JETIR.ORG ISSN: 2349-5162 | ESTD Year : 2014 | Monthly Issue
JOURNAL OF EMERGING TECHNOLOGIES AND INNOVATIVE RESEARCH (JETIR)
An International Scholarly Open Access, Peer-reviewed, Refereed Journal

Effect of Surfactants on Cement Concrete

[1]Basumati Turuk, [2] Abhijit Mangaraj, [3]Surajit Pattnaik

[1]Research Scholar, [2]Assistant Professor, [3]Associate Professor
[1]Department of Civil Engineering,
[1]GIFT Autonomous, Bhubaneswar, India

Abstract : Surfactants are chemical agents that modify the surface properties of liquids and solids in cement concrete. Their addition improves the workability of fresh concrete by reducing surface tension and enhancing dispersion of cement particles. Air-entraining surfactants introduce fine air bubbles, increasing freeze-thaw resistance and durability. At appropriate dosages, surfactants can improve strength and reduce water demand. However, excessive use may lead to reduced strength due to excess air content. The effectiveness of surfactants depends on their type, dosage, and compatibility with other concrete components.

Keywords: Surfactants, Cement Concrete, Workability, Air-entrainment, Strength, Durability, Admixtures.

1. Introduction

Surfactants play a vital role in modifying the properties of cement-based materials, especially in foam concrete. They reduce surface tension and enhance air-entrainment, leading to improved thermal insulation and material savings. This study investigates the effects of both commercial (detergent) and natural (Sapindus Mukorossi) surfactants on cement foam stability, yield stress, and hydrophobicity. Experimental results showed that surfactant type and concentration significantly influence the compressive strength, density, water absorption, and acid resistance of foam concrete. Proper surfactant selection and dosage can optimize performance for sustainable construction.

1.1. Objectives and scope of the study

Surfactants are widely used in various industries as dispersing, wetting, and foaming agents. This study explores the use of natural and commercial surfactants in concrete to evaluate their impact on strength properties. Concrete mixes were prepared with and without surfactants, and tests were conducted to analyze compressive strength and microstructure. The aim was to assess how surfactants influence the physical behavior of concrete and optimize their use for improved performance.

2. Literature review

This chapter presents a concise review of studies focused on the effect of natural and commercial surfactants on the compressive strength and stability of cementitious and foam concrete. Researchers like Akthar & Evans (2010), Amran et al. (2015), and Feneuil et al. (2017) investigated surfactant-induced porosity, yield stress variation, and foam stabilization mechanisms. Surfactants influence concrete rheology, air content, and durability, with their performance depending on type, concentration, and interaction with cement particles. Recent works also highlight sustainable uses, including recycled materials and natural surfactants for eco-friendly concrete development.

3. Materials used

This study aims to analyze the influence of various surfactant types, concentrations, and mixing times on the density and properties of fresh and hardened cement paste. The goal is to identify the most suitable surfactant, its optimal dosage, and mixing time for concrete production. Surfactants are used to create porous concrete by stabilizing air bubbles in the cement matrix, thereby reducing density and enhancing thermal insulation.

3.2. MATERIALS

3.2.1 Cement:

Ordinary Portland Cement (OPC) acts as a binder, setting and hardening to adhere sand and gravel in concrete. Hydraulic cement, such as OPC, sets via hydration and is durable in wet conditions. It contains the following major compounds:

- C3S (Alite)
- C2S (Belite)
- C3A (Tricalcium Aluminate)
- C4AF (Brownmillerite)

Fig: Cement OPC used for the study.

Chemical Reactions:

- $CaCO_3 \rightarrow CaO + CO_2$ (Calcination)
- $2CaO + SiO_2 \rightarrow C_2S$
- $3CaO + SiO_2 \rightarrow C_3S$
- $3CaO + Al_2O_3 \rightarrow C_3A$
- $4CaO + Al_2O_3 + Fe_2O_3 \rightarrow C_4AF$

Properties of OPC:

Property	**Value**
Specific Gravity	3.15
Consistency	30%
Initial Setting Time	60 min
Final Setting Time	260 min

3.2.2 Aggregates

Fine Aggregates: Fine aggregates pass through a 4.75 mm sieve and include natural sand or crushed stone. They affect workability, strength, and durability.

