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Optimizing the Effect of Sodium Dodecyl Benzene Sulphonate on Workability and Strength Properties of Concrete

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ABSTRACT

Concrete production has considerable environmental impacts and contributes significantly to global greenhouse gas emissions. Incorporating admixtures and supplementary materials offers promising approaches to developing more sustainable "green concrete." However, compatibility and long-term performance issues must be addressed. This study evaluates four Sodium dodecyl benzene sulphonate (SDBS)-based modifiers-VIVA, WAW, Klin, and Good-mama—to understand their effects on the tensile, compressive, and flexural strengths of concrete. Tests were conducted at different curing periods. Portland limestone cement concrete cubes and beams were cast with 0-4% dosages of each SDBS modifier by weight of cement. Compressive strength testing followed BS1881-108:1983 at 7, 14, 21, and 28 days. Flexural testing used BS EN 12390-5:2009. Tensile strength was calculated per ACI 318. All SDBS modifiers significantly reduced compressive strength relative to the control, in a dosage-dependent manner. Higher dosages led to more pronounced strength reductions, as low as 30-40% of control strengths. Similar inverse relationships were observed for flexural and tensile strengths. While SDBS modifiers may improve workability and durability, their incorporation substantially weakened concrete mechanically. Further study is required to address compatibility and long-term performance before practical construction applications.

1. **Introduction**

Concrete production has significant environmental impacts, as well as greenhouse gas emissions, natural resource exhaustion, and energy consumption, contributing around 8% of global CO2 emissions [1] and accounting for 36% of global energy consumption and 39% of total greenhouse gas emissions [2]. As infrastructure demand grows, developing eco-friendly "green concrete" alternatives that reduce environmental impact while maintaining performance is crucial [3, 4]. Incorporating supplementary cementitious materials (SCMs) and recycled aggregates in green concrete can reduce CO2 emissions by up to 40% compared to conventional concrete [5]. Utilizing agro-industrial waste and nanoparticles as partial cement replacements enhances the mechanical properties of green concrete while simultaneously reducing the environmental footprint [6].

One promising approach in green concrete production involves the use of a modifier, which are additives that modify the properties of concrete mixtures, offering potential benefits in terms of workability, durability, and sustainability [7, 8]. Among the diverse range of modifiers available, Sodium dodecyl benzene sulphonate (SDBS), a synthetic anionic surfactant widely utilized in construction materials [9, 10], has garnered significant attention for its potential application in concrete production. The incorporation of SDBS as a modifier offers several potential advantages.

Firstly, it can enhance the workability of the concrete mixture, facilitating easier placement and compaction, which can lead to improved strength and durability [11, 12]. Secondly, SDBS can function as an air-entraining agent, introducing small, stable air bubbles into the concrete mixture, thereby enhancing the concrete's resistance to freeze-thaw cycles and improving its durability and longevity, particularly in harsh environmental conditions ([13, 14].

The use of SDBS as a modifier aligns with the principles of sustainable development and green construction [3, 15]. Notably, the incorporation of SDBS into concrete mixtures may facilitate the partial or full substitution of cement with cementitious materials, such as slag, fly ash, or other industrial by-products [16]. This method not only reduces the environmental impact linked to cement production but also promotes the utilization of waste materials, contributing to a circular economy and resource conservation.Top of Form

Despite the potential benefits of SDBS in concrete production, there are also potential challenges and worries that required attention. One key consideration is the compatibility of SDBS with other admixtures commonly used in concrete mixtures, such as water reducers, retarders, or accelerators [17, 18]. Additionally, the long-term durability performance of SDBS-modified concrete requires comprehensive evaluation, particularly in terms of resistance to chloride ingress, carbonation, and sulfate attack [19, 20]. Furthermore, the economic feasibility and availability of SDBS as an admixture should be assessed to ensure its practical implementation in the construction industry, as highlighted by the Guóbiāo Tuījiàn (GB/T) [21] standard, which emphasizes the importance of evaluating the long-term performance and durability of ordinary concrete.

