IJIRAE:: International Journal of Innovative Research in Advanced Engineering ISSN:2349-2163
Volume 13, Issue 03, March 2026 https://www.ijirae.com/archives
https://doi.org/10.26562/ijirae.2026.v1303.05

Strength Assessment of RCC Beam With Partial Replacement of Metakaolin & Marble Powder

Mageshwaran TM
PG., Scholar, Department of Civil Engineering,
Sengunthar Engineering College (Autonomous), Tiruchengode, India
mageshwarantmmestr2026@scteng.co.in

Divyasankari G
Assistant Professor, Department of Civil Engineering,
Sengunthar Engineering College (Autonomous), Tiruchengode, India
divyasankarig.civil@scteng.co.in
https://orcid.org/0009-0008-9525-3786

Publication History
Manuscript Reference No: IJIRAE/RS/Vol.13/Issue03/AEMR26.MRAE10084
Research Article | Open Access | Double-Blind Peer-Reviewed |Article ID:IJIRAE/RS/Vol.13/Issue03/AEMR26.MRAE10084
Received:22,February 2026, Revised: 01, March 2026, Accepted: 16,March 2026,Published Online: 25, March 2026.
https://www.ijirae.com/volumes/Vol13/iss-03/05.AEMR26.MRAE10084.pdf
Article Citation: Mageshwaran,Divyasankari(2026),Strength Assessment of RCC Beam With Partial Replacement of Metakaolin & Marble Powder, IJIRAE: International Journal of Innovative Research in Advanced Engineering, Volume 13, Issue 03 of 2026 pages 124-128 **Doi:>** https://doi.org/10.26562/ijirae.2026.v1303.05
BibTeX Key: Mageshwaran@2026Strength
IJIRAE papers should be cited as IJIRAE (International Journal of Innovative Research in Advanced Engineering, AM Publications, India 2025, ISSN 2349-2163, https://doi.org/10.26562/ijirae.2026.v1303.05The journal's official abbreviation is IJIRAE. Orcid: https://orcid.org/0009-0004-9398-7488

Abstract: Concrete is the most widely used and versatile building material which is generally used to resist compressive force. By addition of some pozzolanic materials as admixtures, the various properties of concrete can be improved. Metakaolin is a calcified clay and is easily available in Gujarat, Maharashtra & Bombay, etc. It is a Dehydroxylated form of the clay mineral Kaolinite. The particle size of Metakaolin is smaller than cement particles. Marble dust is obtained from the cutting and manufacturing industries of marble. In India near about 3500 metric tons of marble dust slurry per day is generated. So, Marble dust is very easily available at a very low cost. So, it is advised to use marble dust as a partial replacement for cement as it has properties. The present study describes an experimental program conducted to investigate the flexural behavior of Reinforced Concrete beams with metakaolin as a partial replacement for cement and marble powder as a partial replacement for rivers and in preparation for concrete. In this study partial replacement of cement has been done at 5%,10%,15%, and 20% with MP(Marble Powder) and 5%, and 10% with MK (Metakaolin). The compressive as well a stensile strength of concrete made with MK-MP has been compared with conventional concrete of grade M30. The durability of concrete was also analyzed with RCMT (Rapid chloride Migration Test).
Keywords: Metakaolin, Marble Powder, RCC Beam, load, deflection, crack width.

1. INTRODUCTION

Concrete is one of the most widely used versatile construction material in the world. With the rise of population and construction demands, cement production has also increased considerably. Production of cement involves release of large amount of harmful CO2 gases and production of other waste materials. New ideas in production of cement or concrete will result on reduction of harmful effect on environment. Concrete is produced from cement which is used in large quantities but only limited recycling of concrete is being carried out worldwide. The continued expansion of global economy leads to increasing demand for construction materials like cement and sand. Cement industry is considered to be one of the most important sectors responsible in building a sustainableenvironmentasitscontributionisaround5%of the global manmade CO2 emissions. Thus, replacement of cement with other materials without compromising on the strength of concrete can be highly beneficial for the environment. Marble dust powder is easily available in the market due to the high demand of marble in finishing work, which results in dust produced during cutting of marble. Marble dust can act as good replacement of fine aggregate due to its enhanced properties. Some of the related works available in literature are reviewed and included in this section. Several investigations were performed to investigate the Flexural behaviour of reinforced concrete beams with partial replacements of metakaolin and marble powder (2021)- R. Rajkumar, N. Umamaheswari, Abhishek Kumar, Mrinal Kumar, L.R. Vineeth Gupta, Raoshan Pandey - Materials Today: Proceedings. Concrete is the most widely used and versatile building material which is generally used to resist compressive force. By addition of some pozzolanic materials as admixtures, the various properties of concrete can be improved. Many modern concrete mixes are modified with the addition of admixtures, which improve the micro structural properties as well as decrease the calcium hydroxide concentration by consuming it through a pozzolanic reaction. Metakaolin is a cementitious pozzolanic material highly efficient and can react rapidly with the excess calcium hydroxide resulting from OPC hydration by a pozzolanic reaction, to produce calcium silicate hydrate and calcium alumino silicate hydrates.

