International Journal of Recent Technology and Engineering (IJRTE)
ISSN: 2277-3878 (Online), Volume-8 Issue-2, July 2019

Sorptivity and Durability Assessment of Dolomite Impregnated Ternary Concrete

MD Ikramullah Khan, Bhavani Challa, S. Haripriya Varma, Mohd Abbas Abdy Sayyed

Abstract*: Traditional testing methods such as absorption test and permeability test are normally not providing accurate results of nature of concrete and there is a need for another type of test to predict the durability of concrete. In this work, industrial by-product like dolomite, marble dust and fly ash are utilized as fraction of cement replacing with 2%, 4%, 6%, 8%, and 10% dolomite, 10% fly ash and 10% marble dust by the weight of cement. The study is conducted on mix designed concrete of M30 grade and compared with conventional concrete. The specimens are casted and tested to examine various properties of concrete like compressive strength, split tensile strength, durability and sorptivity. Durability test is done by hydrochloric acid (HCl) and sulphuric acid (H_2SO_4) on dolomite powder, promising results were obtained in the sorptivity test which shows the dense nature of concrete by the usage of dolomite powder.

***Keywords* : dolomite powder, cement based material, mineral admixtures, durability, sorptivity.**

I. INTRODUCTION

Building industry has flourished widely because of the use of cement concrete as a construction material. On an average, each individual consumes 1 ton of cement every year next highest to the use of water. Cement is the principal component in the concrete due to its ability to impart compressive strength and binding properties. A mixture of argillaceous and calcareous materials is burnt at high temperature to manufacture portland cement. Large amount of CO_2 is discharged in to the environment during the production of cement [1]. Use of cement concrete on huge scale imposes a major environmental challenge during the production and it is a matter of high concern in the world market [2], [3]. To reduce the greenhouse gas emissions during production, different strategies have been extensively studied in the recent past [4]. Researchers have evaluated the performance characteristics of addition of admixtures in concrete in the past few decades. There is controversy on meeting requirements on limitations of shrinkage, their effect on durability and concrete is often appended with chemical and/or mineral admixtures [5]. The interaction of these admixtures with cement constituents within the concrete greatly influences its physicochemical properties, mechanical properties and durability. An admixture's exhibition is subjected to the sort of bond, explicit surface region of bond, extent of dosage, succession of expansion of water and admixture, etc. [6], [7]. By using admixtures, the consumption of cement will gradually reduce, thereby reducing CO_2 emissions. It also gives higher the strength with reference to the concrete of 0% additives [8]. Mineral admixtures include dolomite, marble dust, fly ash, metakaolin, nano-silica, metasilicate, which possess certain characteristics through which they influence the properties of concrete differently [9]–[12]. Mineral admixtures are strongly associated with the hardening property of cement. Comparative studies have been done such as the effect of dolomite powder, marble dust and fly ash on the setting times of the high strength concrete. The physicochemical characteristics of the fresh concrete prepared with these admixtures has also been studied by several researchers [13], [14]. A concrete with or without admixture must be durable and sustain the purpose of the structure. Moisture often travels through permeable means and degrade the concrete thereby affecting its durability. If excess amount of water is used, the concrete is left porous once the water vaporizes. Cement paste consists of gel pores & capillary pores which leads to honeycomb structure, that lowers the strength of concrete. However, proper selection of ingredients, proportioning of mix and adopting good workmanship produces impervious concrete. Traditional methods such as absorption test and permeability test are often applied to study the porosity, with limitations. However, sorptivity test helps to assess the rate of capillary rise of water in an unsaturated concrete [15]. Marble dust is created during the marble stone cutting, molding, and cleaning. Around 20-25% of the processed marble is transformed into the powder. India stands third in the export of marble that produces high amounts of marble waste every year which can be potentially used as replacement of cement concrete. Better performance of concrete is achieved with lower water to cement ration wherein sand is replaced with marble dust [11]. Pozzolanic reaction and micro-aggregate filling is observed to improve when concrete is mixed with marble waste powder and rock dust, thereby improving durability and resistance to sulphate attack [16]. Sharma and Kumar [17] found that cement and sand can be replaced individually up to 10% by marble powder improved the compressive strength of concrete, however beyond 10% replacement, there is a loss of the compressive strength [18].

