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A STUDY TO DETERMINE MIX PROPORTION OF CONCRETE WITH SUPPLEMENTARY CEMENTITIOUS MATERIALS

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Abstract: The present-day construction industry consumes a significant amount of concrete, with cement being the primary binding material utilized. However, the production of cement requires a substantial amount of energy, resulting in approximately 8% of CO2 emissions released into the atmosphere. Considering these environmental concerns, the construction industry has developed a substitute for traditional concrete known as the 'Steel Slag Hydrated Matrix.' This innovative material comprises steelmaking slag, ground granulated blast furnace slag, fly ash, lime, and water. Notably, the majority of its key ingredients are 100% industrial by-products, yet it exhibits similar performance characteristics to conventional concrete materials. In the initial phase of testing, the optimization of raw material quantities such as fly ash and hydraulic lime is conducted to achieve an optimal binding material akin to conventional cement. Standard procedures used for characterizing cement quality are employed in this phase, resulting in the determination of the best raw material composition. Variations in lime content within the lime-fly ash mixture range from 20% to 100%. Mortar cubes are then fabricated using the aforementioned lime-fly ash mixtures, with ground granulated blast furnace slag serving as fine aggregate in proportions of 1:2 and 1:3. Compressive strengths of these cubes are assessed after curing periods of 3, 7, 28, and 60 days. In the subsequent phase of testing, concrete specimens are prepared utilizing steel slag as coarse aggregate, ground granulated blast furnace slag as fine aggregate, and the optimized binder identified in phase one.

Keywords: Granulated blast furnace, fly ash, Supplementary materials, mechanical properties, mortar mix.

Introduction:

In recent years, the escalating concerns surrounding global warming and environmental degradation have prompted a significant shift in societal mindset. The once prevalent ethos of mass-production, mass-consumption, and mass-waste has gradually evolved towards the pursuit of a zero-emission society, emphasizing the utilization of industrial wastes and the conservation of natural resources. Addressing the depletion of natural resources and maximizing the utilization of waste materials present formidable challenges for scientists and engineers worldwide. Numerous studies have been undertaken to explore methods for protecting natural resources, mitigating environmental pollution, and fostering economic sustainability through the innovative utilization of waste materials.

Among the principal by-products of industrial processes are slag and fly ash. In India alone, the annual production of fly ash exceeds 170 million tons, yet only a meager 35 percent of this total is currently being utilized—a notably low figure. Given its ultra-fineness, pozzolanic properties, and other beneficial characteristics, increasing the utilization of fly ash is imperative not only to offset disposal costs but also to mitigate environmental pollution.

Concrete stands as the predominant building material in the construction industry, comprising aggregates—both fine and coarse—bound together by a cement paste composed of cement and water. However, each constituent of concrete carries its own environmental footprint, contributing to various sustainability concerns. The prevailing concrete construction practices are deemed unsustainable due to the substantial consumption of aggregates, drinking water, and an annual global production of one billion tons of cement—an environmentally unfriendly material. The production of cement necessitates a significant energy input and releases approximately 8% of CO_2 emissions into the atmosphere, further exacerbating environmental challenges.

Indeed, numerous by-products and solid wastes possess the potential for utilization in concrete mixes as aggregates or cement replacements, contingent upon their chemical and physical properties post-treatment. The incorporation of fly ash and blast furnace slag into concrete confers numerous technical advantages. Furthermore, the synergistic use of multiple mineral admixtures often yields superior outcomes. Leveraging such industrial by-products or waste materials endowed with desirable properties holds promise for conserving energy and conventional resources.

The present study endeavors to develop a cementitious material capable of substituting conventional cement in concrete construction, utilizing waste products such as fly ash, granulated blast furnace slag, and hydrated lime—without recourse to energy-intensive manufacturing processes. Additionally, the research encompasses the manufacturing and quality assessment of eco-friendly concrete derived from the aforementioned materials, incorporating steel slag as coarse aggregate. This integrated approach aims to address waste disposal challenges while concurrently safeguarding natural resources.

Previous work by H. Matsunaga et al. (2000) has explored the formulation of steel slag hydrated matrix utilizing ground granulated blast furnace slag, fly ash, water, and a small quantity of activator—such as calcium hydroxide or lime dust—without the inclusion of cement or natural aggregate. The physical properties of the steel slag hydrated matrix were evaluated, revealing that its compressive strength increases over extended curing periods, surpassing that of ordinary concrete in the long term.

