MECHANICAL, DURABILITY AND MICRO STUDIES ON PRACTICAL MORTARS AND CONCRETES USING SUSTAINABLE MATERIALS

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Introduction:

The construction industry's increasing emphasis on sustainability and resource efficiency has led to a growing interest in using industrial by-products as supplementary cementitious materials (SCMs) in concrete and mortar. Among these by-products, Ground Granulated Blast Furnace Slag (GGBFS) and its finer variant, micro slag, have gained significant attention for their potential to enhance the strength, durability, and eco-friendliness of cement-based materials. Slag and micro slag not only help in reducing cement consumption but also improve various physical and chemical properties of mortar, contributing to the production of high-performance and sustainable building materials.

By incorporating slag powder and its finer variant micro-slag (MS) as a partial replacement for Portland cement, concrete producers can reduce the consumption of virgin materials, lower energy consumption, and decrease greenhouse gas emissions associated with cement production. By optimizing the mix design of M30 grade concrete with slag and micro-slag powder, this research aims to achieve comparable or enhanced mechanical properties while promoting sustainability in construction practices. Through this investigation, valuable insights will be gained into the potential of slag powder as sustainable alternative in mortars and concrete mix design, contributing to the advancement of environmentally responsible construction practices.

Objectives:

1. To determine the mechanical and durable properties of the concrete and mortar using the slag and micro slag as the partial replacement.
2. To conduct studies on mortar cubes for various proportions of cement, slag and micro slag such as 100 percent of cement, 50 percent of cement and 50 percent of slag, 50 percent of cement 40 percent of slag with 10 percent of micro slag in 1:3 for various water-cement ratios like 0.4, 0.5 and 0.6.
3. To conduct studies on concrete specimens of M30 and M60 grade designed for 100%C, C50%C+50%S, 50%C+45%S+5%MS, 50%C+40%S+10%MS, 50%C+35%S+15%MS for a workability of 100 mm using BIS code of practice.
4. To develop comprehensive mix-design excel program as per BIS code which is user friendly.
5. Through a series of laboratory experiments, including compressive strength tests, workability assessments, smart analysis like SEM, XRD, FTIR spectroscopy tests and durability evaluations, this study aims to establish the most effective mix proportions to enhance the performance of the concrete while reducing its environmental footprint.

Methodology:

PHASE 1: STUDY ON MORTAR

Materials and mix procedure: Ordinary Portland cement of 43 Grade, conforming to IS: 269 2015 has been used in this investigation. The Ground granulated blast furnace slag (GGBS), confirmed in accordance with IS: 16714–2018 and IS: 12089–1987 (Reaffirmed 2008) and micro-slag (of JSW company) respectively has been used in the investigation. The locally available river sand is used as fine aggregate having specific gravity of 2.65. Drinking water confirming to IS: 456-2000 is used.

Mixing proportions: The experimental design involves varying the slag replacement levels 40-50 % and micro slag levels (10%) to observe their effects on strength, workability, and durability over different curing periods with respect to conventional mix.

Mixing: The mixing process involves several stages:

1. Dry Mixing: The OPC, slag, micro slag, and sand are dry mixed to ensure that the SCMs are evenly distributed among the cement particles.
2. Wet Mixing: Wet mixing continues for an additional 2-3 minutes to achieve a smooth, homogenous consistency in the mortar.

Casting and curing of specimens: Once the mixing is complete, the fresh mortar is cast into moulds of 50 cm^2. The moulds are vibrated with a vibrating machine for 2min to prevent voids, which can weaken the mortar and produce inconsistent test results. After 24 hours in the moulds, the samples are removed and submerged in a curing tank filled with water. Curing is typically done for 3, 7, and 28 days, depending on the desired strength testing intervals.

Testing of specimens: All the specimens were taken out of water a day before testing and allowed to air dry. A 600kN capacity of compression test machine (CTM) was used for compression water absorption test was conducted on 27th day as per BIS and Rebound hammer test (NDT) was also conducted at 7 and 28 days.

PHASE 2: STUDY ON CONCRETE

Materials and mix procedure: Ordinary Portland cement of 43 Grade, conforming to IS: 269 2015 has been used in this investigation. The Ground granulated blast furnace slag (GGBS), confirmed in accordance with IS: 16714–2018 and IS: 12089–1987(Reaffirmed 2008) and micro-slag (of JSW company) respectively has been used in the investigation. The locally available river sand is used as fine aggregate having specific gravity of 2.65 and crushed granite stone confirmed to graded aggregate of nominal size between 20 mm and 4.75mm were used as coarse aggregate. Drinking water confirming to IS: 456-2000 is used.

