

Evaluation of Self compacting concrete and Hardened State Characteristics

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Abstract—This research paper aims to investigate the potential utilization of bauxite residue, by-product of aluminum production, in self-compacting concrete (SCC) and evaluate its impact on the rheological behavior and hardened state characteristics of the resulting concrete. Bauxite residue is a red mud waste generated during the extraction of alumina from bauxite ore. Finding sustainable solutions for its disposal or reuse is crucial for environmental and economic reasons.

The research methodology involves laboratory experiments to determine the optimal proportion of bauxite residue in SCC mixtures. The rheological properties of fresh concrete, such as slump flow, flow time, and passing ability, will be assessed using standard tests. Additionally, the effects of bauxite residue on key mechanical properties of hardened concrete, including compressive strength, flexural strength, and durability, will be examined.

Index Terms—Self-Compacting Concrete,

Environmental, Sustainable, Hardened State

I. INTRODUCTION

The building and construction sector have grown rapidly in recent years both globally and inside the European Union (EU). The production of so-called construction and demolition waste (C&DW), among other things, has significantly increased as a result of this rise. The developed or first world consumes the rawest materials on the globe and also produces the most garbage. Without considering garbage from mining (if this were included, the number would approach 5000 kg/person/year), each EU inhabitant generates an average of 2000 kg of waste per year, according to figures from the European Statistical Office, Eurostat. More than a third of this kind of garbage is related to the building industry.

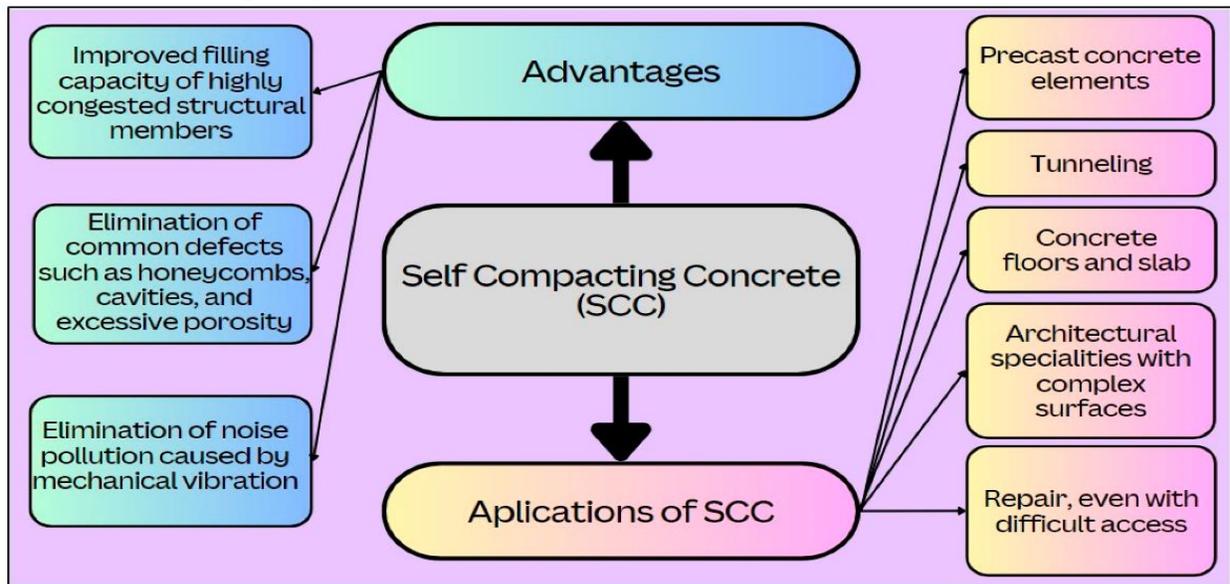


Fig:1 Advantages and application of self-compacting concrete (Patil et al., 2024)

Bauxite residue, also known as red mud, is a byproduct generated during the production of alumina from bauxite ore in the Bayer process. It is a highly alkaline material and contains various impurities such as iron oxide, silica, and titanium dioxide.

The following research paper studies: -

Neil McIntyre (2016) This paper discusses the challenges related to bauxite residue disposal and presents best practices for its management. It covers various methods of disposal, their environmental impacts, and potential solutions for sustainable bauxite residue management.

Siva Kumar et al. (2019) This review paper examines the environmental impacts of bauxite mining, including resistance issues associated with mining activities. The authors analyze the effects on air, water, soil, and biodiversity and propose mitigation strategies.

Duan et al. (2018) The paper reviews the potential utilization of bauxite residue (red mud) in the construction industry, addressing issues related to its disposal. The authors explore various methods to incorporate red mud into building materials and assess their mechanical and environmental performance.

Siti Suhaila et al. (2016) This paper presents the chemical and mineralogical characterization of bauxite residue from Malaysia, which is crucial in understanding its behavior and disposal challenges. The authors discuss the potential environmental impacts and possible remediation techniques.

Binnemans et al. (2020) This paper reviews sustainable practices for managing red mud (bauxite residue) in the metallurgical sector, including challenges related to disposal and potential utilization as secondary raw materials. The authors highlight the importance of a circular economy approach.

Nguyen et al. (2017) The paper assesses the feasibility of using bauxite residue as a supplementary cementitious material in concrete production. The study explores the technical and environmental aspects of such utilization, addressing disposal issues.