Revised Manuscript Received on 30 July 2019.
* Correspondence Author
MD Ikramullah Khan*, Civil Engineering Department, S R Engineering College, Warangal, India. Email: ikrammohammad31@gmail.com
Bhavani Challa, Civil Engineering Department, S R Engineering College, Warangal, India. Email: bhavanichalla036@gmail.com
S. Haripriya Varma, Civil Engineering Department, S R Engineering College, Warangal, India. Email: priya.hari700@gmail.com
Mohd Abbas Abdy Sayyed*, Civil Engineering Department, S R Engineering College, Warangal, India. Email: abbas.vnit@gmail.com

The workability and compressive strength of GGBS and fly ash impregnated concrete improves the mechanical properties of concrete [19]. Fly ash concrete shows low sorptivity and chloride permeability as it reduces the porosity of concrete. The fly ash was investigated to comprehend its micro-structural morphology as the reason behind the improved durability [20]. Siddiqui recommended that replacement of cement in concrete up to 50% Class F fly ash suits best for precast and reinforced cement concrete construction [21]. Dolomite is favored for development material because of its higher surface hardness and thickness [9]. Dolomite is the carbonate of calcium and magnesium $CaMg(CO_3)_2$ and it is applied as a favorable filler due to its higher quality and hardness. Workability of concrete decreases the porosity of the concrete at low water-cement ratio by mixing Fly ash and dolomite powder [22]. The improved microstructure of hardened mortars is obtained for the optimal substitution range of 30-50 % of dolomite powder [23]. Dolomite acts as cement when replaced at low percentage, while at higher dosage, increased the hydration products as a result of crystallization and better water absorption [10]. Early carbonation curing technique results in rapid strength gain when higher amount of dolomite powder replacement is done at low water to cement ratio (0.15). The release of water in carbonation results in formation of nanometer $CaCO_3$ resulting in rapid strength development [24]. In this study, M30 grade cement concrete samples were made by supplanting 0%, 2%, 4%, 6%, 8% and 10% dolomite powder, 10% fly ash and 10% marble dust by weight of cement. Tests have been performed in the laboratory to assess the compressive and split tensile strength, sorptivity, resistance to chloride and sulphate attacks.

II. EXPERIMENTAL PROGRAM

A. *Materials*

53 grade Ordinary Portland Cement (OPC) is used in agreement with IS12669: 2013 of specific gravity 3.10, fineness 8% and standard consistency as 33%. The locally available zone II fine aggregate of specific gravity 2.29, fineness modulus 3.17 and water absorption 0.80% is used. Locally available coarse aggregate of size 20 mm of specific gravity 2.74 and water absorption 0.25% is used. The potable water having pH of 6.5 confirming to IS10500: 2012 is used during casting of the cubes and samples as well as the curing. The dolomite powder (DP) obtained from Astraa Chemicals, Tamil Nadu, India (Fig 1) is used in this study with the properties enlisted in in Table 1. Low- calcium Class F Fly Ash, obtained from local NTPC Bhupalpally, Jayashankar, India of specific gravity 2.2 and specific surface area as 190 m^2/kg containing carbon between 5-10 percent is used. Marble dust is obtained from locally available marble manufacturer at Jangaon District, Warangal, Telangana, India of specific gravity 2.02 for the present study (Fig 2). The physiochemical properties of marble dust are given in Table 2.

B. *Mix Proportion*

Indian Standard Procedure (IS10262: 2009) for mix design of cement concrete was adopted to design M30 grade concrete in the present study. The ratio of cement, fine aggregate and coarse aggregate obtained through mix design is 1:1.83:1.98 with water to cement ratio of 0.5. The concrete was supplanted with 10 wt% fly ash, 10 wt% marble dust and fraction of dolomite powder varied at 0, 2, 4, 6, 8 and 10 wt% as partial replacement for the cement in this experiment. The samples for the varying proportions of dolomite powder was compared with the control mix prepared with no replacement of cement. The quantity of material used to prepare the concrete are given in Table 3.