All the ingredients were first mixed in dry state for one minute. After that the blended mixer of Cement, MS and GGBS was added, the mixing water and super-plasticizer were mixed apart and then added to the dry mix and mixed for about 5 min until the mix became homogeneous. All the mixtures are tested for Slump till to obtain desired value of 100 mm slump before going to casting.

Casting and curing of specimens**:** Thoroughly mixed concrete was placed layer by layer to cast into cubes of size (100mm x 100mm x 100mm), cylindrical specimens (100 mmx 200mm) and prisms (100mm x 100mm x 500mm) to determine compressive, split tensile and flexural strength respectively. The specimens were prepared both by hand compaction as well by imparting vibrating table. Then specimens were demoulded and allowed for curing.

Testing of specimens: All the specimens were taken out of water a day before testing and allowed to air dry. A 1000kN capacity of compression test machine (CTM) was used for compression as well as split tensile test, and 1000kN flexure testing machine was used for flexural strength. The test was carried out at uniform stress after the specimens has been centred in the testing machine.

Results and Conclusions:

1. MORTAR

COMPOSITION	28 DAYS COMPRESSIVE STRENGTH IN MPa		
	0.4 w/c	0.5 w/c	0.6 w/c
C (100%)	37.0	30.2	27.2
C+S (50%+50%)	36.4	31.4	23.8
C+S+MS (10%)	42.0	34.0	25.8

COMPOSITION	WATER ABSORPTION IN %		
	0.4 w/c	0.5 w/c	0.6 w/c
C (100%)	5.98	6.94	7.43
C+S (50%+50%)	5.66	6.70	7.83
C+S+MS (10%)	5.56	4.94	7.88

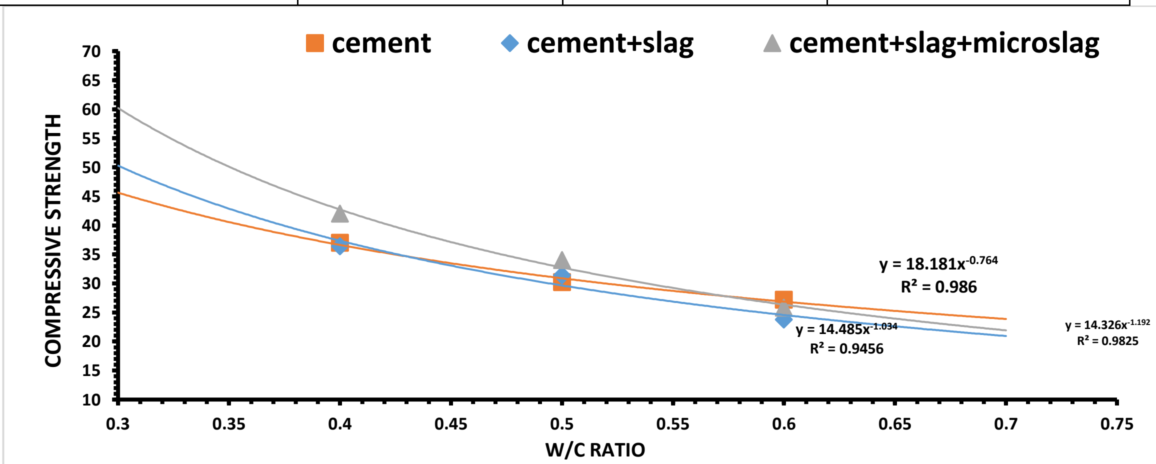
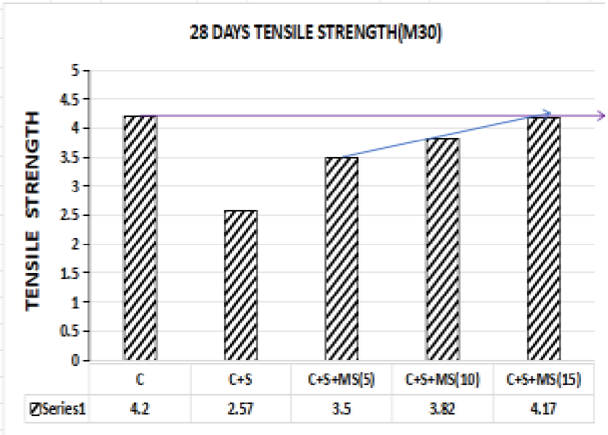


