Effect of Dolomite Powder and Copper Slag on Mechanical Properties of Concrete: A Review

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Abstract - *One of the most essential components of concrete is cement. Cement is responsible for the majority of the properties of concrete. Cement is made by heating argillaceous and calcareous materials to a high temperature. A significant amount of CO_2 is released into the atmosphere during this process. The decrease in cement consumption will lower the cost of concrete while simultaneously lowering CO_2 emissions. Carbon dioxide levels from concrete manufacture have contributed for 5% of worldwide total carbon emissions. At the same time, the number of industrial waste produced grows year after year. Copper slag, a non-toxic and non-hazardous waste material, has recently attracted experts' curiosity as a building material. This work primarily reviews recent relevant literature, critically examines copper slag performance, and considers the influence of partial substitute of copper slag on effectiveness. Copper slag waste is a common byproduct of the copper industry. The mechanical properties of concrete are investigated when fine aggregate is partly substituted with copper slag and cement partly substituted with dolomite powder in this review paper. This review includes a complete observational research on compression, split tensile and flexural strength test after 28 days. From literature review it was found that utilizing copper slag as substituted partly for sand up to 40% and dolomite powder substituted partly for cement between 5%-10% improved the concrete's mechanical qualities. According to the environmental effect analysis, using copper slag as a partial substitute can lessen the environmental impact and concrete costs can be reduced by using dolomite.*

Keywords: **Copper slag, dolomite powder, Aggregate, Concrete, Strength, Durability, Environmental impact.**

1. Introduction

Concrete has a long lifespan as well as tough structure. It has become the most extensively used building material in recent years. Cement manufacture produces a substantial amount of CO_2, which contributes to greenhouse emissions. Cement is produced by calcining argillaceous and calcareous rocks at a high temperature. During this process, a significant amount of CO_2 is emitted into the atmosphere. India is the second-largest cement producer in the world. Manufacturing one ton of cement is predicted to emit 0.8 tons of carbon dioxide. Reduction in cement consumption lowers the cost of concrete while simultaneously lowering carbon dioxide emissions. Since the beginning of the twentieth century, people have become increasingly concerned about pollution, the greenhouse effect, and other environmental challenges. As a result, the influence of cement on the environment should not be neglected. [7]

Dolomite powder, produced by grinding sedimentary rock that yields the mineral dolostone, can be utilized as partial substitute for cement in concrete. Dolomite powder shares some physical properties with cement. Dolomite is a calcium magnesium carbonate $CaMg(CO_3)_2$ mineral. Dolomite is a mineral that forms rocks and is known for its high wet ability and dispensability. Dolomite has a high resistance to weathering. Dolomite is a popular building material because of its high density and surface hardness. [13]

Year after year, amount of natural resources converted to industrial trash grows. In terms of sustainable development, reusing industrial byproducts is the safe and cost-effective solution. Over the last decade, there has been a surge in interest in the study of copper slag in concrete. These research have shown that copper slag has shown to be a useful material for increasing concrete performance.

The use of copper slag improves the properties of concrete and reduces the cost of reconstruction. Furthermore, the cement sector is one of the largest emitters of carbon dioxide. Copper slag can be added to cement-based materials to reduce the quantity of cement used in concrete production, helping to meet resource conservation and environmental goals. It is clear that, copper slag is clean material. Excessive grinding, on the other hand, will degrade the characteristics of the concrete, resulting in bleeding or a lengthy setting time. Furthermore, the impact of copper slag on the mechanical properties of a partial concrete substitute was investigated. For sustainability, copper slag can be used as a substitute. [9]

1.1. Need of study

Following are the need of study:

1. The utilization of copper slag in concrete production will help to address future fine aggregate shortage issues.
2. It will provide partial solutions for copper slag disposal.
3. Dolomite powder will aid in the development of sustainable infrastructure, reducing environmental risks.
4. Dolomite lowers construction costs by lowering the cost of concrete.

1.2. Objective of study

Below are the study's objectives:

1. Investigating the use of dolomite powder and copper slag to improve concrete properties.
2. To determine the optimal dosage of dolomite powder with copper slag for best results.
3. To calculate and compare the compressive strength of concrete with different dolomite powder and copper slag dosages. To create an environmentally friendly and low-cost building material.