Table 1 Properties of Dolomite Powder

S. No.	Property	Description
1	Chemical Formula	$CaMg(CO_3)_2$
2	Specific Gravity	2.65
3	Colour	White
4	Tenacity	Brittle
5	Moisture Content (%)	Nil
6	Crystal system	Trigonal

Figure 1 Dolomite Powder

Figure 2 Marble Dust

C. *Preparation of samples and testing procedure*

The samples were prepared in the

Table 2 Physiochemical properties of Marble Dust

Properties	Al_2O_3	CaO	Fe_2O_3	K_2O	L.O.I.	MgO	Na_2O	SiO_2	SO_3
% by weight	1.09	32.23	1.09	0.91	40	18.9	0.63	4.99	0.07

Table 3 Material quantity to prepare the concrete

Mix labels	Cement (kg/m^3)	MD (kg/m^3)	FA (kg/m^3)	DP (kg/m^3)	Sand (kg/m^3)	CA (kg/m^3)	Water (lit/m^3)
MD-FA-DP-0	426.56	-	-	-	780.61	844.59	213.28
MD-FA-DP-2	332.72	42.66	42.66	8.53	780.61	844.59	213.28
MD-FA-DP-4	324.19	42.66	42.66	17.06	780.61	844.59	213.28
MD-FA-DP-6	315.65	42.66	42.66	25.59	780.61	844.59	213.28
MD-FA-DP-8	307.12	42.66	42.66	34.12	780.61	844.59	213.28
MD-FA-DP-10	298.59	42.66	42.66	42.66	780.61	844.59	213.28

Note: Cement refers to OPC; MD = Marble dust; FA = Class F fly ash; DP = Dolomite powder; CA = Course Aggregate.

laboratory using the manual procedure of dry and wet mixing on the non-absorbing smooth platform, wherein the materials are taken by weigh batching. Concrete cubes of 15 × 15 × 15 cm were casted to assess the compressive strength at 7 and 28 days. The cylinders of dimension 10 cm dia × 20 cm height was used to test it the split tensile strength. The cylindrical samples of size 10 cm dia x 5 cm height cured in water for 28 days, later oven dried at 100 + 10 °C was used to assess the sorptivity by measuring the capillary rise absorption rate of water. The sorptivity test is conducted after 28 days, as the 90% strength is gained by the concrete. Concrete cubes of 10 × 10 × 10 cm size were casted to perform the durability test, wherein 28 days strength was obtained using the 10cm cubes. The remaining 10cm cubes were immersed HCl and H_2SO_4 diluted with distilled water at the rate of 5% v/v for assessment of loss of strength at 56 days and 90 days. The percent loss of weight of concrete due to its immersion in H_2SO_4 is also assessed at 56 days and 90 days.

III. RESULTS AND DISCUSSIONS

A. *Compressive strength*

The compressive strength of the concrete at 7 and 28 days of curing is as shown in Fig. 3. The compressive strength increased for the designed concrete with the variation of dolomite powder is observed as shown in Fig. 3, wherein, marble dust and fly ash replaced the cement at constant of 10% in all the samples except the control mix (CM). However, addition of dolomite powder beyond six percent resulted in the decrease of compressive strength of concrete at 7 days as well as 28 days, though it is higher compared to the strength of the control mix. The compressive strength of the ternary blended concrete in comparison with the control mix increased by about 10.3% at 7 days and 11.22% at 28 days for the mix that contains 6% dolomite powder. The decreased compressive strength due to increased compressive has been attributed to the increased water-cement ratio [23].

B. *Split tensile strength*

The split tensile strength is obtained for concrete as per the requirements of IS516: 1959. The cylinders of dimension 10 cm dia x 20 cm height, were tested in the laboratory and the split tensile strength is obtained at 7 days and 28 days for all the mix proportion taking the average of three samples is plotted and depicted in Fig. 4. The split tensile strength is observed to increase for the increased percentage of dolomite powder in the ternary mix. The maximum increase in the split tensile strength is obtained at 23.26% for 7 days as compared with control mix, which later stabilizes at around 11.95% at 28 days for 8% dolomite powder. However, the split tensile strength of the concrete beyond 8% DP replacement decreases as compared to the control mix. This is attributed to the increased porosity in the concrete wherein the fly ash and other replacements of cement contribute to it.