IJIRAE:: International Journal of Innovative Research in Advanced Engineering ISSN:2349-2163
Volume 13, Issue 03, March 2026 https://www.ijirae.com/archives
https://doi.org/10.26562/ijirae.2026.v1303.05

Due to rapid growth of construction activity, the available sources of natural sand are getting exhausted. Therefore, it is necessary to replace natural sand in concrete by an alternate material either partially or completely without compromising the quality of concrete. Waste marble dust is one such material which can be used to replace sand as fine aggregate in concrete. The present study describes an experimental program conducted to investigate the flexural behaviour of Reinforced Concrete beams with metakaolin as partial replacement for cement and marble powder as partial replacement for rivers and in preparation of concrete. The percentage replacement of cement by metakaolin considered in this experimental study are 0, 2, 4, 6 and 8% by weight of cement and sand by marble powder are 20, 15, 10, 5 and 0%. The mechanical properties such as compressive and split tensile strength are analysed for conventional and modified concretes, at the age of 7, 14 and 28days. Strength and Durability Properties of Concrete with Partial Replacement of Cement with Metakaoline and Marble Dust (2019)- G.Asha Lakshmi & P.Sai Pravallika - International Research Journal of Engineering and Technology (IRJET) Ordinary Portland cement (OPC) is conventionally used as the primary binder to produce concrete. The amount of the CO2 released during the manufacture of OPC due to the calcinations of limestone and combustion of fossil fuel is in the order of one ton for every ton of OPC produced. Attempts are made to reduce the use of Portland cement in concrete are receiving much attention due to environment- related. In the present study Metakaolin and marble dust used as a partial replacement for cement. Metakaolin is a calcinied clay and it is a Dehydroxylated form of the clay mineral Kaolinite. Stone having higher percentage of Kaolinite are known as China clay or kaolin was traditionally used in the manufacture of porcelain ceramic material. The particle size of Metakaolin is smaller than cement particles and where as Marble dust is obtained from cutting and manufacturing industries of marble. In India near about 3500 metric tons of marble dust slurry per day is generated. So, Marble dust is very easily available with very less cost. Kaolinite is also called as green pozzolana becauseitemitslessCO2.Thispaperpresentsresultsofan experimental program to determine mechanical properties of concrete with metakaoline and marble dust.

2. EXPERIMENTAL PROGRAM

Material properties

Metakaolin & Marble Powder

Metakaolin was used as replacement of cement in preparation of concrete and it is found that it improves the mechanical property and durability of the concrete. Specimens in the shapes of cubes, cylinders and prisms will be prepared for the experiment. The curing was done for 7, 14 and 28 days after which appropriate tests will done. The compression, split tensile and flexural strength tests will be carried out for cubes, cylinders and prisms respectively. Waste marble dust as replacement of fine was river sand with particle size of 0-5mm.The specific gravity of fine aggregate and coarse aggregate was 2.63 and 2.72. This concrete mix ratio was used to cast the concrete specimens. The concrete specimens were demouldedafter20hoursandthencuredinawaterstorage tank for 28 days. The average compressive strength of concrete at 28 days was 48.5 MPa. The bond stress-slip response of BFRP bars are shown in Figure-4.The bar slip was not obtained in all the specimens at free ends (unloaded ends) until the specimen reached to ultimate load whereas the loaded end slip was obtained in all the specimens at all stages of loading. The maximum bond stress and corresponding slip was noted in all the specimens at free ends, these slips are very smaller (0.09mm). At loaded ends, the slips of 3.65mm were reached at maximum bond stress. The average bond strength of BFRP bars was about 70% that of the conventional bars.