2. Literature Review

By studying literature review from various authors some were concluded which are follows:

2.1. Literature review on copper slag

2.1.1. Effect of copper slag on compressive strength

Arivalagan et al. (2013) Find out that when the amount of copper slag in the mix grows up to 40%, the compressive strength of the concrete increases, but then declines dramatically due to increases in free water content in the mix. An overabundance of free water in mixes containing copper slag causes bleeding and segregation in concrete. As a result, the strength of the concrete is lowered. With 40% copper slag substitution, the greatest compressive strength was reported to be around 35.11N/mm^2. When compared to the control mix, the compressive strength has improved by more than 30%. When 100% of the sand is replaced with copper slag, the compressive strength is 20 MPa. [2]

Chavan et al. (2013) conducted a compressive strength test on M25 grade concrete with a 40% substitution of copper slag, which resulted in a compressive strength of 43MPa versus 30.36MPa for the control mixture. When compared to the control mix, the strength has increased by about 41.66% after 28 days. Mixtures with 100% copper slag replacement had the lowest compressive strength of 25.14MPa, which is roughly 3.9 percent less than the control mix's strength. [13]

Madheswaran et al. (2014) He discovered that when 50% copper slag was substituted, the compressive strength was around 42MPa, compared to 34MPa for the normal mix. The strength rose by almost 19% as compared to the control mix. According to the findings, the highest limit for sand replacement by Copper slag in standard concrete grades is 50%, and the upper limit for high strength concrete is 75%. [4]

Pranshu et al. (2015) determine that at 28 days, a 40% substitution of copper slag for M30 grade of concrete yielded the highest compressive strength, which was found to be around 46MPacompared to 32MPa for the normal mix. When compared to the normal mix at 28 days, this translates to a nearly 43% increase in strength. [16]

Patnaik et al. (2015) Discovered that by replacing up to 40% of the sand in concrete with copper slag, the compressive strength of the concrete was increased. At 28 and 90 days, M20 Grade Mix Concrete (40 percent copper slag replacement) had compressive strengths of 41N/mm^2 and 55 N/mm^2, respectively, compared to 36N/mm^2 and 44 N/mm^2 for the control mixture. The compressive strength of M30 grade concrete with 40% replacement with copper slag was 47 N/mm^2 and 57 N/mm^2 at 28 and 90 days, respectively, compared to 41 N/mm^2 and 51 N/mm^2 for the control mixture. When compared to Sand, Copper Slag has lesser water absorption capability. Because of the lower water absorption capability, there is more free water in the system, resulting in a drop in compressive strength. [3]

M.V.Patil et al. (2016) carried out research on M30 grade concrete mix. The compressive strength of cubes with different copper slag content as a substitute for fine aggregate at 7, 28, and 56 days curing time. The results show an increasing profile up to 40% copper slag substitution, and then a decreasing as more copper slag was substituted. The highest compressive strength was obtained at 40% copper slag replacement, which was around 35MPacompared to 25MPa for the control mix. This means that strength increased by nearly 42% compared to the control mix after 7 days. The concrete with 100% copper slag substitution had the lowest compressive strength of 23MPa, which was nearly 6.64 percent lower than the control mix. [9]

2.1.2. Effect of copper slag on Split tensile strength

Arivalagan et al. (2013) Split tensile strength was determined by testing 18 cylindrical specimens. Both compressive strength and tensile strengths of concrete behaved similarly. The results demonstrate that when the amount of copper slag added up to 40%, the split tensile strength value decreases but remains over 40% when compared to the normal mix. [2]

Patnaik et al. (2015) Carry out split tensile test on M20 and M30 grade of concrete mix. The split tensile of M20 grade of concrete with 40% substitution of copper slag was 2.2 N/mm^2 and 2.6N/mm^2, respectively, compared to 2.2N/mm^2 and 2.3N/mm^2 for the control mix at 28 and 90 days. The 28-day and 90-day split tensile of M30 grade of concrete mix with 40% copper slag substitution was 3N/mm^2 and 3.7N/mm^2, respectively, compared to 2.9N/mm^2 and 3.3N/mm^2 for the control mix. The results demonstrate that the Copper slag mixed at 40% in concrete mix has higher split tensile strength at the end of 28 day and 90 day time points when compared to normal mix. It was also discovered that when Copper slag mix concrete is compared to normal mix, the early strength gain is lower. Both M20 and M30 concrete were found to have this characteristic. [3]

Patil et al. (2015) Discovered that tensile and compressive strength acted in the same way. When compared to the control mix, the split tensile strength improves as the copper slag quantity grows up to a 20% addition; after that, the split tensile strength number declines somewhat but remains greater than 60%. [9]

Pranshu et al. (2015) Determines that the highest tensile strength was reached by substituting 40% copper slag for the control mixture at 28 days, which was found to be around 9.5MPacompared to 7.24MPa for the control mixture. When compared to the control mix at 28 days, this suggests that the strength has increased by over 31%. [16]

Anwar et al. (2018) Conducted experimental investigation on M40 grade concrete, sand was partly substituted with 40% of copper slag and cement was partly substituted with Silica Fume from 5-15%. This study provides a detailed observational study on split tensile strength at 28 day. When 40% substitution of copper slag is done, the split tensile increase by 9.8% compared to the control mix. [1]

