Civil Engineering and Architecture 11(6): 3314-3321, 2023 http://www.hrpub.org
DOI: 10.13189/cea.2023.110607

Dolomite Powder in Concrete: A Review of Mechanical Properties and Microstructural Characterization

Rahul Shivaji Divekar[*], R. M. Sawant

Department of Civil Engineering, PES College of Engineering, Aurangabad (MH), India

Received February 24, 2023; Revised July 7, 2023; Accepted August 15, 2023

Cite This Paper in the Following Citation Styles

(a): *[1] Rahul Shivaji Divekar, R. M. Sawant , "Dolomite Powder in Concrete: A Review of Mechanical Properties and Microstructural Characterization," Civil Engineering and Architecture, Vol. 11, No. 6, pp. 3314 - 3321, 2023. DOI: 10.13189/cea.2023.110607.*

(b): *Rahul Shivaji Divekar, R. M. Sawant, (2023). Dolomite Powder in Concrete: A Review of Mechanical Properties and Microstructural Characterization. Civil Engineering and Architecture, 11(6), 3314 - 3321. DOI: 10.13189/cea.2023.110607.*

Abstract Nowadays, construction industries use several pozzolanic materials to improve the strength of concrete. These materials include fly ash, silica fume, metakaolin, and limestone. Additionally, limestone is used in cement production, and cement manufacturing industries consume large amounts of it. To reduce the heavy reliance on limestone in cement manufacturing, dolomite powder is an excellent alternative. Dolomite particles enhance the early hydration process and create a compact microstructure in the concrete. The addition of dolomite powder in concrete with fly ash affects the setting time of the concrete mixture. Dolomite particles improve the early hydration process and form a dense microstructure in the concrete. Calcined dolomite powder is produced by heating it to 800 degrees Celsius. The calcined dolomite powder was obtained by giving the temperature of 800 degrees Celsius. Dolomite microparticles contain massive crystals and show the similar morphology to calcite. The literature suggests that dolomite powder can function as a pozzolanic material and can also serve as the primary ingredient in cement production. This review paper has discussed the use of dolomite powder in concrete and their effects. Furthermore, the paper has examined the origins and uses of dolomite.

Keywords White Dolomite Powder, Calcined Dolomite Powder, Mechanical Properties and Microstructural Characterization

1. Introduction

Concrete is a widely used construction material due to its durability, strength, and cost-effectiveness. The addition of supplementary cementitious materials (SCMs) such as fly ash, slag, and silica fume to concrete has been extensively studied to enhance its mechanical and durability properties. In recent years, dolomite powder has emerged as a potential SCM due to its abundant availability and chemical similarity to lime.

Despite the growing interest in dolomite powder as an SCM, the research on its effect on the mechanical properties and microstructural characteristics of concrete is still limited. Many of the previous studies have focused on the use of dolomite powder as a partial replacement for cement, and the results have been inconsistent. The varying quality of the dolomite powder and the differences in test methods and mix design parameters make it difficult to draw definitive conclusions.

Moreover, the microstructural characterization of dolomite powder in concrete is not well understood. While some studies have investigated the impact of dolomite powder on the hydration products and pore structure of concrete, the mechanisms involved are not fully understood. Therefore, this review paper aims to provide a comprehensive overview of the current state of knowledge on the mechanical properties and microstructural characterization of dolomite powder in concrete. By identifying the key limitations of prior work, review paper will help to clarify the potential benefits and challenges associated with the use of dolomite powder as an SCM in concrete. The concrete sector utilizes the most natural resources, consuming around 12.6 billion tons of raw materials per year [1]. To reduce the use of natural coffers, concrete diligences are using cementitious accoutrements similar as Fly ash, Granulated furnace sediment, Silica flume, etc. Although, dolomite greasepaint can be used as a cementitious material due to cementing parcels contained. Various sectors such as the manufacture of rubber, boiler casings, pipes, and chemicals use Dolomite as a sedimentary gemstone. It is also used in open-hearth sword furnaces and first-generation Bessemer converters, and paper manufacture, leather processing, glass manufacturing, stone wares, and serves as padding in diseases, maquillages, and varnishes. Also, dolomite proves salutary in mollifying coal mine dust [2]. The chemical reactivity of dolomite in the end product of Portland cement was significantly more affected by the temperature during curing compared to limestone [3], [4]. Table 1 shows the chemical compositions of OPC, limestone and dolomite [5]-[8]. Fig.1 shows Graphical Representation for Oxide Compositions of OPC, Lime and Dolomite [9].