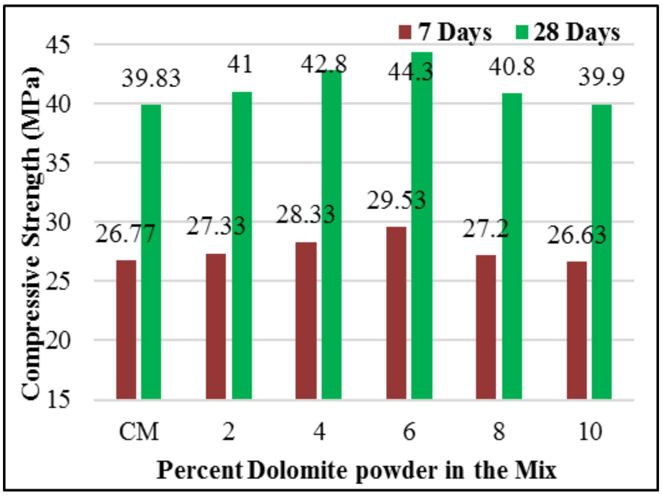

Figure 3 Compressive strength of ternary concrete with varying dolomite powder

C. *Sorptivity Test*

The sorptivity (S) of the concrete indicates the pervious nature of concrete and its ability to transmit water due to capillarity. The total water absorption which is calculated as water absorbed per unit area from the inflow surface. This absorption is proportional to the square root of elapsed time (t). Mathematically, sorptivity is calculated as per Eq. 1,

$$I = S.\, t^{1/2} \qquad (1)$$

where, t = time elapsed in min = 30 min;
cumulative inflow, I = Δw/Ad;
Δw = change in water content i.e., $W_2 - W_1$; A = area of the cylinder; d = density of water.

