International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 11 Issue: 09 | Sep 2024 www.irjet.net p-ISSN: 2395-0072

Effect of Industrial Detergents and Surfactants on Density, Strength and Durability of Lightweight Concrete

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Abstract - *This study investigates the use of industrial detergents and surfactants as foaming agents in concrete to develop lightweight, cost-effective, and sustainable building materials. Surfactant proportions (5%, 10%, 15%, and 20% by weight of cement) were analyzed for their impact on concrete density, compressive strength, tensile strength, flexural strength, and water absorption. Results show that increasing surfactant content significantly reduced concrete density, making it suitable for non-load-bearing and insulation applications. However, this reduction in density led to decreased compressive, tensile, and flexural strengths, limiting load-bearing capabilities. Additionally, higher surfactant levels increased water absorption, raising concerns about durability in moisture-prone environments. Despite these trade-offs, the study highlights the feasibility of using industrial waste products in concrete, promoting sustainable construction by reducing environmental impact and supporting resource recycling. These findings offer a basis for optimizing lightweight concrete formulations to meet specific construction requirements while balancing performance and sustainability.*

***Key Words*: Industrial detergents, foaming agents, lightweight concrete, concrete density, compressive strength, tensile strength, flexural strength, water absorption, etc**

1. INTRODUCTION

Concrete is unique of the utmost widely used construction materials into world, prevalent due to flexibility, strength, and durability. Lightweight concrete is a specialized type of concrete that is designed to be lighter than conventional concrete. Usage of lightweight concrete can also facilitate easier handling and faster construction processes. The combination of industrial detergents and surfactants in concrete production is an advanced technique which received focus in past years. Surfactants and detergents, which are typically used to lower the surface tension of liquids and create foam, can be utilized as foaming agents in concrete to produce foamed concrete.

1.1 Benefits of Using Industrial Detergents and Surfactants

Usage of industrial detergents and surfactants as foaming material or agents in concrete offers several benefits. One significant advantage is cost reduction, as these materials can often be sourced as by-products from other industries, making them feasible substitutes against traditional foaming agents. The resultant foamed concrete benefits from reduced density, which translates to lower overall weight & enhance main thermal insulating characteristics. This can main to energy savings in building operations and reduced structural load on supporting elements. Furthermore, using waste or by-product materials aligns with sustainability goals by recycling industrial waste and minimizing environmental impact. Nevertheless, careful evaluation and testing are necessary to confirm that the use of these ingredients does not undesirably affect concrete's efficacy.

1.2 objectives 2

- Evaluate efficacy of Industrial Detergents and Surfactants as Foaming Agents Assess the ability of various industrial detergents and surfactants to generate and stabilize foam in concrete mixtures.
- Determine the Impact on Concrete Density Measure and compare the density of concrete made with different industrial detergents and surfactants to optimize lightweight properties.
- Assess Mechanical Properties of Foamed Concrete Evaluate the compressive strength, flexural strength, and tensile strength of foamed concrete incorporating industrial detergents and surfactants.
- Conduct a Simple Durability Study Perform a basic durability test to evaluate water absorption and freeze-thaw resistance of foamed concrete made with industrial surfactants.

2. Mix Proportions

Mix Design for Concrete Incorporating Industrial Detergents and Surfactants (IS 10262:2019).

To design concrete mixes incorporating industrial detergents and surfactants as foaming agents at varying proportions (5%, 10%, 15%, and 20% by weight of cement) following IS 10262:2019 guidelines.

Table -1 mix proportions

Component (kg/m^3)	Mix-1 (5%)	Mix-2 (10%)	Mix-3 (15%)	Mix-4 (20%)
Cement	315	330	345	360
Surfactant	15	30	45	60
Water	157.5	165	172.5	180
Fine Aggregate	472.5	495	517.5	540
Coarse Aggregate	945	990	1035	1080

2.1 Experimental Study of Density and Mechanical Properties for Concrete Mixes with Industrial Detergents and Surfactants

The objective of this experimental research for evaluating density and mechanical characteristics of concrete mixes incorporating industrial detergents and surfactants at various proportions (5%, 10%, 15%, and 20% by weight of cement). This study aims to assess the impact of these surfactants on the performance characteristics of concrete, including density, compressive strength, and workability.