Table 1. Chemical compositions of OPC, limestone and dolomite

Oxide Composition	OPC	Lime	Dolomite
Lime(CaO)	60-65%	79.7%	31.7%
Calcium Carbonate($CaCO_3$)	-	-	56.6%
Silica(SiO_2)	17-25%	1.6%	1.5%
Alumina(Al_2O_3)	3.5-9%	0.325%	0.05-0.5%
Iron Oxide(Fe_2O_3)	0.5-6%	0.384%	0.19-0.3%
Magnesia(MgO)	0.5-4%	2.4%	20.5%
Sulfur Trioxide(SO_3)	1-2%	0.104%	0.09%
Potassium Oxide(K_2O)	0.5-1.3%	0.0504%	0.01%
Chloride(Cl)	-	0.0267%	-
Manganese Oxide(MnO)	-	1.12%	0.06%
Phosphorus(P_2O_5)	-	0.00788%	0.07%
Titanium Oxide(TiO_2)	-	-	-
Sodium Oxide(Na_2O)	-	-	-

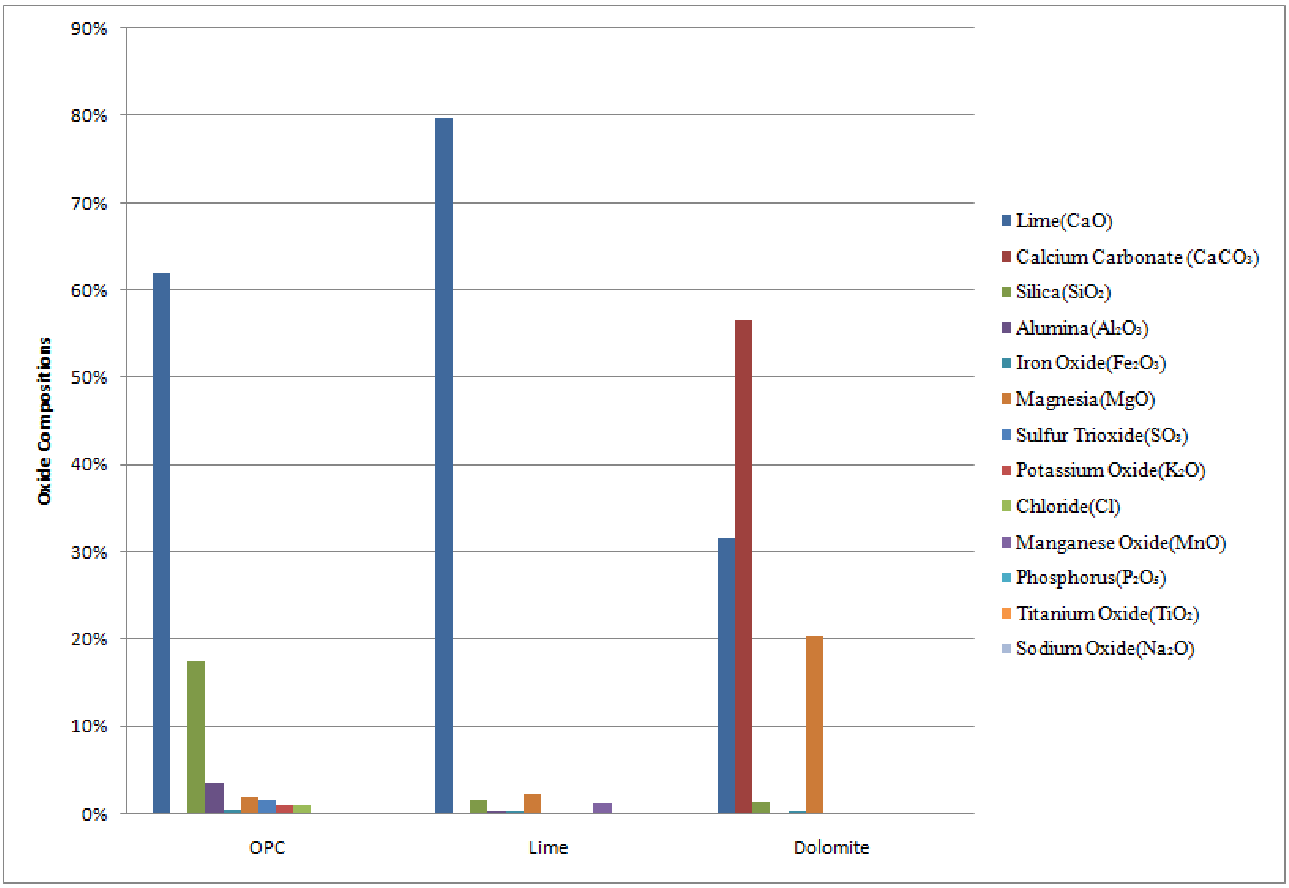

Figure 1. Graphical Representation for Oxide Compositions of OPC, Lime and Dolomite

2. History of Dolomite

Dolomite is a sedimentary rock naturally occurring in an environment and composed mainly of calcium carbonate ($CaCO_3$), magnesium carbonate ($MgCO_3$), and other oxides compositions [10]. The chemical formula of dolomite is $CaMg(CO_3)_2$ [11]. However, most dolomites of sedimentary origin are non stoichiometric with a molar $CaCO_3$:$MgCO_3$ ratio greater than unity [12], [13]. Nicolas de Saussure was a Swiss naturalist who first discovered the dolomite in 1792 and gave the specific name "dolomite" in honor of its first describer known as Dolimeu [14]. Dolomite is derived from calcium carbonate mud that is collected in warm, shallow marine habitats where shell pieces, faeces, coral fragments, and carbonate precipitates were present. Around 89% of the dolomite resources in India are distributed across eight states, with the following approximate distribution: Madhya Pradesh (28%), Andhra Pradesh (13%), Chhattisgarh (11%), Odisha (10%), Karnataka (8%), and Gujarat & Rajasthan (7% each), and Maharashtra (5%). The remaining 11% of the