Literature Review:

Several studies have investigated the utilization of industrial by-products such as steel slag and granulated blast furnace slag (GGBS) in various construction applications. Tatsuhito Takashashi (2002) conducted a

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study on steelmaking slag and GGBS, while Haruyoshi (2003) developed marine blocks using mixtures of steelmaking slag, GGBS, lime, and fly ash. These blocks underwent carbonation upon exposure to carbon dioxide gas and were tested for their effects on cultivating seaweed and other marine organisms.

M. Maslehuddi et al. (2003) focused on regions with limited access to high-quality aggregates and evaluated the mechanical properties and durability of concrete made with steel slag aggregates. Takashi FUJII (2004) explored the development of concrete utilizing a steel-slag hydrated matrix composed of GGBS powder and steelmaking slag, supplemented with an alkali activator if required. The study emphasized the control of pH to ensure consistent strength properties comparable to conventional cement concrete, with enhanced resistance to carbonation and steel rod corrosion attributed to the alkalinity of steelmaking slag.

Further work by Takashi Fujii (2007) concentrated on concrete incorporating steelmaking slag, aiming to reduce environmental impact. Results indicated that the lower resistance to freezing and thawing observed in steelmaking slag concrete was mitigated by adequate air entrainment and the inclusion of sufficient fly ash to consume calcium hydroxide around the aggregates.

Nobuaki et al. (2006) introduced a novel construction material termed "steel slag hydrated matrix" (SSHM), derived from steelmaking slag and GGBS without Portland cement or natural gravel. SSHM exhibited comparable or superior resistance to chloride ion penetration, oxygen permeability, and corrosion of steel reinforcement in marine environments compared to conventional steel-reinforced concrete.

Objective:

The primary objective of this study is to determine the optimal mix proportions of fly ash, lime, GGBS, and water to fulfill the research objectives. Specifically, this involves establishing the water-to-(lime-fly ash) ratio to achieve suitable workability in the design mix. Additionally, the study aims to ascertain the mix proportions of fly ash, lime, GGBS, steel slag, and water necessary to achieve the desired strength characteristics. Furthermore, the investigation seeks to evaluate various fundamental properties, including compressive strength, flexural strength, etc., of the Steel Slag Hydrated Matrix (SSHM) in comparison to ordinary concrete. Finally, the study intends to analyze the influence of curing duration on the strength properties of SSHM.

Experimental Procedure:

The experimental procedure involves characterizing the physical and chemical properties of the raw materials. Two phases of testing are conducted:

1. In the first phase, mortar cubes are prepared using lime and fly ash as binders, combined with GGBS as fine aggregate in ratios of 1:2 and 1:3, with varying lime percentages (20%, 35%, 50%, 65%, and 80%).

2. In the second phase, concrete specimens are fabricated by mixing lime-fly ash binder, GGBS, and steel slag in ratios of 1:1.5:3. Compressive strength and split tensile strength of these samples are evaluated after 7 and 28 days of curing.

Materials Used:

1. Fly ash: Obtained from the Rourkela steel plant, Sundargarh, Orissa. Characterized by a grayish-white color, the fly ash exhibits a specific gravity of 2.25 and a fineness of 8% (by dry sieving method) as per IS: 1727-1967.

2. Steel slag: Locally sourced from the Rourkela steel plant, Sundargarh, Orissa. The steel slag possesses a grayish-white hue, with a specific gravity of 2.98. Compliant with IS: 1727-1967, it falls under Zone-II (by IS: 12020-1982).

3. Ground Granulated Blast Furnace Slag (GGBFS): Procured from the Rourkela steel plant, Sundargarh, Orissa, the GGBFS exhibits an off-white color and conforms to IS: 12089-1987 standards.

4. Lime: Acquired from the market, the lime undergoes air-drying, thorough mixing in dry conditions, and sieving through a 150-micron sieve before storage in an airtight container for subsequent use.

Results and Discussions:

Table 1 presents the initial and final setting times of various lime-fly ash mixes compared to conventional cement. It is noted that both the initial and final setting times of fly ash-lime mixes are relatively higher than those of conventional cement.

The compressive strength of mortar initially exhibited lower strength compared to conventional cement mortar. However, with prolonged curing periods, the strength increased, eventually reaching levels comparable to cement mortar. Detailed results are provided in Table 2 and Table 3.

Upon calculating the compressive strength of each specimen, an average value for 3, 7, 28, and 60 days was determined alongside the respective water-to-(lime-fly ash) ratios.

