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The Effects of Diatomite on Cement Mortar and Concrete: A Review

*Mohan Gupta**

ABSTRACT

Pozzolanic additions form the cornerstone of the strongest and longest-lasting concrete mix designs. By-products including metakaolin, fly ash, silica fume, rice husk ash, and other naturally occurring materials like volcanic ash and pumice are examples of pozzolanic materials. One pozzolanic addition that has been used in the building and industrial sectors to enhance the rheological and mechanical qualities of cement is diatoms. As a sedimentary rock, diatomite is mostly composed of amorphous or active silica. It is widely used in concrete and cement mortar as a pozzolanic addition. It has clearly changed the cement's mechanical and chemical characteristics. The work that has been done to partially replace Portland cement in mortar and concrete with diatomite is discussed in this study. The paper goes into great detail into the various mechanical and rheological properties of cement and concrete, including raw diatomite.

Keywords: *Cement mortar; Cement concrete; Diatomite.*

1.0 Introduction

The naturally occurring amorphous siliceous sedimentary rock known as diatomite, or diatomaceous, is composed of fossilised diatoms. It is a low-density, soft, siliceous rock that is porous and has an abrasive texture that is ground into a white powder. Diatomite, which was once discovered in coastal sediments, is derived from diatoms, which are small single-celled algae. Dead fossilised diatoms had dropped to the bottom of a lake, an ocean, or a sea bed [1]. Recently, numerous studies have employed bacteria in concrete[2]–[5] to increase durability and reduce cracks. It belongs to a class of microalgae that is found in many of the vast oceans, streams, and soil profiles around the globe. Fossilized diatoms are the source of both freshwater and saltwater [6]. Diatoms are typically pale, but a variety of pollutants have caused some of their varieties to exhibit deeper hues. Ancient civilizations have demonstrated that the use of diatom-rich limes lowers the temperature required for mortar calcinations, an important stage in determining the hydraulic qualities of cement. In order to lighten the weight and lengthen the life of the dome of the Hagias Sophia Museum in Istanbul, Turkey, diatomite was also employed as light building material[7]. The kind and purity of diatomaceous earth have a big impact on the cost.

1.1 Chemical composition of diatomite

The table below lists the typical diatomite composition as reported by different writers according to its intended use. Its characteristics have been discovered to be extremely porous, lightweight, chemically stable, and inert [8].

**Assistant Professor, Department of Mechanical, Engineering, United College of Engineering and Research, Prayagraj, Uttar Pradesh, India (E-mail: researchworkhub@gmail.com)*

It is composed of 25–100% amorphous silica (opaline) [1]. Opaline cherts differ from diatomite in terms of internal porosity, however they share a comparable inherent chemical reactivity[9].

Table 1: Chemical Properties of Diatomite

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 has been used in engineering for a while. It has been widely utilised as a filtration agent in various paints and polymers, with functional fillers coming in second [8]. Diatoms are the source of diatomaceous earth, which finds widespread use in a variety of applications such as chromatography, water and beer filtration, building materials, pesticides, soil amendments, nanotechnology, thermal insulation, capacitors, separation techniques, and soil thickener drilling [7].
The utilization of diatomite in concrete results in following adavantages:

- Increased surface area,
- enhanced mechanical characteristics,
- increased sulphate resistance,
- outstanding durability,
- increased compressive strength.

1.3 Reaction mechanism

The addition of diatomite promotes the hydration process and increases the strength of the cement. Kastis et al. claim that diatomite-incorporated cement is more resilient than regular cement during the whole curing process. [16] Because of the partial offset of the dilution impact by the diatom filling effect, the relative strength is slightly higher early on. The reason for this gain in strength is because the pozzolanic process ends sooner than it does with other blended cements; the cement percentage decreases with the amount of calcium hydroxide left over for the pozzolanic reaction [16].