resources are spread across the following states: Arunachal Pradesh, Jharkhand, Haryana, Sikkim, Tamil Nadu, Telangana, Uttarakhand, Uttar Pradesh and West Bengal [15]. Also, dolomite can be formed by the replacement of calcium in limestone by magnesium results in the recrystallization of the limestone [16]. The ideal structure of stoichiometric dolomite is depicted in Fig.2, which consists of layers of carbonate separated by layers of alternately arranged calcium and magnesium ions [17].

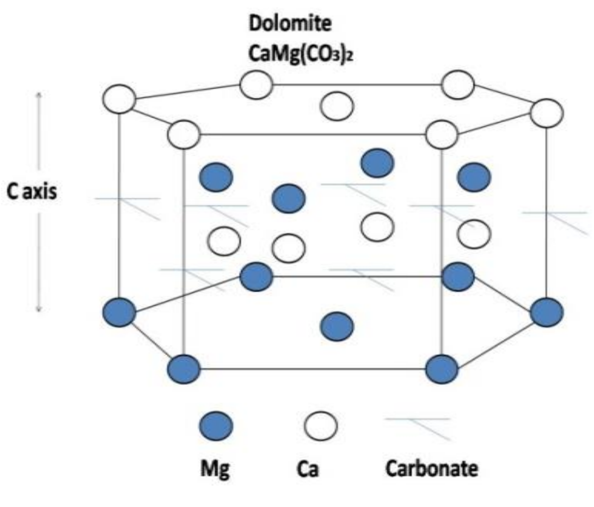

Figure 2. Ideal structure of stoichiometric dolomite

3. Use of Dolomite Powder in Various Industries

Dolomite powder is used for various purposes worldwide, as its composition is similar to limestone. In addition, dolomite is utilized as a flux in the production of ferro-alloys, iron, and steel. Based on the study, it is recommended that the rotary kiln method be preferred over the shaft kiln method for producing sintered dolomite to be used in steel plants, particularly under Indian conditions [18]. Dolomite plays a crucial role as a refractory raw material, predominantly utilized in iron and steel industries. After undergoing calcinations, it is extensively utilized for fettling and lining open-hearth steel production furnaces, basic steel converters, electric furnaces, cupolas, and other applications. However, one of the main challenges associated with the use of calcined dolomite is its tendency to hydrate upon exposure to air [19]. Fig.3 and Fig.4 show the sample of white dolomite powder and calcined dolomite powder respectively [20]. The responsible utilization of dolomite resources is intricately linked to the sustainability and life cycle considerations of construction materials [21].

