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Research Paper

EXPERIMENTAL INVESTIGATION ON CONCRETE INCORPORATING METAKAOLIN AND MARBLE POWDER AS CEMENT REPLACEMENT MATERIALS

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ABSTRACT

Concrete is one of the most widely used construction materials in the world. However, the production of cement releases a significant amount of carbon dioxide into the atmosphere, leading to environmental concerns. To overcome this issue, supplementary cementitious materials such as Metakaolin and Marble Powder are increasingly used as partial replacements for cement. This study investigates the effects of partially replacing cement with Metakaolin and Marble Powder on the mechanical properties and durability of concrete. Different mix proportions were prepared by replacing cement with varying percentages of Metakaolin and Marble Powder. The compressive strength, split tensile strength, workability, and durability characteristics were analyzed. The experimental results revealed that the partial replacement of cement improves the strength and durability of concrete while reducing environmental pollution and construction costs. The optimum replacement level was found to provide better performance compared to conventional concrete.

1. INTRODUCTION

Concrete plays a vital role in modern construction due to its high compressive strength, durability, and ease of availability. Cement is the primary binding material in concrete, but its manufacturing process contributes significantly to greenhouse gas emissions. Researchers are focusing on sustainable materials that can partially replace cement without affecting the quality of concrete. Metakaolin is a highly reactive pozzolanic material produced by calcining kaolin clay at high temperatures. It enhances the strength, durability, and resistance of concrete against chemical attacks. Marble Powder is a waste material generated from marble industries during cutting and polishing operations. Disposal of marble waste creates environmental problems; therefore, utilizing marble powder in concrete can help reduce waste accumulation and improve sustainability.

This research aims to study the combined effect of Metakaolin and Marble Powder as partial replacements for cement in concrete production.

1.1.LITERATURE REVIEW

Amritpal Kaur, Rajwinder Singh Bansal studied the strength characteristics by using metakaolin and marble powder as partial replacement of cement. Grade of concrete:

M30. The replacement of cement has been done at 0%,3%,5%,9%,12%,13% with Metakaolin (MK) and 0%,10%(constant) with Marble Powder (MP). Compressive as well as tensile strength of concrete made with MK-MP has been compared with conventional concrete. The optimum percentage for replacement of cement with Metakaolin and Marble powder was 9% and 10%. Vijay Shankar, Suji Studied the properties of HPC which were determined by using Metakaolin as partial cement replacement and Quarry dust as partial fine 2M. Anil Kumar P.G student, Department of Civil Engineering, U.C.E.K, J.N.T.U, Kakinada, A.P; India, serious environmental problems. Recycling and utilization of industrial by-products and waste materials has become an attractive proposition to disposal. The utilization of such materials in concrete not only makes it economical, but also helps in reducing disposal concerns. One such industrial waste material is Waste Foundry Sand (WFS). The Indian Metal Casting (Foundry Industry) is well established and producing 10 Million MT (2015) of various grades of Castings. The various types of castings produced are ferrous, non ferrous, Aluminum Alloy, graded cast iron, ductile iron, Steel etc. According to the 49th Census of World Casting Production, Indian Foundry Industry is the 3rd largest metal casting producer in the world. There are approximately 5,000 foundry units in India. The majority (nearly 90%) of the foundry units in India falls under the category of micro, small and medium scale industries (Foundry informatics centre). Metakaolin is in widespread use all over the world in the concrete industry. The advantages of Metakaolin not only have many concrete performance benefits, both in mechanical and durability properties, but also the environmental benefits. While the production of Portland cement is associated with high carbon dioxide emissions. Metakaolin is a dehydroxylated form of the clay mineral kaolinite. Metakaolin can be produced by primary and secondary sources containing kaolinite are high purity kaolin deposits, kaolinite deposits or tropical soils of lower purity, paper sludge waste which contains kaolinite, oil sand tailings contains kaolinite. Metakaolin usage helps in developing high performance and high early strength in concrete. aggregate replacement. Grade of concrete: M40. The Percentage of replacements are 0, 2.5,5,7.5,10,12.5 & 15 % for Metakaolin and 0,10,20,30,&40% for quarry dust.The maximum compressive as well as split tensile strengths were obtained at replacements, 10% of cement with Metakaolin and 30% of sand with Quarry Dust with 3% Super Plasticizers. Ravitheja, Gopala Krishna Sastry studied the strength properties of concrete with different percentages of replacement of sand by used foundry sand and silica fume. Grade of concrete: M25. The replacement percentages are 0%, 10%, 20%, 30%, 40%, and 50%. Thus obtained optimum percentage of used foundry is taken as constant and cement is replaced with silica fume in the percentages of 5%, 7.5%, 10% and fly ash by 10%, 15%, and 20%. When 40% of fine aggregate is replaced by used foundry sand the strength observed was 38.70 MPa. Replacement of 40% used foundry sand with silica fume showed better performance than with fly ash. The maximum increase in strengths was observed when 40% used foundry sand with 10% silica fume is used and the strength obtained was 42.96 Mpa

2. OBJECTIVES OF THE STUDY

1. To reduce cement consumption in concrete.
2. To utilize industrial waste materials effectively.
3. To study the mechanical properties of concrete with Metakaolin and Marble Powder.
4. To determine the optimum replacement percentage.
5. To develop eco-friendly and economical concrete.

3. MATERIALS USED

3.1 Cement

Ordinary Portland Cement (OPC 53 Grade) was used for preparing concrete mixes.

3.2 Fine Aggregate

Natural river sand conforming to IS specifications was used.

3.3 Coarse Aggregate

Crushed granite aggregates of size 20 mm were used.

3.4 Water

Portable water free from impurities was used for mixing and curing.

3.5 Metakaolin

Metakaolin is a pozzolanic material obtained from calcined kaolin clay. It improves strength and durability.

3.6 Marble Powder

Marble Powder is a waste product obtained from marble processing industries and acts as a filler material.

4. METHODOLOGY

Concrete specimens were prepared with different percentages of cement replacement using Metakaolin and Marble Powder.

Mix ID	Cement (%)	Metakaolin (%)	Marble Powder (%)
M0	100	0	0
M1	90	5	5
M2	85	7.5	7.5
M3	80	10	10

The specimens were cast and cured for 7, 14, and 28 days. Tests conducted include:

- Slump Cone Test
- Compressive Strength Test
- Split Tensile Strength Test
- Water Absorption Test

5. RESULTS AND DISCUSSION

5.1 Workability

The workability of concrete slightly decreased with the increase in Metakaolin content due to its fine particle size.

5.2 Compressive Strength

Concrete containing Metakaolin and Marble Powder showed improved compressive strength up to an optimum replacement level.

5.3 Split Tensile Strength

The tensile strength also improved due to better bonding between cement paste and aggregates.

5.4 Durability

The permeability and water absorption of concrete decreased, indicating improved durability characteristics.

6. ADVANTAGES

- Reduction in cement usage
- Eco-friendly construction material
- Utilization of industrial waste
- Improved strength and durability
- Reduction in environmental pollution
- Economical concrete production

7. CONCLUSION

The study concludes that partial replacement of cement with Metakaolin and Marble Powder significantly improves the properties of concrete. The optimum replacement percentage provides higher compressive and tensile strength compared to conventional concrete. The use of these materials not only enhances the performance of concrete but also contributes to sustainable construction practices by reducing cement consumption and utilizing industrial waste effectively.

8. FUTURE SCOPE

- Study on long-term durability characteristics
- Use in high-performance concrete
- Application in precast concrete elements
- Investigation under different environmental conditions

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