2.1.3. Effect of copper slag on flexural strength

Arivalagan et al. (2013) Conduct test for flexural strength on eighteen beams, under two point loading conditions. The bending moment causes compressive stress at top of beam and tension at bottom of beam. In tension, the beam breaks. Flexural strength was 25N/mm^2 at 40% replacement, which is 33% higher than the control mix. [2]

Chavan et al. (2013) Found that flexural strength of concrete is greater than the normal mix for all percentage replacements of sand by copper slag. When sand is substituted with copper slag at 20%, the flexural strength increases by 14%. Also, flexural strength is higher for all % substitutes than for design mix. [13]

T.Ch.Madhavi et al. (2015) The flexural strength increased with increasing copper slag content up to 40%, but after that, the strength began to decrease. When compared to a standard mix, the flexural strength increases by 26.3%. [17]

Pranshu et al. (2015) Finds highest flexural strength after 28 days which was achieved with a 40% substitution of copper slag, which was found to be around 4.6MPacompared to 3.7MPa for the normal mix. This means the strength has increased by nearly 25% compared to the control mix after 28 days. [16]

Patnaik et al. (2015) Conducted flexural strength test on M20 and M30 grade concrete mix. On 28 days and 90 days, the flexural strength of M20 grade of concrete was 4.7N/mm^2 and 5.7N/mm^2, respectively, compared to 4.4N/mm^2 and 5.3N/mm^2 for the normal mix. The 28 days and 90 days flexural strength for M30 grade of concrete with substitution of 40% copper slag were 5.3N/mm^2 and 6.4N/mm^2, respectively, compared to 4.9N/mm^2 and 5.8N/mm^2 for the control mix. The results show that at 28 and 90 days, Copper slag mixed with substitution of 40% copper slag, concrete has higher flexural strength than normal concrete mix. [3]

Bhavagna et al. (2017) Casted prisms of size 150mm x 150mm x 150mm for various proportions of 20%, 30%, 40%, and 50% for M30 grade concrete mix. At the beginning, the strength gradually increased, and at 40% replacement of copper slag, the strength was highest, and as the percentage of copper slag increased further by 40%, strength decreases. [14]

Anwar et al. (2018) Conducted test on M40 concrete, the sand was partly substituted with 40% of copper slag and cement with silica fumes from 5- 15%. Author examines flexural strength at the end of 28 days in detail. As 40 percent copper slag was replaced, flexural strength rose by 8.7% when compared to the control mix. [1]

2.2. Literature review on Dolomite powder

2.2.1. Effect of dolomite on Compressive strength

Balakrishnan et al. (2013) Investigate the effects of dolomite powder as a substitute for cement and fly ash in self-compacting concrete. The maximal compressive strength of a combination including fly ash and dolomite powder (12.5% fly ash and 12.5% dolomite powder) as a 25% substitute was determined to be 50N/mm². [6]

Deepthi et al. (2016) Obtain the maximum compressive strength containing 30% tile aggregate + 10% dolomite. The maximum strength was 35N/mm² after tests on various mix designs. [5]

Kumar et al. (2017) Discovers that replacing cement with dolomite powder improves concrete strength. The optimal cement substitute proportion with dolomite was discovered to be 5%, and the highest enhancement in 28th day compression strength was discovered to be 5.8% at this partial replacement. At 5% replacement, the highest compressive strength was determined to be 31N/mm². [7]

Sugathan et al. (2017) Carried out research work on copper slag mechanical characteristics. According to the findings, compressive strength is highest when dolomite powder is added at 7.5%, and further addition reduces compressive strength. [15]

Bhusare et al. (2019) Discovered that ideal substitution percentage of cement with dolomite powder is 10%, and the extreme improvement in the 28th day compression strength is 10.4% at this substitution level. [11]

Dhamne et al. (2019) Discovered that compressive strength is increased by adding dolomite up to 10% of the wt. of cement, and that any further substitution of dolomite reduces compressive strength. At 10% substitution, the compressive strength obtained is 44.7N/mm², which is 13% higher than the control mix. [12]

2.2.2. Effect of dolomite on Split tensile strength

Sugathan et al. (2017) Investigated the effects of M sand (manufacturing sand) and dolomite on various concrete characteristics were investigated. The effect of dolomite on concrete formed from manufacturing sand at varied replacement percentages of 0 percent, 5 percent, 7.5 percent, 10 percent, and 15 percent with cement was discovered. At a cement replacement level of 7.5 percent by dolomite, the specimen's highest splitting tensile was discovered. [15]

Indira et al. (2017) Experiments were conducted to study the effect of dolomite as a cement substitute in concrete. Dolomite was used to replace cement at varying ratios of 0%, 5%, 10%, 15%, and 20%.The tensile strength of 5%, 10 %, 15%, and 20% dolomite was enhanced by 30.3, 53.48, 58.13, and 48.53% respectively. [8]