Figure 1: 28 days compressive strength of C, C+S and C+S+MS (W/C=0.4,0.5,0.6)

COMPOSITION	FLEXURE STRENGTH, MPa	SPLIT-TENSILE STRENTH, MPa	COMPRESSIVE STRENGTH, MPa
C (100%)	6.50	4.20	AWAITED
C+S (50%+50%)	4.98	2.57	AWAITED
C+S+MS (5%)	5.54	4.00	AWAITED
C+S+MS (10%)	6.95	4.10	AWAITED

C+S+MS (15%)	7.80	4.17	AWAITED

2. CONCRETE M30 GRADE (Cement, S-slag, MS- micro-slag) (28 DAYS AVERAGE VALUES IN MPa)



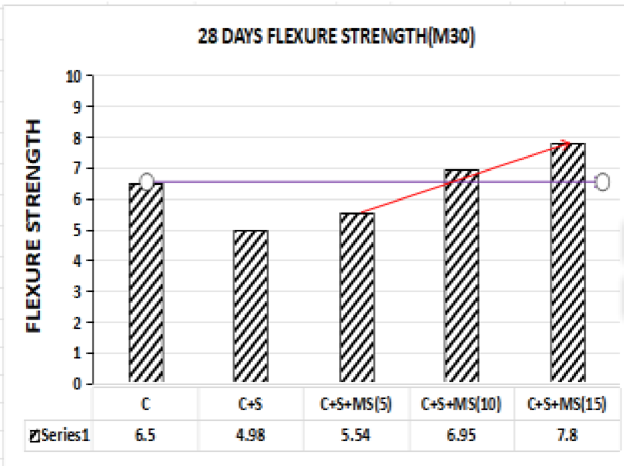


Figure 2: Flexural strength of C, C+S and C+S+MS   Figure 3: Split tensile strength of C, C+S and C+S+MS

Samples from each tested specimens are collected and will be given for SEM, FTIR and XRD tests for micro analysis.

M30 COMPRESSIVE STRENGTH RESULTS - AWAITED

CONCRETE M60 GRADE – Results awaited.

In conclusion,

The partial replacement of cement with slag gives almost same strength as the conventional mortar with 100% cement. The use of micro-slag gives much higher strength than the above two cases. We can also conclude that as the w/c ratio increases strength decreases and vice versa and hence Abram's law is valid.

The water absorption results are less than 10% and the water absorption of the mortar cube with slag and micro slag gave lesser water absorption value than the conventional mortar without slag and micro-slag

In case of concrete, the 28 days flexure strength of conventional concrete is achieved by introduction of 10% of MS with 40% of slag, with 15% of MS the strength further increases slightly. The 28 days split tensile strength of conventional concrete is achieved by introducing 15% of MS.

Project Outcome & Industry Relevance:

The project has a strong industry relevance and can be promoted in cast in situ and precast concrete applications. As the developed concrete is having the comparable strength with that of 100% OPC and also durable from the point of water absorption, the developed mixes can be used in all practical applications. These sustainable concretes can be produced in RMC plants especially in major projects. The concept is in the direction of sustainability goals which are now strongly addressed all fields of engineering. The current trend of education as per NEP and NBA is in the direction of sustainability.

Working Model vs. Simulation/Study:

It is only theoretical and experimental study and no working models are developed as there is no scope.

Project Outcomes and Learnings:

The project outcome in the form of observation and recommendation is as follows

1. Concrete mixes of any grade can be designed using combination of OPC and GGBFS for any level of strength and workability.
2. Use of GGBGS reduces the compressive strength at 28 days by about 20 to 25 percent. However, the designed strength is more than that required for the target strength and hence can be used in the field.
3. The water absorption of GGBFS concrete is comparatively les compared to that of 100% OPC.
4. Use of micro slag at 5%, 10% and 15% will enhance the compressive strength of concrete considerably and the concrete mixes are more durable as well.

5. About 10% of micro slag along with 50% of OPC and 40% of GGBFS will enhance the compressive strength of concrete to that of 100% OPC. In addition, the water absorption of concrete is significantly less compared to that of 100% OPC.
6. The use of 50% GGBFS and micro slag enhanced the strength, workability and durability of concrete and hence the mixes are more durable and sustainable compared to 100% OPC concrete mixes.

Future Scope:

1. The work can be extended further considering the advantages of silica fume and rice husk ash from the point of durability.
2. Durability tests related to carbonation, RCPT, RCMT and corrosion can be taken up to know more about the engineering performances from the point of long-term behaviour.
3. Several results are awaited as the work is not complete.