II. MATERIALS AND METHODS

A. Bauxite residue characterization

Bauxite residue, also known as red mud, is a byproduct of the Bayer process used in the extraction of alumina from bauxite ore. Characterizing bauxite residue is essential to understand its physical, chemical, and

mineralogical properties, which influence its potential applications and environmental impact. The characterization of bauxite residue typically involves the following aspects:

Physical Properties:

Particle Size Distribution: The particle size distribution of bauxite residue is determined to understand the distribution of particle sizes present. Techniques such as sieve analysis or laser diffraction can be used to measure particle size distribution. **Specific Surface Area:** The specific surface area provides information about the available surface area for chemical reactions or adsorption. Techniques like the Brunauer-Emmett-Teller (BET) method or nitrogen adsorption can be employed to determine the specific surface area.

Density: The density of bauxite residue can be measured to assess its compactness and packing characteristics. Density can be determined using methods such as pycnometer or gas displacement.

Chemical Composition: **Oxide Composition:** The chemical composition of bauxite residue is analyzed to determine the concentrations of various oxides, including alumina (Al_2O_3), iron oxide (Fe_2O_3), silica (SiO_2), titanium dioxide (TiO_2), etc. This analysis is typically performed using techniques like X-ray fluorescence (XRF) or inductively coupled plasma (ICP) spectroscopy.

Mineralogical Composition: Bauxite residue contains various minerals, including hematite, goethite, gibbsite, boehmite, and others. Mineralogical analysis, often conducted using techniques such as X-ray diffraction (XRD) or scanning electron microscopy (SEM), helps identify the types and proportions of minerals present.

Geotechnical Properties: **Atterberg Limits:** The Atterberg limits, including liquid limit, plastic limit, and plasticity index, provide information about the moisture sensitivity and plasticity of bauxite residue. These properties are determined through standard geotechnical tests. **Compaction Characteristics:** Compaction tests, such as standard or modified Proctor tests, can be performed to assess the compaction behavior and maximum dry density of bauxite residue.

Hydraulic Properties: - **Permeability:** The permeability of bauxite residue indicates its ability to allow the flow

of water or other liquids. Permeability tests, such as constant head or falling head tests, can be conducted to determine the hydraulic conductivity.

Thermal Properties:

- Thermal Conductivity: The thermal conductivity of bauxite residue is essential for assessing its insulation properties. Techniques such as the heat flow meter method can be employed to measure thermal conductivity.

Environmental impact of bauxite residue utilization

The environmental impact of bauxite residue utilization depends on the specific methods and applications used. While reusing or recycling bauxite residue can offer several environmental benefits, it's essential to consider potential challenges and impacts. Here are some key points to consider:

Land and ecosystem impact: Utilizing bauxite residue can reduce the need for additional land for disposal, which can help mitigate the impact of storage and potential land contamination. However, the reuse of bauxite residue may require land for storage or treatment facilities. It is crucial to assess the potential impact on local ecosystems, including soil quality, water bodies, and biodiversity, when implementing residue utilization methods.

Water pollution and leachate control: Bauxite residue is highly alkaline and can release alkaline leachates when in contact with water. Proper measures need to be in place to prevent the leachates from contaminating groundwater or nearby water sources. This includes adequate storage and containment systems, as well as water management strategies to control and treat any potential leachate.

III. RESULTS AND DISCUSSION

Self-compacting concrete (SCC) exhibits exceptional fresh state properties that distinguish it from conventional concrete, particularly in terms of workability and flowability. The slump flow, V-funnel, and L-box tests typically demonstrate SCC's ability to flow under its own weight without the need for mechanical compaction, ensuring thorough filling of formwork and easy placement around dense reinforcement. These properties are crucial for complex structures where conventional concrete might struggle to achieve uniformity without segregation or bleeding. The filling ability and passing ability of SCC are further validated through its performance in

narrow and congested spaces, where it can navigate through intricate reinforcement layouts without blocking or losing its cohesive nature. Segregation resistance is another vital characteristic, with SCC maintaining a homogeneous mix due to the careful balance of fine aggregates, viscosity-modifying admixtures, and superplasticizers in its mix design. This balance prevents the coarse aggregates from settling or the paste from separating, thereby preserving the integrity of the concrete during placement.

In its hardened state, SCC continues to showcase superior performance, particularly in compressive strength. Studies often reveal that SCC achieves compressive strengths comparable to, or even exceeding, that of conventional concrete at various curing ages, such as 7 and 28 days. This strength is attributed to the dense packing of particles and the reduced water-cement ratio facilitated by the use of superplasticizers, which enhances the concrete's overall density and reduces porosity. Additionally, SCC's homogeneous mix and the absence of segregation contribute to uniform strength distribution throughout the structure, minimizing weak spots that could compromise its load-bearing capacity. Furthermore, SCC generally exhibits improved durability characteristics, including higher resistance to chloride penetration and better performance in aggressive environments, owing to its reduced permeability and dense microstructure. These hardened state characteristics make SCC a preferred choice in projects where long-term durability and structural integrity are paramount.

IV. CONCLUSION

In conclusion, self-compacting concrete (SCC) offers significant advantages over traditional concrete in both fresh and hardened states. Its superior workability, flowability, and resistance to segregation make it an ideal material for complex structural elements with dense reinforcement and intricate formwork. In its hardened state, SCC demonstrates impressive compressive strength, durability, and uniformity, which are essential for ensuring the long-term performance and reliability of concrete structures. The adoption of SCC in construction not only improves efficiency during placement but also enhances the overall quality and longevity of the built environment.

Given these benefits, further research and development in optimizing mix designs for specific applications could expand the use of SCC in even more challenging construction scenarios.

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