The compressive strength of steel slag aggregate concrete demonstrated a decreasing trend with increasing lime content. For instance, the strength ranged from 12.5 MPa for concrete with 20% lime content to 10 MPa for concrete with 35% lime content. Comparatively, the compressive strength of normal concrete was recorded at 24.2 MPa, indicating higher strength than steel slag aggregate concrete. The presence of impurities such as coal particles and burnt soil lumps in the steel slag, along with excess lime, resulted in swelling upon contact with water and subsequent crack formation in the steel slag hydrated matrix. Figure 1 illustrates the crack pattern observed in the cubes.

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Figure 1: crack pattern in Cube

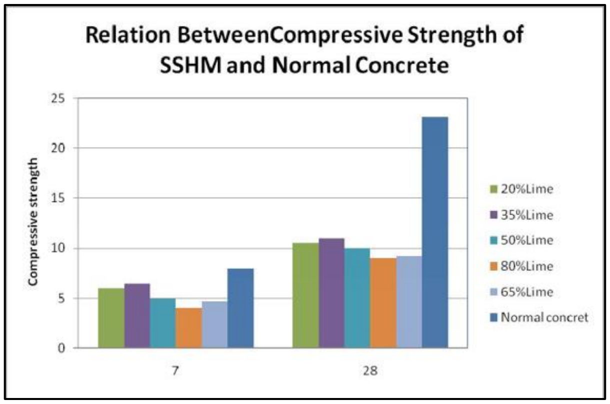

Figure 2: Comparison of Compressive strength of Steel Slag Hydrated Matrix with Normal Concrete.

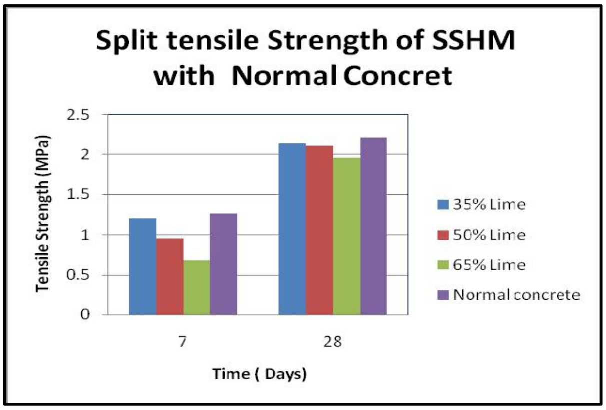

Figure 3: Comparison of Tensile strength of Steel Slag Hydrated Matrix with Normal Concrete.

Table 1 Setting time and consistency Lime+ fly ash

Lime + Fly ash	Water/ Lime + Fly ash		Consistency		Initial Setting Time		Final Setting time	
	Sample 1	Sample 2	Sample 1	Sample 2	Sample1	Sample2	Sample1	Sample2
100+0	0.69	0.69	0.58	0.58	1hr30min	2hr17min	23hr30min	25hr02min
80+20	0.67	0.67	0.56	0.56	1hr25min	2hr14min	23hr35min	25hr01min
65+35	0.65	0.65	0.56	0.56	1hr48min	4hr52min	26hr20min	27hr30min
50+50	0.62	06	0.53	0.51	5hr40min	8hr20min	26hr20min	27hr30min
35+65	0.53	0.52	0.45	0.44	5hr10min	5hr20min	24hr10min	10hr47min
20+80	0.5	0.47	043	0.4	2hr35min	5hr29min	5hr25min	11hr01min

Table 2 Variation of Compressive strength of mortar Lime+ Fly ash: GGBS (1:3)

Water/ Lime, Fly ash ratio	3Days	7Days	28 Days	60 Days
0.50	4.65	7.2	15.4	38.8
0.53	4.43	6.35	13.53	37.86
0.62	4.29	6.28	12.6	34.34
0.65	3.46	6.18	12	31.86
0.68	2.85	5.89	10.37	29.6
0 .69	2.65	5.65	10.12	29.4

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Table 3 Variation of Compressive strength of mortar Lime+ Fly ash: GGBS (1:2)

Water/ Lime, Fly ash ratio	3Days	7Days	28 Days	60 Days
0.50	5.13	17.56	12.6	37.86
0.53	8.87	9.71	13.53	33.36
0.62	7.19	7.33	15.4	30.8
0.65	4.25	12.67	12.78	28.8
0.68	7.84	7.0	10.37	28.2
0.69	6.20	6.5	10.11	28.2

Figures 2, 3, and 4 provide comparisons of compressive strength and split tensile strength between steel slag hydrated matrix concrete and normal concrete. It is evident that the split tensile strength of steel slag aggregate concrete was slightly lower than that of normal concrete but consistent with literature findings.

