedings*,

- 45, 6454–6458 (2020).
- [9] MOHAN, A., PRABHA, G., BALAPRIYA, B., DEEPIKA, M., HEMANTHIMEKALA, B. Tribological Investigations on the Properties of Concrete Containing Recycled Plastic Aggregate, *Journal of Balkan Tribological Association*, 27(6), pp. 1010–1020 (2021).
- [10] AYYASAMY, L.R., MOHAN, A., REX, L.K., ...VIJAYAN, D.S.: Enhanced Thermal Characteristics Of Cuo Embedded Lauric Acid Phase Change Material, *Thermal Science*, 26(2), pp. 1615–1621 (2022).
- [11] THOLKAPIYAN, M., MOHAN, A., VIJAYAN, D.S.: Tracking The Chlorophyll Changes Using Sentinel-2A/B Over The Gulf Of Manner, India, *Oxidation Communications*, 45(1), pp. 93–102 (2022).
- [12] Dr.G.VELRAJKUMAR, R.MURALIKRISHNAN, A.MOHAN, R.BALA THIRUMAL, P.NAVEEN JOHN: Performance of GGBFS and silica fume on self compacting geopolymer concrete using partial replacements of R-Sand, *materials today : proceedings*, Volume 59, Part 1, Pages 909-917 (2022).
- [13] D. S. VIJAYAN , A. MOHAN , C. NIVETHA , VIDHYALAKSHMI SIVAKUMAR , PARTHIBAN DEVARAJAN , A. PAULMAKESH , AND S. ARVINDAN: Treatment of Pharma Effluent using Anaerobic Packed Bed Reactor, *Journal of Environmental and Public Health*, Volume 2022, Article ID 4657628, 6 pages (2022).
- [14] AYYASAMY, L.R., MOHAN, A., VIJAYAN, D.S., ...DEVARAJAN, P., SIVASURIYAN, A.: Finite element analysis of behavior and ultimate strength of composite column ,*Science and Engineering of Composite Materials*, 29(1), pp. 176–182, (2022).
- [15] GOPALAKRISHNAN, R., MOHAN, A., SANKAR, L. P., & VIJAYAN, D. S , Characterisation of Toughness Property of Self-Compacting Fibre Reinforced Concrete. In *Journal of Environmental Protection and Ecology* 21(6) 2153 (2020)
- [16] MOHAN, A., SARAVANAN, J., Characterization Of Geopolymer Concrete By Partial Replacement Of Construction And Demolition Waste – A Review., *Journal of the Balkan Tribological Association*, 2022, 28(4), pp. 550–558.
- [17] SRIVIDHYA K , MOHAN A, THOLKAPIYAN M, ARUNRAJ A, “Earth Quake Mitigation (EQDM) Through Engineering Design”, *Materials Today : Proceedings*, Volume 22, 1074-1077, (2020).

- [18] MOHAN, A, Experimental Investigation on the Ecofriendly External Wrapping of Glass Fiber Reinforced Polymer in Concrete Columns, *Advances in Materials Science and Engineering*, Volume 2021, Article ID 2909033, 12 pages .
- [19] KARTHIKA, V.S. , MOHAN, A. , KUMAR, R.D. , JAMES, Sustainable consideration by characterization of concrete through partial replacement of fine aggregate using granite powder and iron powder, *Journal of Green Engineering*, 9 (4), 514-525, 2020.
- [20] A JOTHILAKSHMI, M. , CHANDRAKANTHAMMA, L. , DHAYA CHANDHRAN, K.S. , MOHAN Flood control and water management at basin level-at orathur of Kanchipuram district *International Journal of Engineering and Advanced Technology*, 2019, 8 , *International Journal of Engineering and Advanced Technology* 8 (6), 1418-1421
- [21] THOLKAPIYAN, M., MOHAN, A., VIJAYAN, D.S., TRACKING THE CHLOROPHYLL CHANGES USING SENTINEL-2A/B OVER THE GULF OF MANNER, INDIA, *Oxidation Communications*, 2022, 45(1), pp. 93–102.
- [22] A MOHAN, K. S. DHAYA CHANDHRAN, M. JOTHILAKSHMI, L. CHANDHRKANTHAMMA, Thermal Insulation and R- Value Analysis for Wall Insulated with PCM, *International Journal of Innovative Technology and Exploring Engineering* volume 12 S, 912-921, 2019.
- [23] THOLKAPIYAN, M., MOHAN, A., VIJAYAN, D.S. Spatial And Temporal Changes Of Sea Surface Phytoplankton Pigment Concentration Over Gulf Of Manner, India *Oxidation Communications*, 2021, 44(4), pp. 790–799