TEST SPECIMENS

A total of six concrete one-way Beams reinforced with BFRP and conventional steel reinforcements were tested. The Beams measured 2000mm long, 500mm wide and 100mm depth. A clear concrete cover of 20mm thickness was kept constant for all reinforcement. The reinforcement ratios ρ_f [0.58% (3bars), 0.79% (4 bars), 0.98% (5 bars)] and concrete compressive strength 40Mpa were used. The reinforcement ratios (ρ_{fj}) were higher than the balanced reinforcement ratios (ρ_{fb}) according to ACI 440.1R-06guidelines.TheexpectedfailuremodeofBFRP reinforced Beams were mostly the concrete crushing.Figure-5 shows the slab specimens after casting. The reinforcement ratio (ρ_f) and balanced reinforcement ratio (ρ_{fb}) were determined by Eqs (1) and (2), aggregate will be used in preparation of concrete. The concrete mix will be designed for M30 grade. Twelve types of concrete cubes, four types of cylinders and four types of prisms for different replacements will be cast. The curing will be done for 7,14 and 28 days after which appropriate tests will be done. Compression and split tensile tests will be done for cubes and cylinders respectively. Super plasticizers will be added for better results. The feasibility of utilization of marble waste as a substitution for cement will be examined. The parameter includes compressive, flexural and tensile strength. Where A_f is the area of FRP reinforcement (mm^2), f'c is the compressive strength of concrete (Mpa), b is the width of slab(mm), d is the effective depth of slab (mm),$f_{fu}$is the design tensile strength of BFRP reinforcement (MPa), ε_{cu} is the ultimate strain in concrete, E_f is the modulus of Marble waste which comes from stone industry operations such as mining, extraction, sawing etc. exerts pollution load on the environment. It was noted that physical, chemical and mechanical properties of concrete gradually elasticity of concrete (Mpa) and β1 factor.

$$\rho_f = \frac{A_f}{bd} \quad (1)$$

$$\rho_{fb} = 0.85 \frac{f'_c}{f_{fu}} \beta_1 \frac{E_f \varepsilon_{cu}}{E_f \varepsilon_{cu} + f_{fu}}$$

Test setup and procedure is the strength reduction increase up to a certain limit then gradually decreases. Some durability studies will be conducted for concrete prepared with metakaolin. It was found that metakaolin will accelerate the setting time of cement pastes but can reduce the workability of concrete.

IJIRAE::International Journal of Innovative Research in Advanced Engineering ISSN:2349-2163
Volume 13, Issue 03, March 2026 https://www.ijirae.com/archives
https://doi.org/10.26562/ijirae.2026.v1303.05

2.1.2 Concrete mix

The pullout test was carried out by testing five specimens according to ASTM D7913. The detailed mix ratio of cement-water-fine aggregate-coarse aggregate-super plasticizer was1:0.38:1.56:2.72:0.005.Themaximum size of coarse aggregate was 20mm and the fine aggregate All slab specimens were tested under four-point bending up to failure at the Advanced structural laboratory, Annamalai University. Load frame of capacity 50Tonnes was used for testing the slab specimens. All Beams were equipped with a dial gauge at mid span and at one-third points for measuring deflections. Demec gauge pellets were fixed at the top most compression fibre and at the level of reinforcements of slab to observe the strains. The static loads were gradually applied on the Beams via hydraulic jack and measured with a proving ring (Figure- 6). During loading, the crack formation and the corresponding loads was marked on both slab sides until failure. The crack width was measured by using handheld electronic microscope.