Another area of exploration is the potential synergistic effects of SDBS when combined with other sustainable materials or techniques, such as supplementary cementitious materials, recycled aggregates, or advanced curing methods [22, 15].

Sodium Dodecyl Benzene Sulphonate (SDBS), a surfactant primarily known for its industrial and chemical applications, offers exciting potential in revolutionizing concrete technology. This research delves into how SDBS interacts at the microscopic level with cement particles, reshaping the internal structure of the mix to significantly enhance both workability and strength. This integration could potentially yield enhanced concrete properties and further improve the overall sustainability of the construction process. Unlike conventional plasticizers and superplasticizers, SDBS introduces novel mechanisms that address key limitations in existing admixture solutions.

A core aspect of the study focuses on optimizing the SDBS dosage to strike an ideal balance between ease of handling and critical mechanical properties, such as compressive and tensile strength. The research further explores the impact of SDBS on fundamental processes like hydration dynamics, the distribution of air voids, and pore network refinement, aiming to unlock its untapped potential. Moreover, the use of SDBS as a modifier may have implications for the rheological properties and fresh state behaviour of concrete mixtures, which can influence the workability, pumpability, and self-compacting characteristics of the material [11, 23]. To ensure practical applicability, the study incorporates field trials that translate lab-scale findings into real-world construction scenarios. Particular emphasis is placed on infrastructure exposed to demanding environments, such as marine settings or sulfate-rich soils, where enhanced durability is critical. This innovative approach positions SDBS as a transformative addition to the realm of concrete engineering.

2. Methodology

2.1 Materials

The materials considered in this research were Portland limestone cement complying with BS EN 197-1:[24] specifications, and fine and coarse aggregates with specific gravities of 2.62 and 2.75 respectively were considered in this investigation. The coarse aggregates had a maximum nominal size of 10 mm. The concrete mix of 1:2:4 was adopted based on their expected 28-day characteristic strength according to BS EN 206: [25]. A normative water-cement ratio (w/c) of 0.5 was used according to Neville [26] to ensure adequate workability and strength development. The modifiers (SDBS) used were viva, waw, klin, and goodmama detergents, as shown in Figure 1.

Figure 1. (a) WAW SDBS; (b) Goodmama SDBS; (c) DIVA SDBS; (d) Klin SDBS

Figure 1 showcases four different types of Sodium dodecyl benzene sulphonate (SDBS) modifiers: (a) WAW SDBS, (b) Goodmama SDBS, (c) DIVA SDBS, and (d) Klin SDBS. These modifiers are commonly used in concrete production to potentially enhance the properties of concrete and improve the overall sustainability of the construction process.

2.2 Method

2.2.1 Compressive strength (f_c) test

According to BS EN 12390: [27], twelve (12) concrete cubes of 150 x 150 x 150 mm were produced with a mix ratio and a normative water-cement ratio (w/c) of 0.5 for each 0, 5, 10, 15, and 20% addition of SDBS as a modifier relative to the weight of cement. A total of 240 concrete cubes were cast and cured in water for durations of 7, 14, 21, and 28 days and were tested according to BS EN 12390: [27], on the 2000 kN compressive testing machine. Workability test following ASTM C143 [28] standards were performed on the fresh concrete. Figure 2(b) shows the testing of concrete cubes sample.

(a) (b)

Figure 2. (a) Flexural test set up: (b) Compressive test

2.2.2 Flexural strength or Modulus of rupture test

Beam samples of 750 x 150 x 150 mm as specified by BS EN 12390-5:[29] with varying percentages (0%, 5%, 10%, 15%, and 20%) of SDBS added as a modifier relative to the weight of cement were produced. The specimens were cured for seven, fourteen, twenty-one, and thirty-eight days. The flexural beam samples were tested as simply supported beams. The flexural strength (MR) is determined by dividing the calculated bending resistance by the elastic section modulus of the beam, as outlined in BS EN 12390-5:[29]. Figure 2(a) illustrates the test setup.