Bhusare et al. (2019) Did an experimental examination on M30 grade concrete and discovered that the best replacement level for split tensile strength is 5%, and at this substitution, the % improvement in split tensile is 7.5%. [11]

Dhamne et al. (2019) Conduct research on the mechanical properties of dolomite in concrete mix the obtained results show that the addition of dolomite increases split tensile strength by 10%, which was partially substituted by the wt. of cement, and that any further addition of dolomite resulted in the split tensile decreasing. The split tensile obtained at 10% replacement is 3.5N/mm², which is 9.7% higher than the normal mix. [12]

2.2.3. Effect of dolomite on Flexural strength

Preethi et al. (2015) Conduct research into the characteristics of concrete utilizing dolomite as a cement replacement. The effective replacement values for dolomite in concrete mixtures were determined to be 5 percent, 10 percent, 15 percent, and 20 percent. With a 10% substitution, the author discovered that substituting cement binder with dolomite enhances flexure strength by 17.78%. [10]

Kumar et al. (2017) Replaces cement with dolomite powder, which has been shown to increase concrete strength. In the various mixes, dolomite was used to replace 0% to 20% (5% interval) of the binding material cement. The optimal cement substitution percentage with dolomite was discovered to be 5%, and at this substitution, the highest increase in 28th day flexural strength was discovered to be 2.7%. At 5% replacement, the maximum flexural strength was 8.6N/mm². [7]

Indira et al. (2017) Conduct research to determine the impact of dolomite quarry waste as a cement and sand replacement in concrete. In the following quantities, dolomite was utilized to replace cement and sand: 0%, 5%, 10%, 15%, and 20%, respectively. The use of dolomite as cement in concrete was shown to increase flexure strength by 15%, however there was a reduction at 20%. The maximum flexure strength of 9.7MPa was discovered when 10% of the cement binder and river sand were replaced with dolomite quarry waste. [8]

Bhusare et al. (2019) Determine that, for M30 concrete the ideal substitution of cement with dolomite was found to be 5%, and at this substitution, the extreme increase in flexural strength was found to be 8.5% at the end of 28 days. [11]

3. Properties of dolomite and copper slag

Table 1: Chemical properties of copper slag

CHEMICAL CONSTITUENTS		
Ferric Oxide	Fe_2O_3	51.6
Silicon Dioxide	SiO_2	38.7
Calcium Oxide	CaO	2.2
Magnesium Oxide	MgO	1.26
Aluminum Oxide	Al_2O_3	2.88
Copper	Cu	0.68
Zinc	Zn	0.31
Lead	Pb	LT 0.01
Chloride	Cl	LT 0.01
Other oxide		LT 0.01
PH		7.2

Table 2: Physical properties of copper slag

PHYSICAL PROPERTIES	
Appearance	White Powder
Grade	500 fine mesh
Moisture content	Nil
Specific Gravity	2.85

Table 3: Chemical properties of dolomite

CHEMICAL CONSTITUENTS		
Calcium Oxide	CaO	52.48
Magnesium Oxide	MgO	35.23
Ferric Oxide	Fe_2O_3	0.29
Silicon Dioxide	SiO_2	3.32
Aluminum Oxide	Al_2O_3	0.19
Potassium Oxide	K_2O	LT 0.01
Other oxide		LT 0.01
Loss of Ignition LOI		42.99
PH		6.9

Table 4: Physical properties of dolomite

PHYSICAL PROPERTIES	
Appearance	Black, Glassy
Granule Shape	Angular, Sharp Edges, Multi Faced
Specific Gravity	3.51

Figure 1: Copper slag particles

Figure 2: Dolomite powder

4. Conclusion

Following are the conclusions from the review study:

1. Dolomite, when used as a cement substitute, increases the mechanical strength of the cement. According to the findings of the literature review, dolomite waste could be used to replace 5–10% of the cement in order to achieve effective results.

2. The addition of dolomite waste as a substitute for cement in concrete increases the compressive, flexure, and split tensile strength up to a certain limit. Concrete's mechanical properties improve as its microstructure improves.

3. Incorporating coarse copper slag improves the mechanical properties of concrete. This is probably due to properties of the copper slag and the strong bond between the copper slag aggregate and the cement paste.

4. Due to the required quantity of calcium oxide concentration in copper slag, replacing fine aggregate with copper slag improves compressive strength of conventional concrete up to 40%.

5. Copper slag, a waste by-product of the copper industry, can be utilized beneficially as aggregate in concrete mix, as evidenced by the improvement in mechanical qualities of concretes using copper slag.

As a result of various research investigations, it can be determined that using copper slag in concrete saves money by reducing the use of natural resources and, more importantly, by reducing environmental dangers caused by the massive dumping of copper slag industrial waste. Dolomite's restricted use in concrete has tremendous promise for sustainable and greener production.

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