Influence of Diatomite on the properties of mortar and concrete: A Review

1*Neha Sharma, 2Prashant Sharma, 3 Sujit kr Verma
1* Research Scholar Department of Civil Engineering, GLA UNIVERSITY, Mathura 281406, INDIA
2Assistant Professor Department of Civil Engineering, GLA UNIVERSITY, Mathura 281406, INDIA
3Associate Professor Department of Civil Engineering, GLA UNIVERSITY, Mathura 281406, INDIA

1*Corresponding author Email: neha.sharma@glau.ac.in

Abstract. Pozzolanic additives set off a fundamental part of high strength and most durable concrete mix design. Pozzolanic materials include natural products such as volcanic product (ashes and pumice) and by-product includes metakaolin, rice husk ash, silica fume, fly ash etc. Diatoms have been utilized as one of the pozzolanic additives in industrial sectors and construction industries to improve the rheological and mechanical properties of cement. Diatomite is sedimentary rocks comprised of amorphous or active silica as its main origin. It is being used very frequently as a pozzolanic additive in cement mortar and concrete. It has manifested appreciable effect in altering mechanical and chemical properties of cement. This paper gives an outlook of the work executed on application of diatomite as partial replacement for Portland cement in mortar and concrete. Different mechanical and rheological properties of cement and concrete containing raw diatomite have been widely discussed in the paper.

Keywords: Diatomite; Mortar; Concrete; Sedimentary rock; Chemical properties

1. Introduction
Diatomite, also termed as diatomaceous, is naturally occurring amorphous siliceous sedimentary rock composed of fossilized diatoms. It is soft siliceous rock that crushed into white powder having abrasive feel, low density and high porosity. Remains of microscopic single-celled algae (diatoms) from marine sediments leads to the formation of diatomite. Died diatoms settled down on the bottom part of oceans, sea beds or lake and then it fossilized [1]. Recently, many researchers used bacteria in concrete to
enhance the durability and minimize the cracks[2]–[5]. It is a class of microalgae that occurs in world’s large oceans, waterways and different soil profiles. Both salty sea water and fresh water sources consists of fossilized diatoms as its origin[6]. Diatoms found to have in whitish appearance however some of its verities have darkened color due to different kind of impurities present in it. It has been proven in ancient civilizations that application of diatom-rich limes lower down the temperature needed for mortar calcinations that is a crucial process to achieve hydraulic properties of cement. diatomite were also used as light building blocks in the dome of Hagias Sophia Museum, Istanbul, Turkey to minimize its weight and allowing it to last more than 1500 years[7]. The cost of diatomaceous earth varies considerably depending on the type and purity.

1.1. Chemical composition of diatomite
Typical composition of diatomite provided by different authors as per their usage has been given in the table. It is found to be highly porous, light weight, inert and chemically stable[8]. It contains 25 to 100 percent amorphous silica (opaline) [1]. Opaline cherts resembles the inherent chemical reactivity and differs in internal porosity of diatomite[9].

| SiO₂ | Al₂O₃ | MgO | CaO | TiO | LOI | REFERENCES |
|------|-------|-----|-----|-----|-----|------------|
| 92.0 | 0.05 | 2.40 | 0.01 | 0.11 | 6.01 | [10]       |
| 91.70 | 3.61 | 0.33 | 0.57 | 0.6 | - | [11]       |
| 89.0 | 3.00 | 0.7 | 0.4 | 0.2 | - | [6]        |
| 79.56 | 6.54 | 0.79 | 2.45 | - | 3.88 | [12]       |
| 74.37 | 8.416 | 1.45 | 1.9 | - | - | [13]       |
| 74.30 | 8.07 | 0.47 | 0.48 | 0.11 | 9.10 | [14]       |
| 67.20 | 10.09 | 0.63 | 1.36 | - | - | [15]       |
| 37.58 | 5.23 | 0.74 | 32.99 | - | 26.74 | [16]       |
| 69.20 | 9.49 | 0.64 | 1.63 | - | 2.76 | [8]        |
| 72.3 | 6.07 | 0.23 | 0.4 | 0.21 | 10.3 | [17]       |