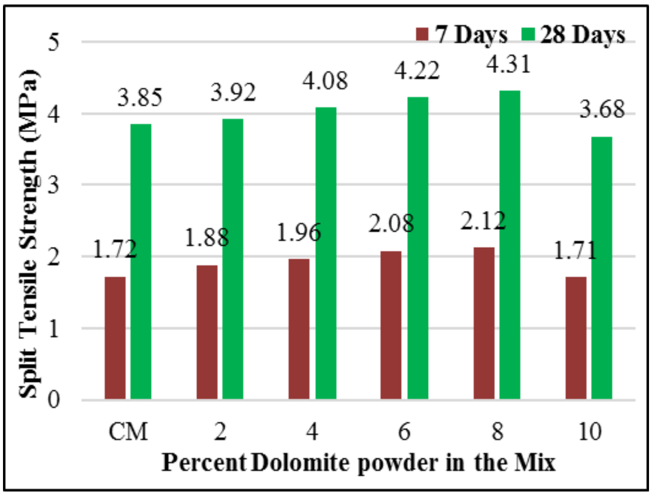

Figure 4 Split tensile strength of ternary concrete with varying dolomite powder

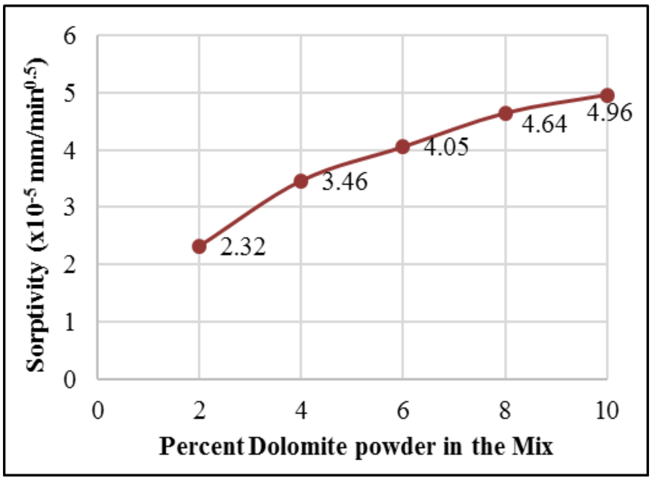

Figure 5 Sorptivity values obtained at 90 days for concrete mixes

The sorptivity is an index of moisture transport through the interconnected voids in an unsaturated hardened concrete. More sorptivity is not a good sign for the concrete in a long term. Martys and Ferraris [25] showed that sorptivity is indispensable element for predicting the service life of concrete. However, researchers have reported in the past and recent that the addition of certain admixtures to the concrete increased the sorptivity [26], [27]. The results obtained in the present study showed that the sorptivity measured at 28 days steadily increased with the increase in addition of dolomite powder. The increase may be attributed to non-adjustment of water-cement ratio.

D. *Durability Test*

Though concrete may have a high compressive strength, it is essential to test its performance under the extreme environmental conditions. An electrical test, Rapid Chloride Permeability is used to test the durability of concrete in which lower levels of charge indicate more durable concrete. The durability of concrete can also be assessed by obtaining the strength characteristics of the cubes that are kept immersed in diluted acid at 56 days and 90 days. The plates of the concrete cubes kept immersed in diluted HCl and H_2SO_4 are given in Fig. 6.

(a)

(b)

Figure 6 Sample concrete cubes immersed in (a) HCl and (b) H_2SO_4

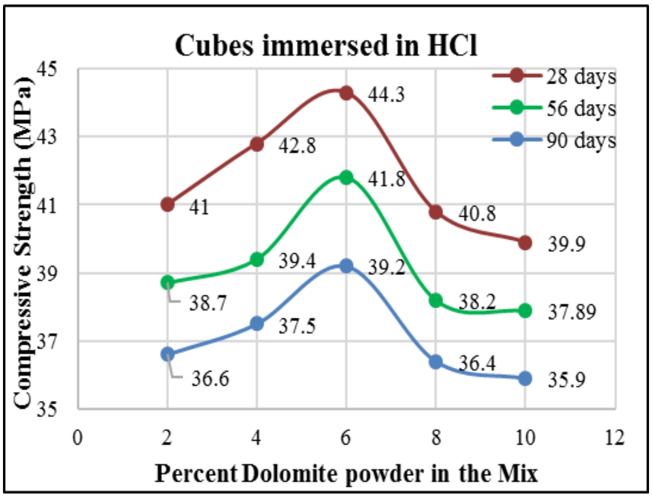

Figure 7 Reduced compressive strength of concrete immersed in HCl at 56 and 90 days

Concrete mixes with different combinations of dolomite powder showed higher resistance to acid attack with increase percentage. However, the strength characteristic of the immersed concrete at 56 days and 90 days are depicted in Fig. 7 for HCl. The pattern of the strength for all the variations of dolomite is nearly same for 28, 56 and 90 days.

Retrieval Number: B2896078219/19©BEIESP
DOI: 10.35940/ijrte.B2896.078219
Journal Website: www.ijrte.org

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication

The concrete cubes were also tested for their weight loss when subjected to chloride attack (Fig. 9). Acid attacks of H_2SO_4 are more severe and the strength characteristic of concrete immersed in H_2SO_4 are reproduced in Fig. 8. The percent loss of weight of concrete immersed in H_2SO_4 are shown in Fig. 10. The increasing percentage of dolomite powder in the ternary concrete shows a good resistance to the acid attack up to 6%, further increase in

DP causes more loss of weight in chloride as well as sulphate attack.