Figure 3. White dolomite powder

Figure 4. Calcined dolomite powder

4. Properties of Dolomite Powder Added in Concrete

Among the properties, the effect of dolomite powder on the physical properties in the mechanical properties and microstructural characterization are discussed in detail.

4.1. Fresh State Properties

Dolomite powder added to concrete causes it to initially and ultimately set up more slowly [22]. Concrete mix with dolomite powder added shows improvement in workability and provides the proper required slump flow [23]. Dolomite powder improves the performance of the self-compacting mortar modified with slag-cement binder, according to one study [24]. Additionally, dolomite powder and fly ash, which take the place of pozzolanic filler, speed up the early hydration process of regular portland cement [25]. In addition, more water is needed to achieve the same flow diameter and uniformity due to the dolomite in alkali-activated slag [26].

4.2. Mechanical Properties

The crystalline structure of dolomite and its tiny particle size give it characteristics that are comparable to those of limestone. A pozzolanic substance known as dolomite powder improves not only the density but also strengthens the hardness of concrete. Concrete with a 25% dolomite powder addition has better compressive strength and more potential nucleation spots [27], [28]. Additionally, incorporating dolomite powder into cement mortar reduces strength loss and improves the overall strength of the mortar. To increase the strength of the concrete, 3:1 mixture of fly ash and dolomite powder produces adequate results [29]. Dolomite powder, which consists primarily of very tiny particles that form a dense microstructure, enhances not only compressive strength but also split tensile strength and flexural strength [30]-[32]. Dolomite powder is also used to granulated blast furnace slag geopolymer concrete to increase its compressive, split tensile, and flexural strengths [33].

4.3. Microstructural Characterization

In order to investigate the microstructure of the concrete with dolomite powder added, techniques including X-ray diffraction, mercury intrusion porosimetry, scanning electron microscopy, and others are used. These instruments offer an accurate and comprehensive image of the microstructure. With a grain size of roughly 20 mm, the calcined dolomite's morphology has been vividly seen using X-ray diffraction [34]. The hydration process is improved and the densification of interface structures is aided by the dolomite particles' fineness. In accordance with it, the dolomite microparticles have massive crystal phases and show similar morphology to the calcite. Dolomite addition increases the number of centers, which in turn triggers more intense crystallizations, which in turn increases the hydration rate. Along with that, dolomite powder acted as nuclei of crystallization, resulting in acceleration of product formation and refinement of products crystal size [35]. Alkali activated slag paste with dolomite inclusion rarely exhibits obvious new solid hydrated phases in X-ray diffraction, with the exception of the unreacted dolomite and calcite that persists. In contrast, increasing dolomite content is accompanied by a higher amount of hydration products, as a result of crystallization on the fine dolomite grains and better water absorption, [36]. Figure 5 shows SEM pictures that illustrate how the temperature of the calcinations process affects the morphology of the calcined powders. Images reveal changes in the size, distribution, and composition of MgO grains and other compounds as the calcinations temperature rises from 1100 ℃ to 1250 ℃.When the temperature is 1150 ℃, MgO grains are small and scattered in clusters, creating larger voids between the particles. As the temperature increases to 1200 ℃, the clusters and MgO grains grow larger, and are encompassed by CaO or other compounds. At 1250 ℃, the calcinations products exhibit the greatest degree of sintering, with some grain growth occurring. Compared to those at 1100 ℃, the MgO grains are roughly twice as large, with a tighter wrapping and fewer pores between the grains. Additionally, more MgO grains are enclosed by CaO and binary or ternary compounds are formed from the CMS system.