2.2.3 Tensile strength test

The tensile values of concrete modified with SDBS were calculated according to the guidelines provided by ACI 318 [30], as shown in Equation (1). The code provides specific formulas, methodologies, or factors for calculating the tensile strength of concrete. These values are crucial for assessing the structural integrity and performance of concrete structures.

$$Concrete\ tensile\ strength, f_t = 0.62\sqrt{f_{ck}} \tag{1}$$

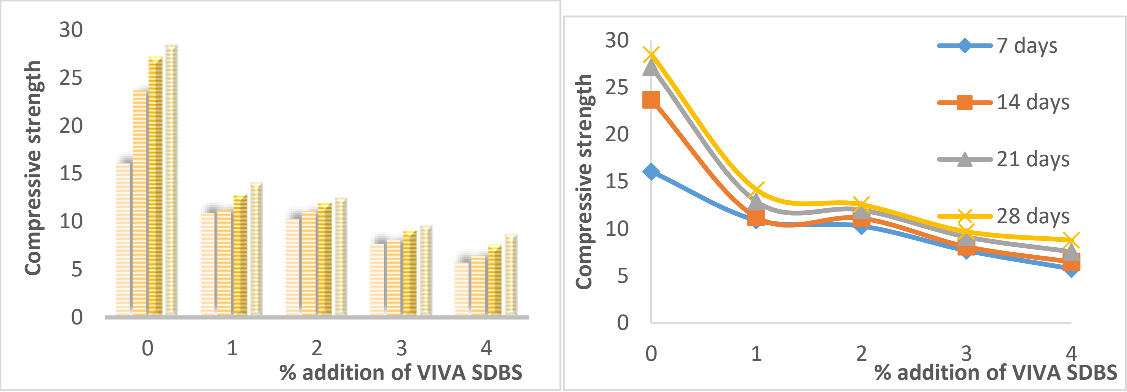
where,

$f_{ck} = Compressive\ \ strength\ of\ concrete\ (MPa)$

3. Results and Discussion

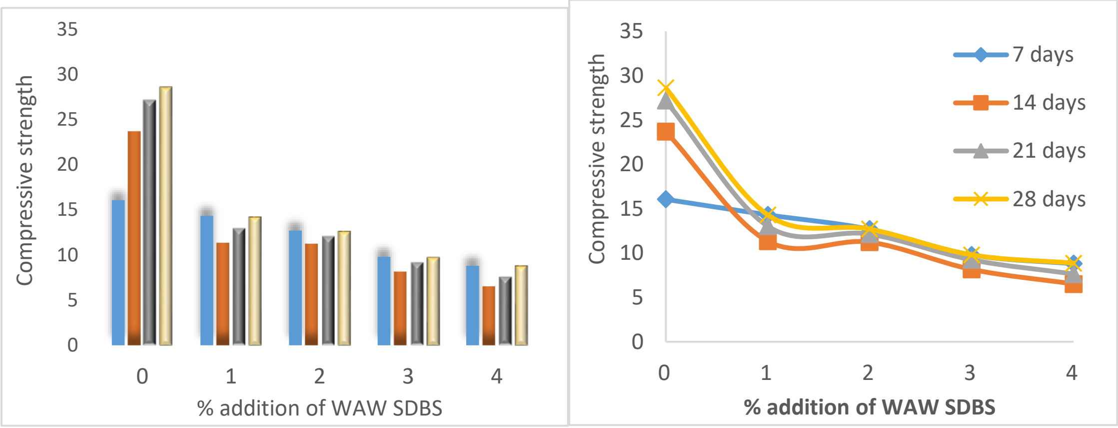
The data showed in Figures 3 - 6 demonstrate the variation in compressive strength of concrete modified with the SDBS modifiers. Figures 3 - 6 exhibit the strength values at different curing days (7-day, 14-day, 21-day, and 28-day) for various percentages of SDBS addition (0%, 1%, 2%, 3%, and 4%) relative to the weight of cement.