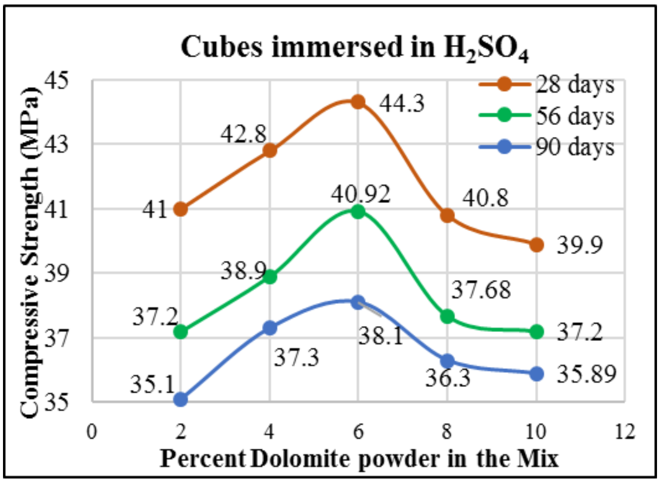

Figure 8 Reduced compressive strength of concrete immersed in H_2SO_4 at 56 and 90 days

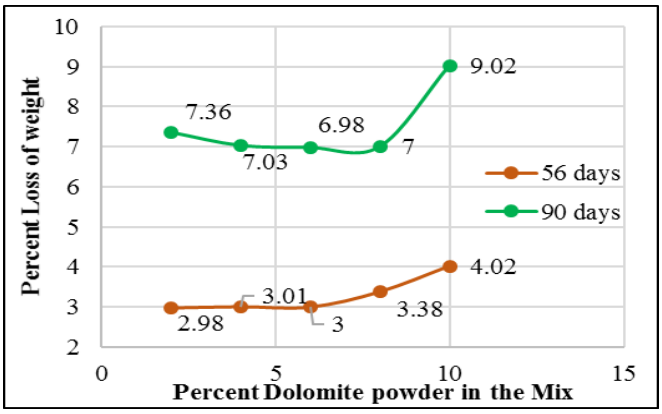

Figure 9 Percent loss of weight of concrete cubes at 56 and 90 days (HCl)

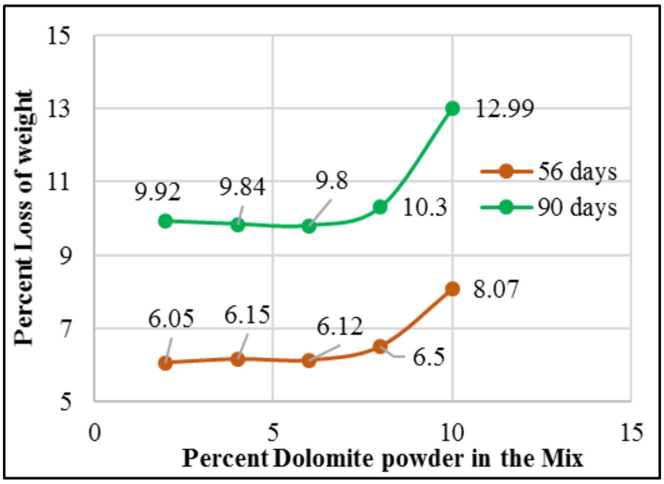

Figure 10 Percent loss of weight of concrete cubes at 56 and 90 days (H_2SO_4)

IV. CONCLUSIONS

The present study obtained the engineering properties of the ternary concrete, wherein the cement got replaced with 10% marble dust, 10% fly ash and varying percentages of dolomite powder. Based on the experimental results, we conclude that,

1. The optimum percentage of DP that can be replaced in the ternary concrete used in this study to obtain increased compressive strength is identified as 6%. The compressive strength obtained in this experiment at 7 days is 29.53 N/mm^2 and 44.3 N/mm^2 at 28 days, respectively.
2. The optimum dosage of dolomite powder for split tensile strength is obtained at 8 wt% DP as partial replacement for OPC. The 7 days tensile strength of concrete is obtained as 2.12 N/mm^2 and 4.31 N/mm^2 at 28 days, respectively.
3. The sorptivity increases with the increase in the percentage of dolomite powder as replacement of cement in the ternary concrete. Further research is required to vary the other mineral admixtures that were used in this experiment to find the proportion such that sorptivity is not affected.
4. The concrete mix with 6 wt% DP showed better resistance to chloride attack. The decrease in the compressive strength was marginal for the mixes at 56 and 90 days of immersion. The compressive strength decreased by 6% for 56 Days and 10% for 90 days.
5. The concrete mix with 6% DP showed better resistance to sulphate attack. The decrease in the compressive strength was marginal for the mixes at 56 and 90 days of immersion. The compressive strength decreased by 11% for 56 days and further decreased to 16% in 90 days.
6. The weight of the ternary concrete containing 6 wt% DP reduced by 3% and 7% for 56 and 90 days, respectively for chloride attack (Fig. 9). Similarly, the weight reduction was observed as 6% and 10% for 56 and 90 days respectively for sulphate attack.
7. It is concluded that in this ternary concrete, the cement can be replaced up to 6 wt% with dolomite powder for improved performance of the concrete.