2.0 Mechanical Properties

2.1 Compressive strength

For their experiment, Posi and colleagues employed diatomite as an aggregate in pressed lightweight concrete. He used 400o C for calcining coarse aggregate, 600o C for fine and medium aggregate, and 600o, 600, 800, and 1000o C for fine and medium aggregate. He discovered that when

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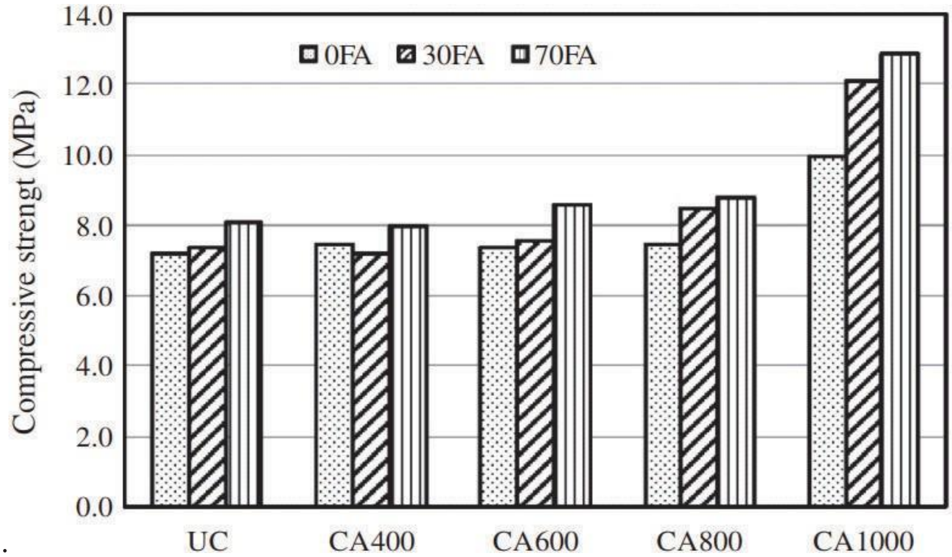
the calcining temperature rises, the compressive strength of calcined DE pressed cubes increases by 28 days. Furthermore, when the amount of fine aggregate increases, the compressive strength will grow relative to the control mix. When compared to regular aggregate, the usage of calcined Diatomaceous Earth aggregate was found to increase compressive strength and decrease heat conductivity [14]. In order to investigate the characteristics of cement mortar, Ahmad et al. substituted raw diatomite for 15, 30, and 40% (by dry weight of cement) of cementitious material. When the dose of diatomite is increased, mortar cube compressive strength decreases by 3 days; however, this decrease is compensated for at higher curing ages when compressive strength increases by increasing the diatomite content. Degrimenci et al. looked into using diatomite in mortar as a partial replacement for Portland cement. He substituted diatomite for 5, 10, and 15% of the cement in each mix, but kept the amounts of sand and water constant. Diatomite substitution is claimed to increase the compressive strength of mortar specimens, with the exception of the 5 percent diatomite concentration after 25 freeze-thaw cycles. Figure 1 illustrates the compressive strength of cement concrete with different proportions of diatomite as fine aggregate.[14]

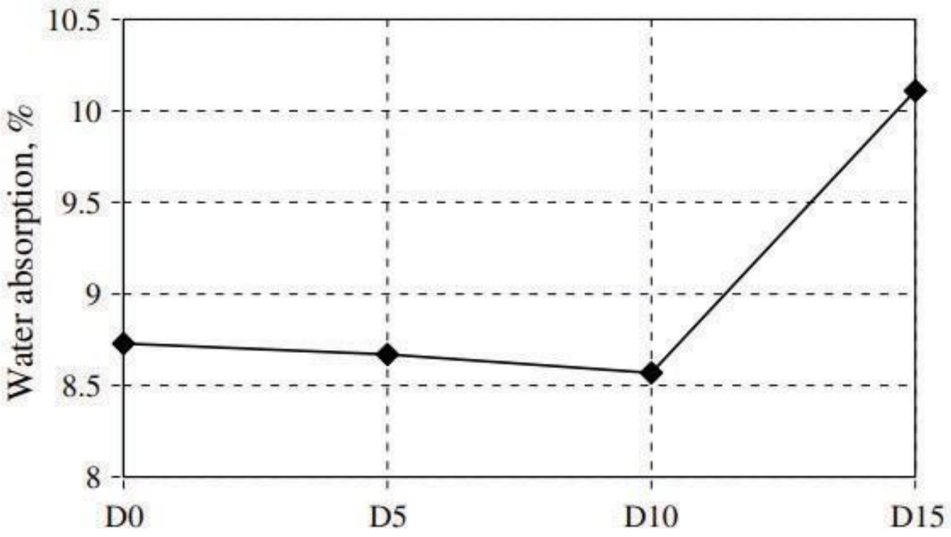
Figure 1: Compressive Strength of Concrete Incorporated with Different Dosage of Fine Aggregate as Diatomite[14]