1.2. Application of Diatomite
Diatomite found its application in distinct field of engineering. It has been widely used as a filtrating agent followed by functional fillers in different kind of paints as well as in plastics[8]. Diatomaceous earth originates from diatoms has typically found its multiple uses in chromatography, soil thickener drilling, insecticides, soil amendment, nanotechnology, thermal insulation, capacitors, separation techniques, super hydrophobic, pharmaceutical, biomedical applications, building materials, water and Beer filtration etc[7].

Diatomite application advantages
- Increase in surface area
- Improved mechanical properties
- Higher sulphate resistance
- Excellent durability
- Increased compressive strength

1.3. Reaction Mechanism
The addition of diatomite in cement prefers the hydration process and also helps in the strength development of the cement. kastis et al found that relative strength of cement incorporated with diatomite have higher relative strength as compared to ordinary cement at all curing stages.[16] At early stages, the dilution effect has been counteract by filler effect of diatoms and leads to slightly increased relative strength. This enhancement in strength accredited to the stoppage of the pozzolanic reaction at larger curing ages than the other blended cements, as lesser the cement content lesser will be the available calcium hydroxide left for the pozzolanic reaction[16]

2. Mechanical Properties
Effect of diatomite on mechanical properties of cement and concrete has been given below as:

2.1. Compressive strength
Posi et al carried out his work on pressed lightweight concrete using diatomite as an aggregate. He calcite fine and medium aggregate at 600º C and coarse aggregate at 400, 600, 800 & 1000ºC. He revealed that 28 days compressive strength of calcined DE pressed cube increases with increase in calcined temperature. Also, higher the amount of fine aggregate, higher will be its compressive strength as compared to control mix. The application of calcined Diatomaceous Earth aggregate found to enhances the compressive strength, and minimizes thermal conductivity when compared to normal aggregate[14].

Ahmad et al examined the properties of cement mortar by replacing 15, 30, and 40% (by dry weight of cement) of cementitious material by raw diatomite. He revealed that 3 days compressive strength of mortar cubes decreases by increasing the dosage of diatomite but this decrease has been compensated at higher curing ages as at higher curing stage, compressive strength increases by increasing the content of diatomite. Degrimenci et al investigated the effect of diatomite as partial replacement for Portland cement in mortar. He replaced 5, 10, and 15% of cement by diatomite keeping sand and water quantities constant for all mixes. It was reported that compressive strength of mortar specimen enhances by diatomite replacement except 5% diatomite content after 25 freeze thaw cycle. Compressive strength of cement concrete containing different amount of diatomite as fine aggregate has been shown in figure[14].

![Fig. 1 Compressive strength of concrete incorporated with different dosage of fine aggregate as diatomite][14]

2.2. Water absorption
Incorporation of diatomite in cement mortar (above 15%) slightly increases the moisture storage due to high specific area and porous behavior[8] (as shown in figure). Diatomaceous Earth has been extensively reactive towards lime in cement and concrete as it has high content of amorphous silica and also found to have unique particle size distribution that results in High specific surface area that affects the cement
paste consistency and increases the water demand. Due to higher specific surface area of diatoms, the capacity of water absorption enhances that results in higher plasticity value, water retention, workability, shorter carbonation times and crystal interlocking that leads to increased ultimate strength development. Due to pozzolanic behavior of diatoms, it leads to formation of greater amount of hydrated products and bound water increases with the proportion of diatomites in cement results in higher water paste demand.