REFERENCES

1. M. Taylor, C. Tam, and D. Gielen, "Energy efficiency and CO2 emissions from the global cement industry," *Korea*, vol. 50, no. 2.2, pp. 61–67, 2006.
2. A. M. Rashad, "A brief on high-volume Class F fly ash as cement replacement--a guide for civil engineer," *Int. J. Sustain. Built Environ.*, vol. 4, no. 2, pp. 278–306, 2015.
3. R. Kajaste and M. Hurme, "Cement industry greenhouse gas emissions--management options and abatement cost," *J. Clean. Prod.*, vol. 112, pp. 4041–4052, 2016.
4. J. Wei, K. Cen, and Y. Geng, "Evaluation and mitigation of cement CO 2 emissions: projection of emission scenarios toward 2030 in China and proposal of the roadmap to a low-carbon world by 2050," *Mitig. Adapt. Strateg. Glob. Chang.*, vol. 24, no. 2, pp. 301–328, 2019.
5. I. S. Kim, S. Y. Choi, and E. I. Yang, "Evaluation of durability of concrete substituted heavyweight waste glass as fine aggregate," *Constr. Build. Mater.*, vol. 184, pp. 269–277, 2018.
6. J. Cheung, A. Jeknavorian, L. Roberts, and D. Silva, "Impact of admixtures on the hydration kinetics of Portland cement," *Cem. Concr. Res.*, vol. 41, no. 12, pp. 1289–1309, 2011.