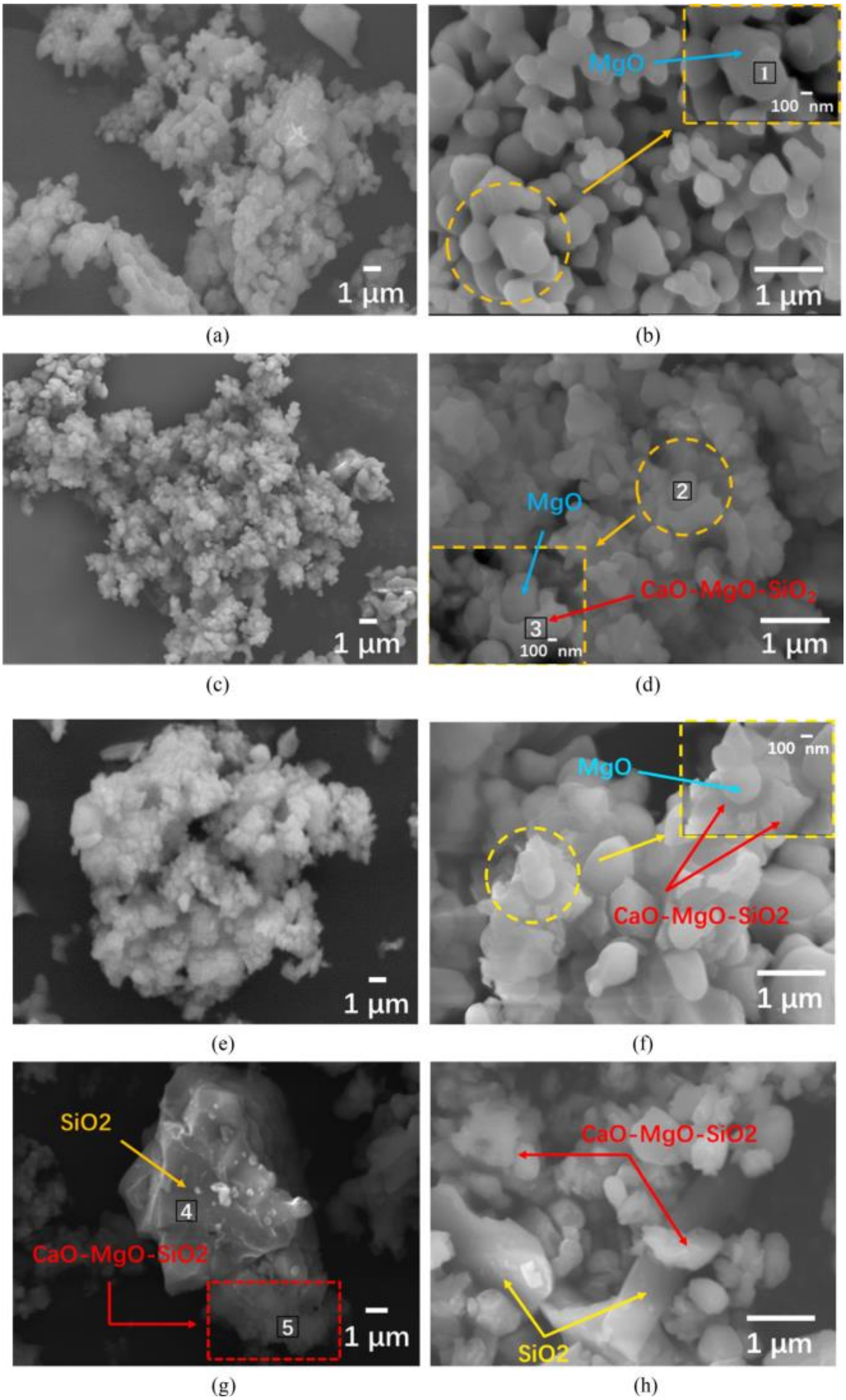

Figure 5. Scanning electron microscope images of dolomite-quartz powder after calcinations, (a and b) calcined sample T1150-R1.5 before grinding, (c and d) calcined sample T1200-R1.5 before grinding, (e and f) calcined sample T1250-R1.5 before grinding, (g and h) calcined sample T1200-R1.5 before grinding (g) and after grinding for 30 min in an agate mortar (h) [14].

5. Applications of Dolomite Powder and its Benefits to Concrete Industry

Dolomite powder is a versatile material used in a variety of applications, including as a substitute for limestone in the production of cement, in the construction industry to improve the strength and workability of concrete, and in the production of open-hearth steel furnaces, basic Bessemer converters, pipe, boiler covering as heat insulation, rubber, chemical industries, paper, leather, glass, potteries, filler in fertilizer, paints, varnishes, and in reducing dust in coal mines. In construction industries, dolomite powder can be used as a pozzolanic material and also as the main content in cement manufacturing. The addition of dolomite powder to concrete can improve its mechanical properties such as compressive and flexural strength, as well as its durability and resistance to environmental factors such as sulfate attack and alkali-silica reaction. Dolomite powder is a byproduct of the processing of dolomite rock, which is a naturally occurring mineral composed of calcium magnesium carbonate ($CaMg(CO_3)_2$). When used as a partial replacement of cement in concrete, dolomite powder reacts with the hydration products of cement to form calcium magnesium carbonate hydrates, which contribute to the strength and durability of the concrete.