As confirmed in Figures 3 - 6, the compressive strength of the control mixture (0% SDBS addition) increased steadily from 16.07 MPa at 7 days to 28.51 MPa at 28 days, which is consistent with the expected strength development of ordinary concrete [26]. However, the incorporation of SDBS as a modifier led to a notable decrease in the concrete's compressive strength across all curing period.



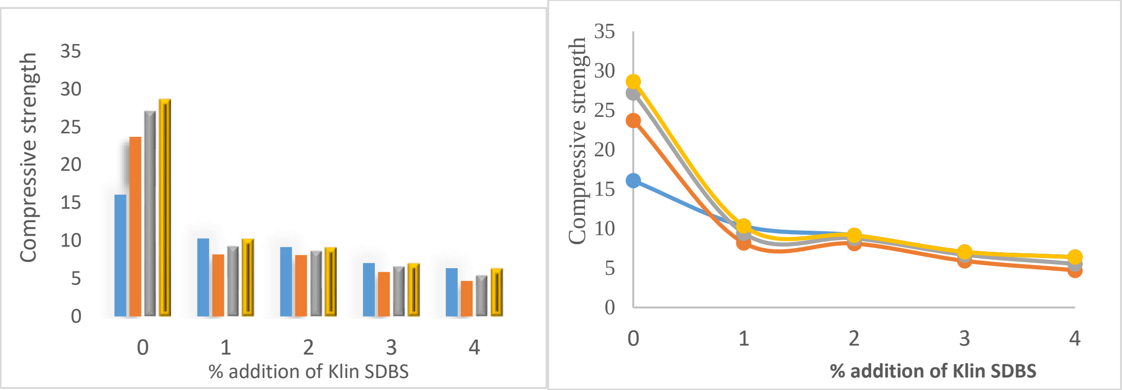
(a) (b)

Figure 3. (a) Variation of Compressive Strength; (b) Trend of strength variation with VIVA as modifier



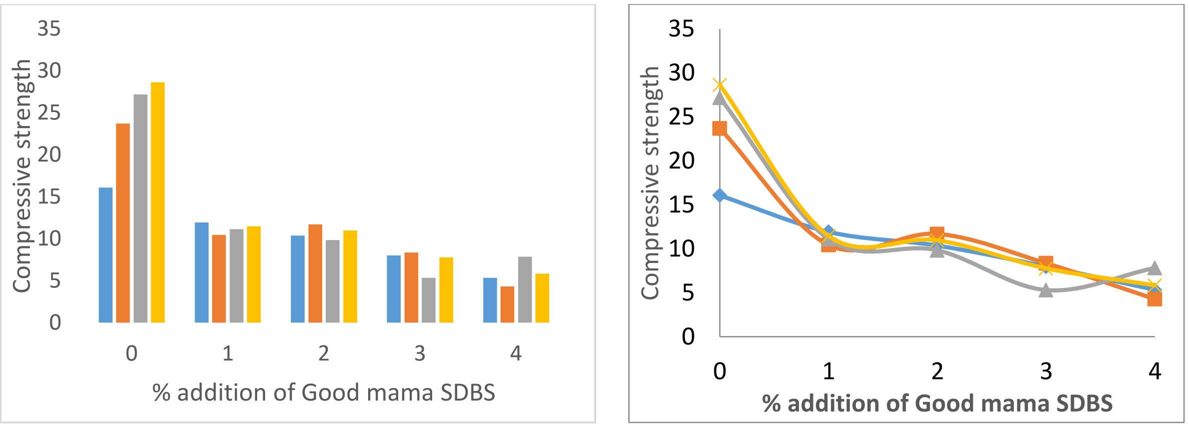
(a) (b)

Figure 4. (a) Variation of Compressive Strength; (b) Trend of Strength Variation with WAW as modifier



(a) **(b)**

Figure 5. (a) Variation of Compressive Strength; (b) Trend of strength variation with Klin as modifier



(a) **(b)**

Figure 6. (a) Variation of f_c; (b) Trend of strength variation with good mama as modifier

The trend of strength variation with SDBS addition, as depicted in Figures 3(b) 4(b), 5(b) and 6(b), indicates a clear inverse relationship between the SDBS dosage and the fc of the concrete. As the SDBS content increased from 1% to 4%, the fc at 28 days, the strength decreased by about 70%, representing a significant reduction in strength compared to the control mixture.