2.2 Water absorption

Due to its wide specific area and porous nature, diatomite incorporation in cement mortar (over 15 percent) significantly increases moisture storage [8]. (as shown in figure). Diatomaceous earth's unique particle size distribution and high amorphous silica concentration have been found to make it very reactive to lime in cement and concrete. This changes the cement paste's fluidity and raises the need for water. Diatoms have larger specific surfaces than other materials, so they can absorb more water more effectively. This improves their workability, plasticity value, and water retention. It also shortens carbonation times and improves crystal interlocking, which further contributes to the development of ultimate strength. As the amount of diatomite in cement increases, more hydrated products are formed as a result of the pozzolanic activity of diatoms [16]. This increases the need for water paste.

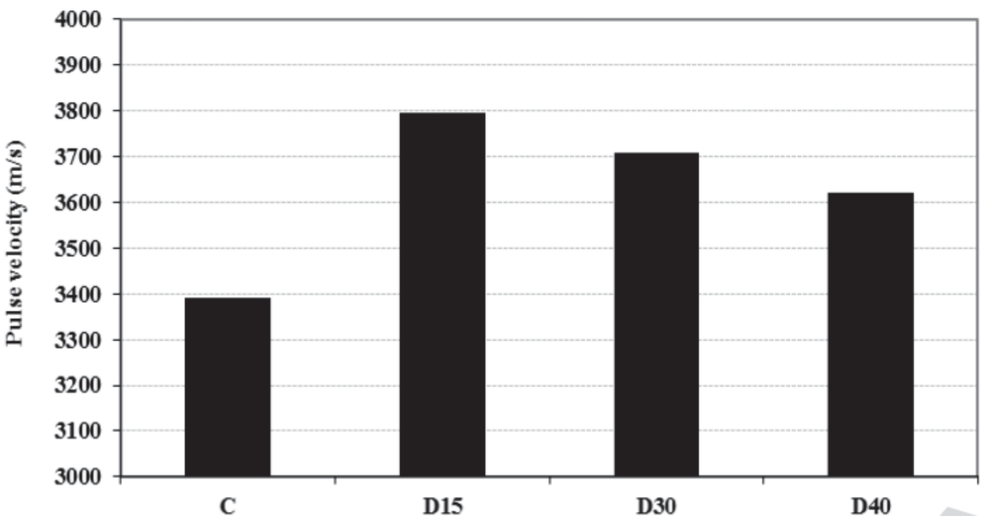
Figure 2: Water Absorption of Mortar Incorporated with Different Amount of Diatomite[8]



2.3 Ultra sound pulse velocity

To determine how porous the components of concrete are, a non-destructive ultrasonic technique called the ultrasound pulse velocity test (UPV) is utilised. The porosity of the material is assessed using an ultrasonic pulse velocity test, which is based on the theory of ultrasonic transmission techniques. This is the standard procedure for assessing the porosity behaviour and structure of concrete in order to identify internal defects, voids, cracks, and delimitations. The pulse velocities of cement mortar samples containing diatomite powder were higher than those of standard mortar specimens. The pulse velocity of cement mortars increased by no more than 12 percent when cement was replaced with 15 percent diatomite powder. This increased pulse velocity demonstrated how cement mortars' internal and pore structures can be improved by adding the right amount of diatomite[10].