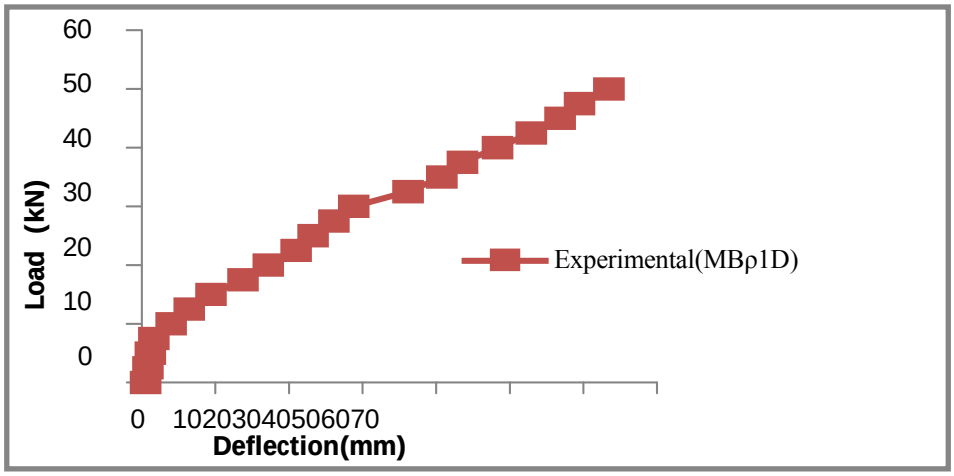
3. TEST RESULTS AND DISCUSSIONS

From the theoretical and experimental test results, it is observed that the increase in reinforcement ratios exhibited greater strengths, lesser deflections and reduced crack widths than those of identical Beams (Ahmed H.Ali etal.[8], Craig.Retal.[9]). By increasing the reinforcement ratios 0.79% and 0.98%, the ultimate load carrying capacity of the BFRP reinforced Beams increases by 10% and 20% respectively than the BFRP reinforced slab of reinforcement ratio 0.58%.At the same time, the ultimate deflection of BFRP reinforced Beams reduces to 1.02 and 1.04 times than that of references lab. Also, the crack widths of BFRP reinforced Beams were 1.27 and 1.56 times lesser than that of reference slab. When the reinforcement ratios of conventional steel reinforced Beams were increased 0.79% and 0.98%, the ultimate load carrying capacity increases by 11% and 16% than that of conventional steel reinforcement ratio of 0.58%.However, the ultimate load carrying capacity of BFRP reinforced Beams were partially higher than the ultimate load carrying capacity of conventional steel Beams. These BFRP reinforced Beams produce higher deflection and crack widths compared to conventional steel Beams. All Beams reinforced with BFRP reinforcements failed by concrete crushing due to higher deserved strength of BFRP bars whereas the Beams reinforced with conventional reinforcements failed by steel yielding followed by concrete crushing.

Table-1. Experimental and Theoretical results of MP and conventional steel reinforced Beams.

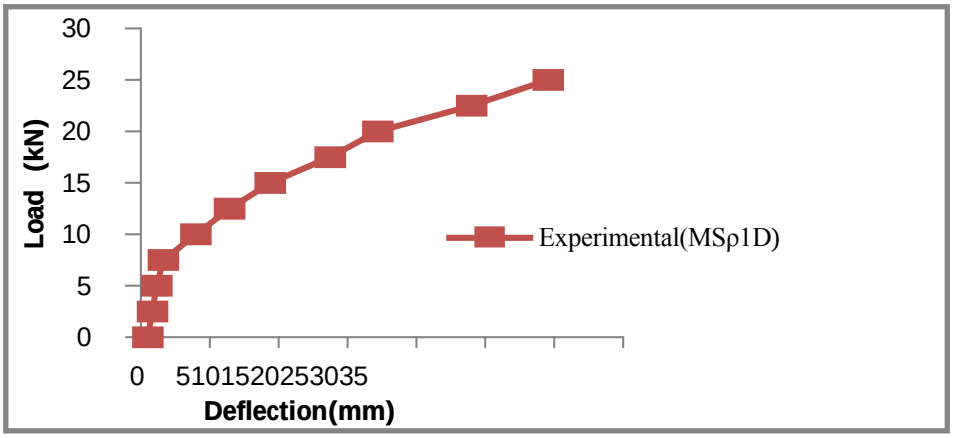
S.No	Designation of Beams	Experimental	□□□□□	□□□□	W_{cr}
		P_u			
1	MBρ_1D	50	72.16	63.16	2.18
2	MBρ_2D	55	71.32	62.42	1.72
3	MBρ_3D	60	69.89	60.89	1.40
4	MSρ_1D	25	33.54	29.72	0.34
5	MSρ_2D	32.5	31.27	26.56	0.33
6	MSρ_3D	37.5	28.05	25.41	0.32

M = Grades of concrete M_{40}; *B,S* = Basalt fibre reinforced polymer and steel reinforcements; ρ_1,ρ_2,ρ_3= Different reinforcement ratios 0.58 %, 0.79 %, 0.98 % respectively; *D*=Thickness of slab,100mm; P_u= Static ultimate load in k N:.δ = Ultimate deflection in mm; W_{cr}=Crack width in mm.