These findings are similar to the observations described in earlier investigations, which have also noted the unfavourable effects of certain surfactant-based admixtures, such as SDBS, on the fc of concrete [17, 18]. The reduction in fc can be ascribed to the potential incompatibility between SDBS and other common concrete admixtures, such as water reducers or retarders, which may interfere with the hydration process and the formation of a cohesive cement paste matrix [17, 18]. Moreover, the use of SDBS as an air-entraining agent, while potentially improving the concrete's resistance to freeze-thaw cycles [13, 14], may also have a negative impact on the compressive strength by introducing excessive air voids within the concrete matrix [11, 12]. The existence of these air voids can disrupt the continuity of the cement paste, leading to a reduction in the overall load-bearing capacity of the concrete. The SDBS as a modifier in concrete production should be carefully evaluated, considering the potential trade-offs between the desired workability, durability, and strength performance.

These results align with the general trend observed for VIVA, WAW, and Klin SDBS, further emphasizing the need for comprehensive assessments and compatibility studies when incorporating SDBS-based admixtures in concrete mixtures. The findings underscore the importance of carefully evaluating the use of SDBS as a modifier in concrete production, considering the potential trade-offs between the desired workability, durability, and strength performance.

The compatibility of SDBS with other commonly used admixtures, such as water reducers, retarders, or accelerators, needs to be evaluated [17, 18]. Additionally, the long-term durability performance of SDBS-modified concrete, including resistance to chloride ingress, carbonation, and sulfate attack, requires comprehensive evaluation ([19, 20]. Furthermore, the economic feasibility and availability of SDBS as an admixture should be assessed to ensure its practical implementation in the construction industry, as emphasized by the GB/T [21] standard, which highlights the importance of evaluating the long-term performance and durability of ordinary concrete.

While the use of SDBS as a modifier offers potential benefits in terms of workability and durability, the results presented in this study indicate a significant reduction in compressive strength with increasing SDBS dosages. These findings align with Lackey [17] and Nmai et al. [18] and suggest that the incorporation of SDBS in concrete mixtures should be carefully evaluated, considering the potential trade-offs between the desired properties and the potential adverse effects on strength.

To address these challenges and concerns, future research efforts should focus on exploring the potential synergistic effects of SDBS when combined with other sustainable materials or techniques, such as supplementary cementitious materials, recycled aggregates, or advanced curing methods [5, 6, 15]. Such combinations could potentially yield enhanced concrete properties and further improve the overall sustainability of the construction process.

While the use of SDBS as a modifier in concrete production offers potential benefits, the results presented in this study, along with previous research, highlight the need for comprehensive assessments and compatibility studies to ensure optimal performance and long-term durability. The findings underscore the importance of carefully evaluating the trade-offs between the desired workability, durability, and strength performance when incorporating SDBS-based admixtures in concrete mixtures.

3.1 Tensile and Flexural Strength Results

Table 1 presents the variation in tensile and flexural strength at 28 days for different percentages of SDBS additions. Each column represents a different SDBS type, while each row corresponds to a specific percentage addition.

For instance, at a 0% addition of VIVA SDBS, the tensile strength is 3.31 MPa, with a strength variation of 40.05 compared to the control. As the percentage addition increases, there's a trend of decreasing tensile strength across all types of SDBS modifiers.

Table 1: 28-Day tensile and flexural Strength Variation

(%) Addition	**VIVA SDBS**		**WAW SDBS**		**KLIN SDBS**		**GOODMAMA SDBS**	
	f_t (MPa)	MR (MPa)	f_t (MPa)	MR (MPa)	f_t (MPa)	MR (MPa)	f_t (MPa)	MR (MPa)
0	3.31	40.05	3.32	40.14	3.32	40.14	3.32	40.14
1	2.33	28.22	2.35	28.37	1.99	24.09	2.10	25.40
2	2.20	26.59	2.21	26.73	1.88	22.70	2.05	24.83
3	1.93	23.33	1.94	23.47	1.65	19.92	1.73	20.91
4	1.84	22.21	1.85	22.32	1.57	18.96	1.50	18.12

Comparing the different SDBS types, it's evident that they all have a similar effect on tensile strength variation. However, there are slight variations in the magnitude of the effect depending on the type of SDBS used and the percentage of addition.