Figure 3: Pulse Velocity of Mortar Incorporated with Different Dosage of Diatomite[10]



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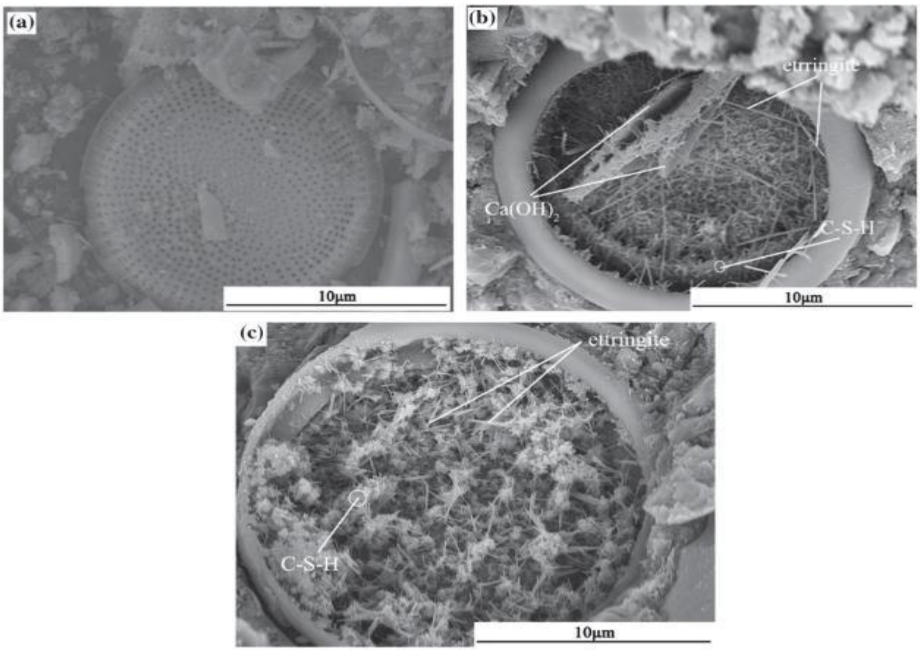
2.4 Workability

As the quantity of diatomite powder increases, the fresh cement mortar specimens combined with it lose their ability to flow. The addition of more diatomite powder to the mortar mixture resulted in a decrease in flow value. The much-increased fineness and specific surface area of the diatomite powder are the reason for the significantly lower flow value of the cement mortar containing diatomite. Diatomite powder has around 2.5 times more specific surface area than cement and a specific gravity that is 10% lower than cement's. Diatomite powder absorbs more water due to its greater specific surface area and lower specific gravity when compared to cement, which significantly reduces the flowability of cement mortars that use diatomite powder [10].

2.5 Scanning electron microscopy

Diatoms enhance the durability, strength, and internal structure of concrete structures. The induction period and the second exothermic peak are both noticeably extended when cement is mixed with raw diatomite. Heat flow is greatly increased by diatomite. Amorphous phases have profited considerably from the diatomite's particle sizes and reactivity from very early on in the hydration process. According to SEM scans, as shown in figure[18], the finer the diatomite used in cement and concrete, the more ettringite and calcium hydroxide (CH) there is. Monosulphate develops early due to diatomite.

Figure 4: SEM Images of Diatomite at 1, 3 and 27 Day[18]



3.0 Conclusion

This review study has following conclusions:

- Due to diatomite's filler packing ability, cement mortar containing raw diatomite usually has a higher compressive strength. The strength and transport properties results demonstrate the potential of using high-volume raw diatomite powder to produce an inexpensive, green cement substitute.

- Because diatomite has a large specific surface area and requires more paste water, the flowability of fresh cement mortars drops dramatically as the diatomite percentage increases. To make concrete and cement more workable and to lessen water leakage and segregation, diatomite is added.
- Because of the pozzolanic activity of raw diatomite, adding it to cement and concrete boosts the specimens' tensile strength at later stages of curing.
- It was frequently discovered that specimens of cement mortar containing diatomite had a significantly higher ultrasonic pulse velocity than typical specimens. This rise in pulse rate indicates that diatomite powder improved the internal pore structure of the cement and concrete matrix.

Therefore, when used in appropriate amounts, diatomite in cement and concrete improves the mechanical qualities, strength, density, durability, thermal conductivity, and frost resistance of the latter over regular concrete.

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