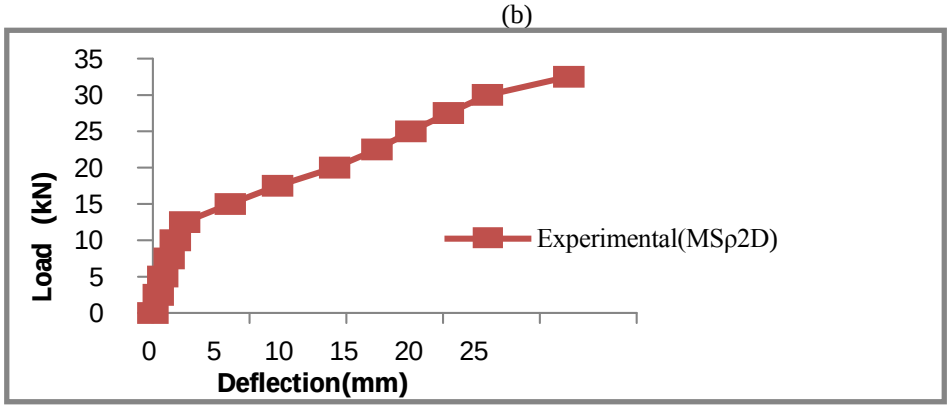


(a)

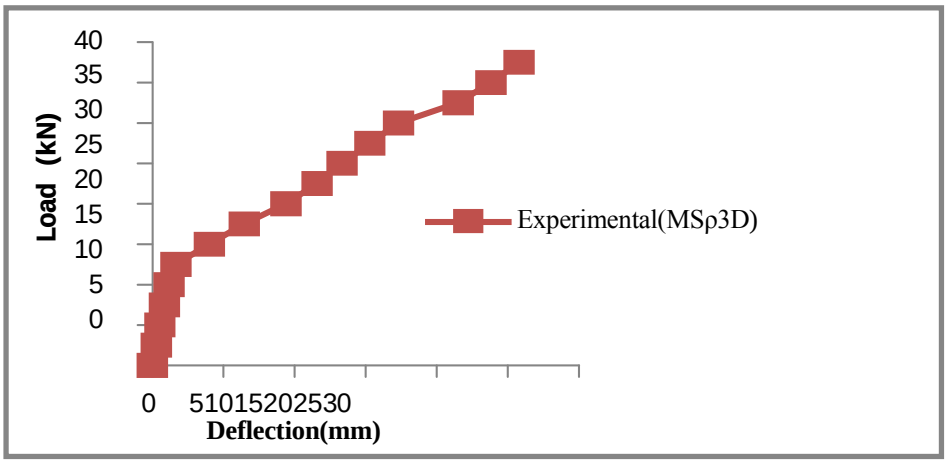
IJIRAE::International Journal of Innovative Research in Advanced Engineering ISSN:2349-2163
Volume 13, Issue 03, March 2026 https://www.ijirae.com/archives
https://doi.org/10.26562/ijirae.2026.v1303.05



(b)



(c)



(d)

Figure-7. Experimental load and deflection relationship of Beams (a) MBρ_1D (b) MBρ_2D (c) MBρ_3D (d) MSρ_1D (e) MSρ_2D(f) MSρ_3D.

4. CONCLUSIONS

In this experimental study, a conventional reinforced concrete beam and modified concrete beams prepared with partial replacement at different levels, of cement by metakaolin and fine aggregate by marble powder were considered.Atotalof27beamswerecastandtestedunder four-point bending. Earlier compressive and split tensile strength properties have been tested for different curing ages such as 7, 14 and 28 days. From the analysis of test results, the following conclusions were drawn:

- The maximum value of compressive strength of concrete cubes was obtained with the use of 10% of Metakaolin as partial replacement of cement and 10% of Marble powder as partial replacement of fine aggregate.
- The maximum value of split tensile strength of concrete cylinders was obtained with the use of 10% of Metakaolin as partial replacement of cement and 10% of Marble powder as partial replacement of fine aggregate.
- The maximum value of flexural strength of concrete beams was obtained with the use of 10% of Metakaolin as partial replacement of cement and 10% of Marble powder as partial replacement of fine aggregate.