Several factors were identified that contributed to the observed limitations in the strength of steel slag hydrated matrix concrete, including the presence of foreign particles in steel slag and GGBFS, inadequate storage conditions for GGBFS, poorly graded steel slag, and a high water-to-powder ratio.

Conclusions:

1. Mortar with a proportion of lime: fly ash: GGBFS (35:65:300) exhibited compressive strengths of 15.6 N/mm2 at 28 days and 38.8 N/mm2 at 56 days.
2. Mortar with a proportion of lime: fly ash: GGBFS (35:65:200) achieved compressive strengths of 13.53 N/mm2 at 28 days and 35.4 N/mm2 at 56 days.
3. Fly ash-lime powder (binder) displayed initial setting times, final setting times, and consistency approximately 30%, 25%, and 46% higher than cement, respectively.
4. Compressive strength of steel slag hydrated matrix mortar increased with curing time, eventually matching that of normal cement mortar after 56 days.
5. The 28-day compressive strength of steel slag hydrated matrix concrete was lower than that of normal cement concrete.
6. Compressive strength of steel slag hydrated matrix concrete ranged from 9 N/mm2 to 13 N/mm2 after 28 days of curing, contrasting with literature findings of 20 N/mm2 to 30 N/mm2.
7. Split tensile strength of steel slag hydrated matrix concrete after 28 days was comparable to normal concrete.

8. Steel slag sourced from RSP contained numerous carbon particles and burnt soil lumps, affecting sample preparation.

9. Steel slag hydrated matrix exhibits characteristics such as 100% recycled resources, equivalent strength to ordinary concrete, excellent wear resistance, low alkaline dissolution, and favorable habitat for marine organisms.

References:

1. Akyuz, S., & Oner, A. (2007). Experimental study on optimum usage of GGBS for the compressive strength of concrete. Cement & Concrete Composites, 29, 505–514.
2. Binici, H., et al. (2007). Performance of ground blast furnace slag and ground basaltic pumice concrete against seawater attack. Construction and Building Materials, 22, 1515-1526.
3. Dippenaar, R. (2005). Industrial uses of slag—The use and re-use of iron and steelmaking slags. VII International Conference on Molten Slags Fluxes and Salts, The South African Institute of Mining and Metallurgy, 32, 35-46.
4. Fujii, T., Tayano, T., & Sakata, K. (2007). Freezing and thawing Resistance of Steel making slag concrete. Journal of Environmental Sciences for sustainable society, 1, 1-10.
5. Coastal Development Institute of Technology. Coastal Development Institute of Technology Library. no. 16, Manual on Steel Slag Hydrated Matrix. 2003-03.
6. Hisahiro, M., et al. (2003). Steelmaking Technologies Contributing to Steel Industries. Concrete Journal, 41, 47.
7. Haruyoshi, T., & Masayki, N. (2003). Steelmaking Technologies Contributing to Steel Industries. NKK Technical Review No.88, 18-27.
8. Kyong, Y., & Kyum Kimb, E. (2005). An experimental study on corrosion resistance of concrete with ground granulate blast-furnace slag. Cement and Concrete Research, 35, 1391-1399.
9. Kimur, T., & Otsuk, N. (2006). Study on applicability of Steel Slag Hydrated Matrix to steel reinforced members under marine environment. Technical Report of International Development Engineering, ISSN 1880-8468.
10. Matsunga, et al. (2003). Steel making technologies contributing to steel industries. Concrete journal, 41, 47-54.
11. Maslehuddi, M. (2003). Comparison of properties of steel slag and crushed limestone aggregate concretes. Construction and Building Materials, 17, 105-112.
12. Mathur, et al. (1999). Utilization of Industrial Wastes in Low-Volume Roads. Transportation Research Board of the National Academic, 1652, 246-256.
13. Moosberg-bustnes, H. (2004). Steel-slag as filler material in concrete. VII International Conference on Molten Slags Fluxes and Salts, The South African Institute of Mining and Metallurgy, 384-392.
14. Tatsuhito, T., & Yabuta, K. (2002). New Applications for Iron and Steelmaking Slag. NKK Technical Review, 87, 38-44.
15. Yabuta, K., Tozawa, H., & Takahashi, T. (2004). New Applications of Iron and Steelmaking Slag Contributing to a Recycling-oriented Society. JFE GIHO No. 6, 24–29.

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16. Diamond, S. (1986). Particle morphologies in fly ash. Cement. Concrete Research, 16(4), 569–579.
17. Sowmya, T., & Raman Sankaranarayanan, S. (2004). Application of optical basicity parameter to foaming of slags, 51–54.