![Figure 2: Water absorption of mortar incorporated with different amount of Diatomite][8]

2.3. Ultra sound pulse velocity
The ultrasound pulse velocity tests (UPV) is a non-destructive ultrasonic test and used to provide information about the porosity of materials in concrete. Theory of ultrasound transfer methodology is adopted for the material and porosity of the material is finding out by ultrasonic pulse velocity test. This is the customary technique used for knowing the porous structure and behavior of concrete material to find out the internal defects, voids, internal cracks and delimitations. Cement mortars specimens having diatomite powder revealed increased pulse velocity as compared to ordinary mortar specimen. 15% of replacement of cement by diatomite powder revealed maximum of 12% increase in the pulse velocity of cement mortars. This enhanced pulse velocity showed that diatomite when used in appropriate amount improve the pore structure as well as internal structure of cement mortars.
2.4. Workability
Flow ability of the fresh cement mortars specimen incorporated with diatomite powder reduces with increase in the amount of diatomite powder content. This decrement in flow value is due to enhancement in the amount of diatomite powder in mortar mix. The significant decrement in flow value of the cement mortar incorporated with diatomite is due to extremely greater fineness and specific surface area of diatomite powder. Diatomite powder has been approximately 2.5 times higher Blain’s specific surface area as compared to cement and found to have 10% lower specific gravity than that of cement. The increment in specific surface area surface area and decrement in specific gravity of diatomite powder as compared to cement is responsible for considerable enhancement in water absorption of diatomite powder and significant reduction of flowability of cement mortars incorporated with diatomite[10].

2.5. Scanning Electron Microscopy
Diatoms ameliorate the internal structure, strength as well as endurance of concrete structure. Incorporation of raw diatomite in cement causes enhancement in induction period and much greater second exothermic peak of the cement incorporated with diatomite. Diatomite cause strong increment in the heat flow. At very early stage of hydration, amorphous phases have been largely improved by the particle sizes and reactivity of diatomite. Diatomite lead to early formation of monosulphate SEM images revealed that the amount of ettringite and calcium hydroxide (CH) increases as finer the diatomite used in cement and concrete as shown in figure[18].
3. Conclusion
The following conclusions can be written from the whole literature review study:

- Due to filler packing characteristic of diatomite, compressive strength of the cement mortar incorporated with raw diatomite generally increases. The results on strength and transport properties represent a very effective and successful use of high volume raw diatomite powder to produce an environmental-friendly and affordable cement-based material.

- Due to high specific surface area and higher paste water demand of diatomite, Flowability of fresh cement mortars considerably reduces with escalation in diatomite content. So addition of diatomite in cement and concrete improves workability and minimize segregation and bleeding of water.

- Due to pozzolanic action of diatomite, incorporation of raw diatomite in cement and concrete increases the tensile strength of specimens at higher curing stages.

- Ultrasonic Pulse velocity of the cement mortar specimens containing diatomite generally found to be much higher than that of ordinary specimen. this increment in pulse velocity represents that diatomite powder augmented the internal pore structure of cement and concrete matrix.

Hence the use of diatomite in cement and concrete within permissible amount helps in improvement in mechanical properties, strength, density, durability, thermal conductivity and the frost resistance of concrete as compared to ordinary concrete.
References

[1] O. M. Jensen and P. F. Hansen, “Water Entrainment in Concrete: Techniques and Optimum Size of Inclusions,” *Aalborg Dep. Mech. Eng., Aalborg Univ.*, 2001.

[2] P. Sharma, N. Sharma, P. Singh, M. Verma, and H. S. Parihar, “Examine the effect of setting time and compressive strength of cement mortar paste using iminodiacetic acid,” *Mater. Today Proc.*, 2020, doi: 10.1016/j.matpr.2020.04.336.

[3] P. Kumar Tiwari, P. Sharma, N. Sharma, M. Verma, and Rohitash, “An experimental investigation on metakaolinite GGBS based concrete with recycled coarse aggregate,” *Mater. Today Proc.*, no. xxxx, 2020, doi: 10.1016/j.matpr.2020.07.691.

[4] A. K. Parashar, N. Gupta, K. Kishore, and P. A. Nagar, “An experimental investigation on mechanical properties of calcined clay concrete embedded with bacillus subtilis,” *Mater. Today Proc.*, Sep. 2020, doi: 10.1016/j.matpr.2020.08.031.