A. Density

$$\text{Density} = \frac{\text{Weight of the specimen}}{\text{Volume of the specimen}}$$

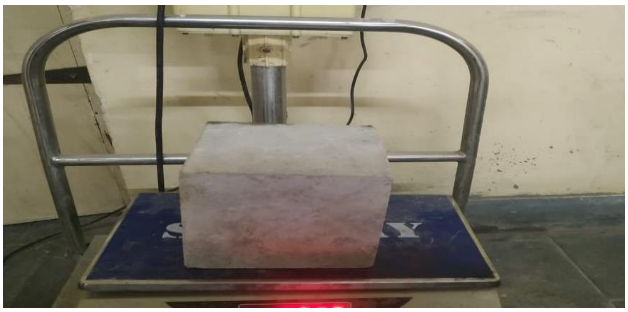
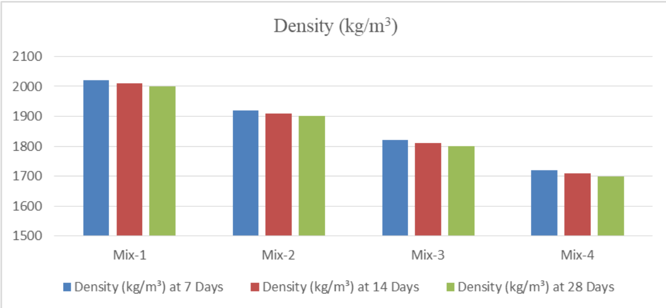


Fig -1 weight of cube

Table -2 Density Result

Mix	Surfactant (%)	Density (kg/m^3) at 7 Days	Density (kg/m^3) at 14 Days	Density (kg/m^3) at 28 Days
Mix-1	5%	2020	2010	2000
Mix-2	10%	1920	1910	1900
Mix-3	15%	1820	1810	1800
Mix-4	20%	1720	1710	1700



Graph-1 Density (kg/m^3)

B. Mechanical properties

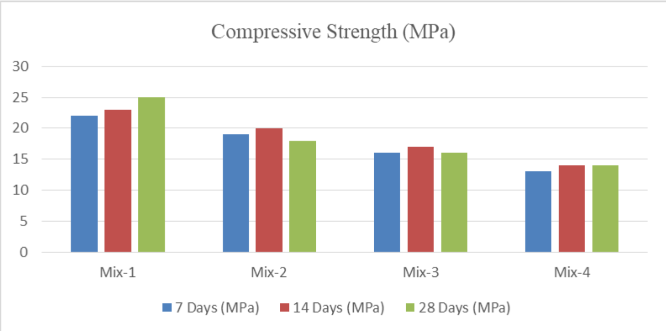
i. Compressive strength

$$\text{Compressive Strength} = \frac{\text{Maximum Load Applied}}{\text{Cross Sectional Area}}$$

Fig -2: compressive strength machine

Table -3 Compressive Strength Result

Mix	Surfactant (%)	7 Days (MPa)	14 Days (MPa)	28 Days (MPa)
Mix-1	5%	22.0	23.0	25.0
Mix-2	10%	19.0	20.0	18.0
Mix-3	15%	16.0	17.0	16.0
Mix-4	20%	13.0	14.0	14.0



Graph-2 Compressive Strength (MPA)