In addition to its mechanical and durability benefits, the use of dolomite powder in concrete can also improve its workability and reduce the amount of cement required for a given strength. This can result in cost savings and a lower carbon footprint, as cement production is a significant source of greenhouse gas emissions.

Overall, the use of dolomite powder in concrete can produce a stronger, more durable, and more sustainable concrete mix.

6. Effects of Dolomite Powder on Mechanical Properties and Microstructural Characterization of Concrete

Several studies have investigated the effects of dolomite powder on the mechanical properties and microstructural characterization of concrete. Dolomite particles improve the early hydration process and form a dense microstructure in the concrete, which results in improved strength and workability. The calcined dolomite powder is more effective than the untreated dolomite powder due to its higher reactivity and improved pozzolanic properties. Research has shown that the addition of dolomite powder in concrete results in an increase in compressive strength, tensile strength, and flexural strength. Furthermore, dolomite powder can reduce the water-cement ratio and increase the density and porosity of concrete, which improves the durability and resistance to freeze-thaw cycles. The use of dolomite powder in concrete can also reduce the amount of cement required, which can lead to cost savings and reduced environmental impact.

Microstructural characterization studies have revealed that the incorporation of dolomite powder in concrete leads to a denser and more compact microstructure with reduced voids and improved interfacial transition zones. The formation of calcium silicate hydrate (C-S-H) gel is enhanced with the addition of dolomite powder, leading to improved bonding between the cement paste and aggregates.

7. Conclusions

While studying the existing literature, it is understandable that dolomite powder has emerged as a potential supplementary cementitious material in the construction industry due to its abundant availability and chemical similarity to lime. To summarize, the incorporation of dolomite into concrete results in notable effects on its properties. Dolomite addition increases the number of centers, leading to intensified crystallization and an accelerated hydration rate. This process is accompanied by the formation of a thin layer of calcium hydroxide growths consisting of plate crystals with perfect cleavage on the cement particle surfaces. Over time, this layer thickens, reaching up to 4 µm after 90 days, resulting in a pronounced densification of the concrete structure. The modified concrete structure exhibits improved adhesion at the interface layer, leading to increased strength and density. However, when incorporating dolomite limestone in quantities exceeding 5 wt. % or 25 wt. %, a reduction in compressive strengths is observed after 14 and 28 days. Notably, specimens containing 25% dolomite limestone powder by weight demonstrate the highest compressive strengths. These findings highlight the technical benefits of adding dolomite to concrete. It contributes to structural improvement and densification while potentially enhancing early strength, without compromising the long-term properties of the concrete. Understanding these mechanisms provides valuable insights for optimizing the utilization of dolomite in concrete applications, thereby promoting sustainable and efficient construction practices.

REFERENCES

[1] P. K. Mehta, “Greening of the concrete industry for sustainable development”, Concrete International, July 2002.

[2] J. Yu, J. Qian, F. Wang, J. Qin, X. Dai, C. You, X. Jia, “Study of using dolomite ores as raw materials to produce magnesium phosphate cement”, Construction and Building Materials, Vol. 253(2020), pp. 119147, 9 April 2020, DOI: 10.1016/j.conbuildmat.2020.119147.

[3] J. Xu, D. Lu, S. Zhang, Z. Xu & R.D. Hooton, "Reaction mechanism of dolomite powder in Portland-dolomite", Cement, Construction and Building Materials, Vol. 270, pp. 121375 18 October 2020, DOI: 10.1016/j.conbuildmat.2020.121375.

[4] J. Yu, J. Qian, F. Wang, Z. Li &X. Jia, "Preparation and properties of a magnesium phosphate cement with dolomite", Cement and Concrete Research, Vol. 138(2020), pp. 106235, 24 September 2020, DOI: 10.1016/j.cemconres.2020.106235.