7. V. S. Ramachandran and J. J. Beaudoin, *Handbook of analytical techniques in concrete science and technology: principles, techniques and applications*. Elsevier, 2000.
8. T. Ayub, S. U. Khan, and F. A. Memon, "Mechanical characteristics of hardened concrete with different mineral admixtures: a review," *Sci. World J.*, vol. 2014, 2014.
9. O. Mikhailova, G. Yakovlev, I. Maeva, and S. Senkov, "Effect of dolomite limestone powder on the compressive strength of concrete," *Procedia Eng.*, vol. 57, pp. 775–780, 2013.
10. M. Szybilski and W. Nocuń-Wczelik, "The effect of dolomite additive on cement hydration," *Procedia Eng.*, vol. 108, pp. 193–198, 2015.
11. A. A. Aliabdo, A. E. M. A. Elmoaty, and E. M. Auda, "Re-use of waste marble dust in the production of cement and concrete," *Constr. Build. Mater.*, vol. 50, pp. 28–41, 2014.
12. K. Turk, M. Karatas, and T. Gonen, "Effect of fly ash and silica fume on compressive strength, sorptivity and carbonation of SCC," *KSCE J. Civ. Eng.*, vol. 17, no. 1, pp. 202–209, 2013.
13. G. Preethi and G. Prince, "Effect of replacement of cement with dolomite powder on the mechanical properties of concrete," *Int. J. Innov. Sci. Eng. Technol.*, vol. 2, no. 4, pp. 1083–1088, 2015.
14. S. O. Folagbade, "Sorptivity of cement combination concretes containing Portland cement, fly ash and metakaolin," *Int. J. Eng. Res. Appl.*, vol. 2, pp. 1953–1959, 2012.
15. J. Pitroda, F. S. Umrigar, B. Principal, and G. I. Anand, "Evaluation of sorptivity and water absorption of concrete with partial replacement of cement by thermal industry waste (Fly Ash)," *Int. J. Eng. Innov. Technol.*, vol. 2, no. 7, pp. 245–249, 2013.
16. M. S. Hameed and A. S. S. Sekar, "Properties of green concrete containing quarry rock dust and marble sludge powder as fine aggregate," *ARPN J. Eng. Appl. Sci*, vol. 4, no. 4, pp. 83–89, 2009.
17. N. Sharma and R. Kumar, "Use of Waste Marble Powder as Partial Replacement in Cement Sand Mix," *Int. J. Eng. Res. Tech.*, vol. 4, no. 5, pp. 501–504, 2015.
18. S. Sahni, S. Arora, and R. Singh, "Influence of Waste Marble Powder and Metakaolin on Strength Properties of Concrete: A Short Review," in *Recycled Waste Materials*, Springer, 2019, pp. 105–109.
19. A. A. Phul, M. J. Memon, S. N. R. Shah, and A. R. Sandhu, "GGBS And Fly Ash Effects on Compressive Strength by Partial Replacement of Cement Concrete," *Civ. Eng. J.*, vol. 5, no. 4, pp. 913–921, 2019.
20. A. K. Saha, "Effect of class F fly ash on the durability properties of concrete," *Sustain. Environ. Res.*, vol. 28, no. 1, pp. 25–31, 2018.
21. R. Siddique, "Performance characteristics of high-volume Class F fly ash concrete," *Cem. Concr. Res.*, vol. 34, no. 3, pp. 487–493, 2004.
22. D. Balakrishnan and K. C. Paulose, "Workability and strength characteristics of self compacting concrete containing fly ash and dolomite powder," *Am. J. Eng. Res.*, vol. 24, no. 4, pp. 43–47, 2013.
23. H.-A. Nguyen, "Enhancement of engineering properties of slag-cement based self-compacting mortar with dolomite powder," *J. Build. Eng.*, vol. 24, p. 100738, 2019.
24. H. Yang, Y. Shao, and others, "Early carbonation behavior of high-volume dolomite powder-cement based materials," *J. Wuhan Univ. Technol. Sci. Ed.*, vol. 30, no. 3, pp. 541–549, 2015.
25. N. S. Martys and C. F. Ferraris, "Capillary transport in mortars and concrete," *Cem. Concr. Res.*, vol. 27, no. 5, pp. 747–760, 1997.
26. B. B. Sabir, S. Wild, and M. O'farrell, "A water sorptivity test for martar and concrete," *Mater. Struct.*, vol. 31, no. 8, p. 568, 1998.
27. K. Amini, P. Vosoughi, H. Ceylan, and P. E. P. Taylor, "Linking air-void system and mechanical properties to salt-scaling resistance of concrete containing slag cement," *Cem. Concr. Compos.*, p. 103364, 2019.

AUTHORS PROFILE

MD Ikramullah Khan received B.Tech degree in Civil Engineering in 2015 and M.E. degree with Structural Engineering in 2017 from Muffakham Jah College of Engineering and Technology, Hyderabad. Currently, he is an Assistant professor at Department of civil Engineering in SR Engineering College, Warangal.

Bhavani Challa received the B.Tech degree in Civil Engineering in 2019 from S R Engineering College, Warangal.

S. Haripriya Varma received the B.Tech degree in Civil Engineering in 2014 and M.Tech degree with Structural and Construction Engineering in 2016 from Warangal Institute of Technology and Science, Warangal. Currently, she is an Assistant Professor in the Department of Civil Engineering , S R Engineering College, Warangal..

Dr. Mohd Abbas Abdy Sayyed completed his Ph.D. in 2017 and M.Tech in 2008 in Civil and Environmental Engineering from VNIT, Nagpur. He is alumni of Govt. College of Engineering, Amravati, Maharashtra. His area of specialization is water distribution network optimization. He has been active in research and owns a good number of cited national and international publications. He is currently associated with S R Engineering College as Associate Professor in the Department of Civil Engineering. He is also the reviewer for journals nationally and internationally.