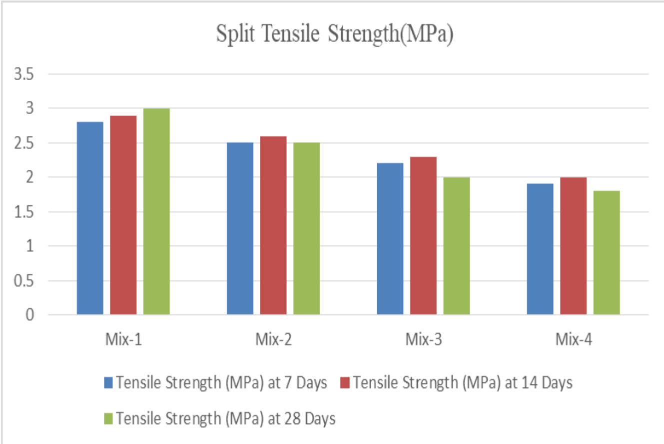
ii. Tensile strength

Tensile Strength $= \frac{2 \times \text{Maximum Load Applied}}{\pi \times \text{Daimeter} \times \text{Height}}$

Fig -3 Flexural Strength

Table -4 Tensile Strength

Mix	Surfactant (%)	Tensile Strength (MPa) at 7 Days	Tensile Strength (MPa) at 14 Days	Tensile Strength (MPa) at 28 Days
Mix-1	5%	2.8	2.9	3.0
Mix-2	10%	2.5	2.6	2.5
Mix-3	15%	2.2	2.3	2.0
Mix-4	20%	1.9	2.0	1.8



Graph-3 Split Tensile Strength

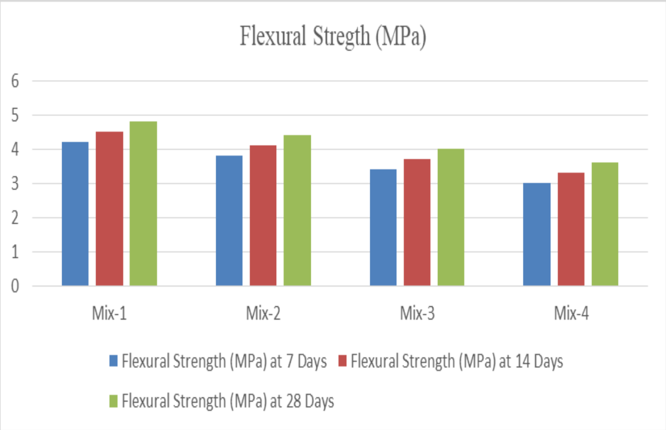
iii. Flexural Strength Result

Flexural Strength $= \frac{PL}{bd^2}$

Fig -4 Tensile Strength

Table -5 Flexural strength

Mix	Surfactant (%)	Flexural Strength (MPa) at 7 Days	Flexural Strength (MPa) at 14 Days	Flexural Strength (MPa) at 28 Days
Mix-1	5%	4.2	4.5	4.8
Mix-2	10%	3.8	4.1	4.4
Mix-3	15%	3.4	3.7	4.0
Mix-4	20%	3.0	3.3	3.6



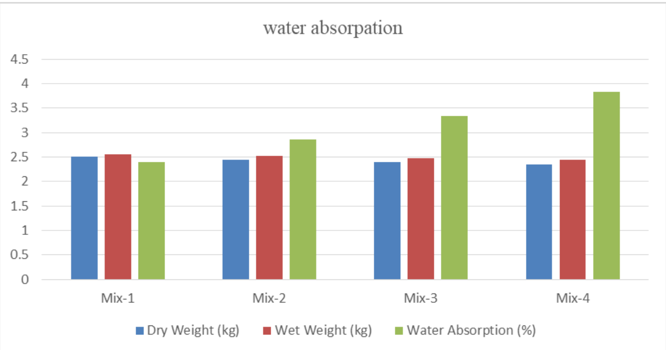
Graph-4 Flexural Strength

iv. Water absorption

$$\text{Water Absorption } (\%) = \frac{W1 - W2}{W1} \times 100$$

Table -6 water absorption

Mix	Surfactant (%)	Dry Weight (kg)	Wet Weight (kg)	Water Absorption (%)
Mix-1	5%	2.50	2.56	2.40
Mix-2	10%	2.45	2.52	2.86
Mix-3	15%	2.40	2.48	3.33
Mix-4	20%	2.35	2.44	3.83



Graph-5 water absorption

3. Result and Discussion

Density

Observations:

- The density of the concrete decreases as the surfactant content increases.
- For Mix-1 (5% surfactant), the density at 28 days is 2000 kg/m^3, whereas for Mix-4 (20% surfactant), it is 1700 kg/m^3.