[5] E.A. Azimi, M.M.A. B. Abdullah, P.Vizureanu, Mhd. A.A. Mhd. Salleh, A.V. Sandu, J. Chaiprapa, S. Yoriya, K. Hussin and I.H. Aziz, "Strength Development and Elemental Distribution of Dolomite/Fly Ash Geopolymer Composite under Elevated Temperature", Materials, 24 February 2020, DOI: 10.3390/ma13041015.

[6] M.S. Shety, "Concrete Technology: Theory and Practice", S. Chand, 8th revised edition, 2008, pp. 628.

[7] P.C. Sena, M.R.K. Rao a& H.V.B. Rao, "Indian Dolomites: A Raw Material Study", Transactions of the Indian Ceramic Society, 11 Jul 2014.

[8] S.L. Reddy, R. L. Frost, G. Sowjanya, N. C. G. Reddy, G. S. Reddy, and B. J. Reddy, "EPR, UV-Visible, and Near-Infrared Spectroscopic Characterization of Dolomite", Advances in Condensed Matter Physics, Vol. 2008, 21 October 2008, DOI: 10.1155/2008/175862.

[9] Rahul Divekar, 2023, Figure 1: Graphical Representation for Oxide Compositions of OPC, Lime and Dolomite.

[10] J.R. Goldsmith & D. L. Graf, "Structural and Compositional Variations in Some Natural Dolomites", University of Chicago and Illinois State Geological Survey, 12 October 2016, DOI: 10.1086/626547.

[11] A. Gruszecka-Kosowska, M. Wdowin, T. Kosowski& A. Klimek, "An analysis of the chemistry, mineralogy and texture of waste dolomite powder used to identify its potential application in industry", Geology, Geophysics & Environment, Vol. 41(4), pp. 343-352, December 2015, DOI: 10.7494/geol.2015.41.4.343.

[12] I.B. Ivanishin& H. A. Nasr-El-Din, "Effect of Calcium Content on the Dissolution Rate of Dolomites in HCl Acid", Journal of Petroleum Science and Engineering, Vol.202, pp. 108463, 23 January 2021, DOI:10.1016/j.petrol.2021.108463.

[13] T.Madhu, B.N. Swamy, U.I. Basha&M.Rajasekhar, "Dolomite Mineral Occurrence In NarpalaMandal In Ananthapuramu District, Andhra Pradesh, South India", IJSTR, Vol. 8, Issue 12, December 2019.

[14] F.M.V. Tuyl, "The Origin of Dolomite", R. Henderson, State Printer, 1 January 1916, pp. 180.

[15] Government of India, "Indian Minerals Yearbook 2015", Part-III: Minerals Reviews, 54th Edition, Ministry of Mines Indian Bureau of Mines, January, 2017.

[16] V. Purohit, "Strengthening of Concrete by Incorporation of Nano-Silica and Dolomite Powder", International Journal of Engineering Research & Technology, Vol. 8 Issue 05, pp. 358-367, May-2019.

[17] J. Warren, "Dolomite: occurrence, evolution and economically important associations", Earth-Science, Vol. 52(2000), pp. 1-81, 7 July 2000, DOI: 10.1016/s0012-8252(00)00022-2.

[18] M.R. Rao, P.C. Sena & H.V.B. Rao, "A Study on the Suitability of some Indian Dolomite for Use in Steel Plants", Transactions of the Indian Ceramic Society, 11 Jul 2014, DOI: 10.1080/0371750X.1963.10855467.

[19] P.R. Matos, R. Pilar, L.H. Bromerchenkel, R.A. Schankoski, P. J. P. Gleize & J. Brito, "Self-compacting mortars produced with fine fraction of calcined waste foundry sand (WFS) as alternative filler: Fresh-state, hydration and hardened-stateproperties", Journal of Cleaner Production, Vol. 252(2020), pp. 119871, 28 December 2019, DOI: 10.1016/j.jclepro.2019.119871.

[20] Indiamart(Dolomite photos), https://dir.indiamart.com/search.mp?ss=Dolomite+powder&mcatid=148853&catid=184&prdsrc=1&stype=attr=1|attrS&res=RC4"

[21] V. Vaganov, A. Kireev, S. Avdeev, G.Šahmenko& M. Šinka, "Prospects for Effective Use of Dolomite in Concrete Compositions", Construction Science, Vol. 19, pp. 27–32, 19/2016, DOI: 10.1515/cons-2016-0008.