REFERENCES

1. Er.Amritpal Kaur & Er. Rajwinder Singh Bansal., "Strength and Durability Properties of Concrete with Partial Replacement of Cement with Metakaolin and Marble Dust" International Journal of Engineering Research & Technology (IJERT) - Vol. 4 Issue 07, July-2015.
2. R.Rajkumar,N.Umamaheswari,Abhishek Kumar, Mrinal Kumar, L.R.Vineeth Gupta & Raoshan Pandey "Flexural behavior of reinforced concrete beams with partial replacements of metakaolin and marble powder",MaterialsToday:Proceedings-March2020.
3. Achint Verma & Devi Charan Dubey "Experimental Investigation in Concrete by Partial Replacement of Sand with Marble Dust: A Review" International Research Journal of Engineering and Technology (IRJET) - Volume: 09 Issue: 08 | Aug 2022.
4. G.Asha Lakshmi& P.Sai Pravallika, "Strength and Durability Properties of Concrete with Partial Replacement of Cement with Metakaoline and Marble Dust", International Research Journal of Engineering and Technology(IRJET)-Volume: 06 Issue:11| Nov 2019.
5. Rander Sarveshwar & P.Naveen Kumar "Strength and Durability Properties of Concrete with Partial Replacement of Cement with Metakaolin and Marble Dust", Anveshana's International Journal of Research in Engineering and Applied Sciences - Volume 5, Issue 10 (2020, Oct).
6. DeveshanL.Pillay,OladimejiB.Olalusi,PaulO. Awoyera, Carlos Rondon, Ana Maria Echeverra, and John Temitope Kolawole "A Review of the Engineering Properties of Metakaolin Based Concrete: Towards Combatting Chloride Attack in Coastal/Marine Structures", Hindawi Advances in Civil Engineering Volume 2020, Article ID 8880974.
7. Sakthieswaran,N.,"Study on effect of marble powder and waste foundrys and as fine aggregates on the properties of metakaolin-cement concrete", Revista Ingeniería de Construcción - RIC Vol 38 November 3 2023.
8. Ishan Anand, Atul Verma, Mukesh Kumar Dubey, Dr.VijayRaj, & SusantaKumar Sethy,"AReview Paper On Properties Of Concrete With Jute Fibre Reinforced Concrete With Partial Replacement of Cement With Metakaolin", International Journal of Mechanical Engineering-Vol.7No.4 April, 2022.
9. Junaid Mansoor, Syyed Adnan Raheel Shah, Mudasser MuneerKhan, Abdullah NaveedSadiq, Muhammad Kashif Anwar, Muhammad Usman Siddiq and Hassam Ahmad, "Analysis of Mechanical Properties of Self Compacted Concrete by Partial Replacement of Cement with Industrial Wastes under Elevated Temperature", Journal of Applied Science 2018.
10. Memduh Karalar, Yasin Onuralp Özkılıç,Ceyhun Aksoylu,Mohanad Muayad Sabri Sabri, Alexey
11. N.Beskopylny, SergeyA. Stel'makh and Evgenii M.Shcherban, "Flexural behavior of reinforced concrete beams using waste marble powder towards application of sustainable concrete", Frontiers in Materials, 12 December 2022.
12. Shahid Ashraf Shah & Ashish Kumar, "Partial Replacement of Cement in Concrete by Metakaolin and Marble Dust", International Journal of Innovative Technology and Exploring Engineering (IJITEE)ISSN:2278-3075,Volume- 9 Issue-4, February 2020.
13. Dhiraj Ganpat Hulwan & V.S. Shingade, "A Survey on Experimental Analysis of Concrete Using Metakolin Powder", International Journal of Innovative Research in Science, Engineering and Technology (IJIRSET), Volume 9, Issue 8, August 2020.
14. Jawad Ahmad, Osama Zaid, Muhammad Shahzaib, Muhammad Usman Abdullah, Asmat Ullah, and Rahat Ullah,"Mechanical properties of sustainable concrete modified by adding marble slurry as cement substitution", AIMS Materials Science, 8(3): 343–358, 26 May 2021.
15. M.Amala,Dr.A.N.Swaminathen,Dr.M.Siva,Dr.S.Meenakshi Sudarvizhi, R.Saleema Begum & Dr.K.Mohandas, " Study on the Performance of High Strength Concrete using Basalt Fiber with Metakaolin", Eur. Chem. Bull. 2023,12(4), 2207-2222.