[5] A. K. Parashar and A. Gupta, “Investigation of the effect of bagasse ash, hooked steel fibers and glass fibers on the mechanical properties of concrete,” *Mater. Today Proc.*, no. xxxx, 2020, doi: 10.1016/j.matpr.2020.10.711.

[6] S. Anthony, “Use of diatomaceous earth as a siliceous material in the formation of alkali activated fine-aggregate limestone concrete,” no. June, 2009.

[7] *Diatoms: Fundamentals and Applications*. 2019.

[8] N. Degirmenci and A. Yilmaz, “Use of diatomite as partial replacement for Portland cement in cement mortars,” *Constr. Build. Mater.*, vol. 23, no. 1, pp. 284–288, 2009, doi: 10.1016/j.conbuildmat.2007.12.008.

[9] R. C. Mielenz, K. T. Greene, and N. C. Schieltz, “Natural pozzolans for concrete,” *Econ. Geol.*, vol. 46, no. 3, pp. 311–328, 1951, doi: 10.2113/gsecongeo.46.3.311.

[10] Z. Ahmadi, J. Esmaeili, J. Kasaei, and R. Hajialioghli, “Properties of sustainable cement mortars containing high volume of raw diatomite,” *Sustain. Mater. Technol.*, vol. 16, no. 2017, pp. 47–53, 2018, doi: 10.1016/j.susmat.2018.05.001.

[11] J. Zahalkova and P. Rovnanikova, “Study of the effect of diatomite as a partial replacement of cement in cement pastes,” *Mater. Sci. Forum*, vol. 865, pp. 22–26, 2016, doi: 10.4028/www.scientific.net/MSF.865.22.

[12] H. Gerengi, Y. Kocak, A. Jazdzewska, M. Kurtay, and H. Durgun, “Electrochemical investigations on the corrosion behaviour of reinforcing steel in diatomite- and zeolite-containing concrete exposed to sulphuric acid,” *Constr. Build. Mater.*, vol. 49, pp. 471–477, 2013, doi: 10.1016/j.conbuildmat.2013.08.033.

[13] Mehmehdi Vehbi GÖKÇE, “Use of diatomite in the production of lightweight building elements with cement as binder,” *Sci. Res. Essays*, vol. 7, no. 7, pp. 774–781, 2012, doi: 10.5897/sre11.236.

[14] P. Posi, S. Lertnimoolchai, V. Sata, and P. Chindapasri, “Pressed lightweight concrete containing calcined diatomite aggregate,” *Constr. Build. Mater.*, vol. 47, pp. 896–901, 2013, doi: 10.1016/j.conbuildmat.2013.05.094.

[15] I. B. Topçu and T. Uygunoğlu, “Properties of autoclaved lightweight aggregate concrete,” *Build. Environ.*, vol. 42, no. 12, pp. 4108–4116, 2007, doi: 10.1016/j.buildenv.2006.11.024.

[16] D. Kastis, G. Kakali, S. Tsivilis, and M. G. Stamatakis, “Properties and hydration of blended
cements with calcareous diatomite,” *Cem. Concr. Res.*, vol. 36, no. 10, pp. 1821–1826, 2006, doi: 10.1016/j.cemconres.2006.05.005.

[17] L. Xiao, Z. Zhao, R. Li, and J. Hu, “Research on diatomite high-performance concrete admixtures,” *Key Eng. Mater.*, vol. 517, pp. 371–375, 2012, doi: 10.4028/www.scientific.net/KEM.517.371.

[18] R. Liu, Y. Yang, X. Zhao, and B. Pang, “Quantitative phase analysis and microstructural characterization of Portland cement blends with diatomite waste using the Rietveld method,” *J. Mater. Sci.*, vol. 56, no. 2, pp. 1242–1254, 2021, doi: 10.1007/s10853-020-05429-1.