Overall, the table provides a detailed comparison of how different SDBS modifiers and their varying percentages affect tensile and flexural strength at the 28-day curing period.

3.2 Workability Results

Table 2 presents the variation in workability, as measured by slump test values according to ASTM C143 [28], of concrete mixtures modified with different dosages of SDBS. The control mixture without any SDBS achieved a slump value of 2.5 cm, indicating low workability. However, the addition of SDBS as a modifier led to substantial increases in the workability of the concrete mixtures across all dosage levels.

Table 2. Workability of concrete modified with SDBS

(%) Addition	**VIVA SDBS**	**WAW SDBS**	**KLIN SDBS**	**GOODMAMA SDBS**
	Slump (mm)	Slump (mm)	Slump (mm)	Slump (mm)
0	40	40	40	40
1	144	137	115	130
2	180	171	144	162
3	195	185	156	176
4	200	190	160	180

As shown in Table 2, the slump values gradually increased with rising SDBS content. The mixture with 1% SDBS dosage attained a slump of 4 cm, representing a 60% increase over the control. Further incremental rises in SDBS dosage up to 4% led to stepwise growths in the workability, with the 4% mixture recording the highest slump of 200 mm representing a 220% enhancement compared to the reference mixture.

These outcomes align with previous findings that SDBS acts as an effective plasticizer and water-reducing admixture when incorporated into concrete [11, 12]. As Domone [11] explained, SDBS is capable of dispersing cement particles and breaking up water-cement agglomerations, thereby lubricating the interaction between solid particles and enhancing the mobility of the cement paste phase. Kett [12] also attributed the workability-enhancing properties of SDBS to its anionic surfactant character, which aids in reducing the surface energy of cement grains and improves the fluidity of the cementitious system.

The observations from Table 6 validate these earlier studies, demonstrating that increasing SDBS content proportionally elevates the flowability and ease of placement of fresh concrete Lackey [17] found in their investigations, SDBS dosages beyond 4% offered diminishing benefits to workability due to saturation effects. This upper limit of 4% validates with the data from the current experiment.

The results from Table 6 are consistent with previous research attributing the workability-improving attributes of SDBS to its ability to disperse cement particles, break agglomerations, and reduce surface energy through its surfactant character [12]. The study validates that SDBS effectively modifies fresh concrete properties when appropriately dosed.

4. Conclusion

The introduction of SDBS-based modifiers (VIVA, WAW, Klin, Good Mama) led to a substantial reduction in compressive, tensile, and flexural strengths across all dosage levels (1% to 4%). The highest dosage of 4% SDBS resulted in a compressive strength reduction of up to 70% at 28 days compared to the control mixture.

An inverse correlation was observed between the amount of SDBS added and the concrete's compressive, tensile, and flexural strengths. As the SDBS percentage increased, all strength parameters consistently declined, confirming the detrimental impact of higher SDBS dosages on concrete strength. Despite the negative impact on strength, SDBS significantly improved the workability of concrete. Slump values increased by up to 220% with the addition of SDBS, indicating its effectiveness as a plasticizer and water-reducer, enhancing the fluidity and ease of handling of concrete mixtures. The adverse effects of SDBS on concrete strength might be due to its interaction with the cement hydration process and its potential incompatibility with other admixtures, such as water reducers or retarders. The air-entraining properties of SDBS also contribute to the strength loss by introducing voids that reduce load-bearing capacity.

The trade-off between enhanced workability and reduced strength performance when using SDBS-based modifiers necessitates careful consideration in practical concrete applications. While SDBS improves workability, its negative effects on strength may limit its use in structural applications where load-bearing capacity is critical.

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