[22] J. Xu, J. Chen, D. Lu, Z. Xu & R.D. Hooton, "Effect of dolomite powder on the hydration and properties of calcium sulfoaluminate cements with different gypsum contents", Construction and Building Materials, Vol. 225(2019), pp. 302-310, 7 July 2019, DOI: 10.1016/j.conbuildmat.2019.07.050.

[23] S. Muthukumaran, N. Muralimohan& P. Sudha, "Investigation on Strengthening of Concrete with Partial Replacement of Dolomite and M-Sand for Cement and Fine Aggregate", International Journal of Research in Engineering, Science and Management, Volume-1, Issue-10, pp. 94-99 October-2018.

[24] Hoang-Anh Nguyen, "Enhancement of engineering properties of slag-cement based self-compacting mortar with dolomite powder", Journal of Building Engineering, Vol. 24(2019), pp. 100738, 13 March 2019.

[25] H. Nguyen, T. Chang, J. Shih, H.S. Djayaprabha, "Enhancement of low-cement self-compacting concrete with dolomite powder", Construction and Building Materials, Vol. 161(2018), pp. 539-546, 27 November 2017, DOI: 10.1016/j.jobe.2019.100738.

[26] H. Yea, C. Fub & G. Yang, "Influence of dolomite on the properties and microstructure of alkali activated slag with and without pulverized fly ash", Cement and Concrete Composites, Vol. 103(2019), pp. 224-232, 15 May 2019, DOI: 10.1016/j.cemconcomp.2019.05.011.

[27] O. Mikhailovaa, G. Yakovlevb, I. Maevac & S. Senkov, "Effect of Dolomite Limestone Powder on The Compressive Strength of Concrete", Procedia Engineering, Vol. 57(2013), pp. 775-780, 2013, DOI: 10.1016/j.proeng.2013.04.098.

[28] Z. Chen, M. Deng & P. Liu, "Application of light-burnt dolomite as mineral addition in concrete", ICE Publishing, 26 March 2019, DOI: 10.1680/jadcr.18.00206.

[29] S. Barbhuiya, "Effects of fly ash and dolomite powder on the properties of self-compacting concrete", Construction and Building Materials, Vol. 25(2011), pp. 3301-3305, 27 March 2011, DOI: 10.1016/j.conbuildmat.2011.03.018.

[30] G. Preethi& A. G. Prince, "Effect of Replacement of Cement with Dolomite Powder on the Mechanical Properties of Concrete", IJISET, Vol. 2 Issue 4, April 2015.

[31] G.V.V Satyanarayana, B.V.N Ravi Teja Reddy, "Effect of Dolomite Powder on Mechanical Properties of M40 Grade Concrete When Cement was Partially Replaced", IJITEE, Vol. 8, No. 12, October 2019, DOI:10.35940/ijitee.L2670 .1081219.

[32] L.R. Kumar, J. Kiran & P. Rangarajan, "Properties of Concrete Incorporating Dolomite Powder, IOSR Journal of Mechanical and Civil Engineering", Volume 14, Issue 2, pp. 78-80, Mar. - Apr. 2017 DOI: 10.9790/1684-1402027880.

[33] P. Saranya, P. Nagarajan, A.P. Shashikala, P. A. Salam, "Flexural Behaviour of GGBS-Dolomite Geopolymer Concrete Beams under Cyclic Loading", Materials Science Forum, Vol. 969, pp 291-296, 17 Feb 2019, DOI: 10.4028/www.scientific.net/MSF.969.291.

[34] M. Baghriche, S. Achour& O. Baghriche, "Combined effect of cement kiln dust and calcined dolomite raw on the properties of performance magnesium phosphate cement", Case Studies in Construction Materials, Vol. 13(2020), pp.386, 18 May 2020, DOI: 10.1016/j.cscm.2020.e00386.

[35] Y. Huamei, H. Zhen & S. Yixin, "Early Carbonation Behavior of High-volume Dolomite Powder-cement Based Materials", Journal of Wuhan University of Technology-Mater. Sci. Ed., pp. 541-549, June 2015, DOI: 10.1007/s11595-015-1186-6.

[36] M. Szybilskia& W. N. Wczelik, "The effect of dolomite additive on cement hydration", Proceeding Engineering, Vol. 108(2015), pp. 193–198, 2015, DOI: 10.1016/j.proen g.2015.06.136.