Discussion:

- The reduction in density with higher surfactant content is attributed to the increased air voids introduced by the foaming action of the surfactants.
- Lower density can be beneficial for applications where lightweight concrete is desirable, such as in non-load-bearing structures or insulation purposes.

7.1.2 Compressive Strength

Observations:

- Compressive strength decreases as the surfactant content increases.
- At 28 days, the compressive strength for Mix-1 (5% surfactant) is 25 MPa, while for Mix-4 (20% surfactant) it is 14 MPa.

Discussion:

- The decline in compressive strength with higher surfactant content is due to the increased porosity and reduced density.
- This suggests a trade-off between weight reduction and load-bearing capacity, where higher surfactant content might not be suitable for structural applications requiring high compressive strength.

Tensile Strength

Observations:

- Tensile strength follows a similar trend to compressive strength, decreasing with higher surfactant content.
- At 28 days, Mix-1 (5% surfactant) shows a tensile strength of 3.0 MPa, while Mix-4 (20% surfactant) is at 1.8 MPa.

Discussion:

- The reduction in tensile strength is consistent with the increased air void content and reduced density.
- This further emphasizes the need to balance the amount of surfactant used to maintain adequate tensile properties for applications where tensile strength is critical.

Flexural Strength

Observations:

- Flexural strength decreases with the increase in surfactant content.
- For Mix-1 (5% surfactant), the flexural strength at 28 days is 4.8 MPa, compared to 3.6 MPa for Mix-4 (20% surfactant).

Discussion:

- Similar to compressive and tensile strength, the reduction in flexural strength with higher surfactant content can be attributed to the increased porosity and reduced density.
- Lower flexural strength indicates that higher surfactant content concrete may be less suitable for applications requiring high bending resistance.

Water Absorption

Observations:

- Water absorption increases with the increase in surfactant content.
- Mix-1 (5% surfactant) has a water absorption rate of 2.40%, whereas Mix-4 (20% surfactant) shows a rate of 3.83%.

Discussion:

- The higher water absorption with increased surfactant content is due to the increased porosity.
- Higher water absorption rates may lead to lower durability, as the concrete may be more susceptible to water ingress, freeze-thaw cycles, and chemical attacks.
- This necessitates careful consideration of the surfactant dosage, particularly for concrete exposed to harsh environmental conditions.

4. CONCLUSIONS

- **Density Reduction**

The use of industrial detergents and surfactants significantly reduces the density of concrete, making it suitable for lightweight applications.

- **Compressive Strength**

Increasing surfactant content decreases the compressive strength of concrete, limiting its suitability for structural applications requiring high load-bearing capacity.

- **Tensile Strength**

Higher surfactant content leads to a reduction in tensile strength, affecting the concrete's performance under tension.

- **Flexural Strength**

Flexural strength decreases with increasing surfactant content, indicating lower bending resistance.

- **Water Absorption**

The incorporation of surfactants increases water absorption, suggesting higher porosity and potential durability concerns, especially in environments exposed to moisture and freeze-thaw cycles.

- **Application-Specific Considerations**
  - Lightweight concrete with surfactants may be suitable for non-load-bearing structures, insulation, and applications where reduced weight is a priority.
  - For structural applications, careful consideration of surfactant dosage is necessary to maintain adequate strength and durability.

- **Environmental Impact**

Utilizing industrial detergents and surfactants as foaming agents contributes to sustainable construction practices by recycling industrial waste products

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