Property	Value
Specific Gravity	2.60
Water Absorption	1%
Fineness Modulus	2.5

Coarse Aggregates: Coarse aggregates are retained on a 4.75 mm sieve and may range up to 63 mm. They form the rigid structure of concrete and influence durability, shrinkage, and cost.

Requirements:

- Hard, strong, and durable
- Free from organic matter and excessive fines
- Ideally cubical or spherical
- Chemically inert and non-porous

3.2.3 Surfactants

Foam concrete is produced by mechanically mixing foam into a concrete matrix, resulting in a porous, lightweight material. Surfactants help in forming and stabilizing the foam.

Types Used:

1. **Commercial Surfactant (Detergent):**
   - 1g detergent per 100ml water
   - Foam prepared and mixed into cement blend
   - Used in M25 grade concrete

Fig : Natural Surfactant - dodan

Fig: detergent (Commercial surfactant)

Fig: foam generated from natural surfactant

Fig: Foam from commercial surfactant

1. **Natural Surfactant (Sapindus Mukorossi/Reetha):**
○ Indigenous, cost-effective surfactant
○ Mixed similarly as detergent
○ Used to form eco-friendly foam concrete

Objective: To evaluate low-cost alternatives for foam concrete using commercial and natural surfactants while maintaining structural performance.

3.2.4 Water

Water is essential for hydration, lubrication, and uniform distribution of cement. The water-cement ratio significantly influences workability, strength, and durability. Potable water is used for mixing.

MIXING AND CASTING OF SAMPLES

3.3.1. MIX PROPORTION

One mixture MI (without surfactant) is designed as per Indian standard specification IS:
10262-2009(1:1.58:2.38, w/c-0.45) for mix design M25 to achieve target strength 31.60 MPa. The other two concrete mixtures are made by using commercial and natural surfactants. The detail mix proportion is given in Table

Mix Identification	Concrete Mix Proportion
M1	M25 concrete without Surfactant
M2	M25 concrete with Commercial surfactant
M3	M25 concrete with Natural Surfactants

Table no (3.3) Detail Mix proportion of concrete

3.3.2. MIX DESIGN

Concrete mix design is the process of finding right proportions of cement, sand and aggregates for concrete to achieve target strength in structures. So, concrete mix design can be stated as Concrete Mix = Cement : Sand : Aggregates. The concrete mix design involves various steps, calculations and laboratory testing to find right mix proportions. This process is usually adopted for structures which requires higher grades of concrete such as M25 and above and large construction projects where quantity of concrete consumption is huge. Benefits of concrete mix design is that it provides the right proportions of materials, thus making the concrete construction economical in achieving required strength of structural members. As, the quantity of concrete required for large constructions are huge, economy in quantity of materials such as cement makes the project construction economical.

The calculated mix design for m25 concrete is given below.

➢ Step-1

Calculating the target strength
Fck ` =Fck+1.65*s (standard deviation)
M25=S=4.0
Fck `=25+1.65*4.0=31.60 N/mm2

➢ Step-2

Assume a water cement ratio=0.45(w/c ratio value varies from (0.3-0.6).

➢ Step-3

Assume the air cement=depends upon the maximum size of aggregates we use=20mm size of aggregate=air content as 1%

➢ Step-4: -

Assume the water content=for 20mm size of aggregate the water content value=202.74kg/m3

➢ Step-5: -

The water content value depends upon the slump value.
25-50mm=0%
51-75mm=3%
76-100mm=6%
101-125mm=9%
Water content for the slump 25-50mm-202.74kg/m3

➢ Step-6: -

Cement content-water content/water cement ratio=202.74/0.45=450.53kg/m3 (minimum cement content value as per IS = 320 kg/m3) we take cement 450.53kg/m3

- Step -7

  Volume of CA & FA
  Assume total volume of concrete = 1
  Total volume of CA = 0.6
  Total volume of FA = 1 – 0.6 = 0.4

- Calculation: -

  As the total volume of concrete = 1m3
  Volume of cement = mass of cement / sp.

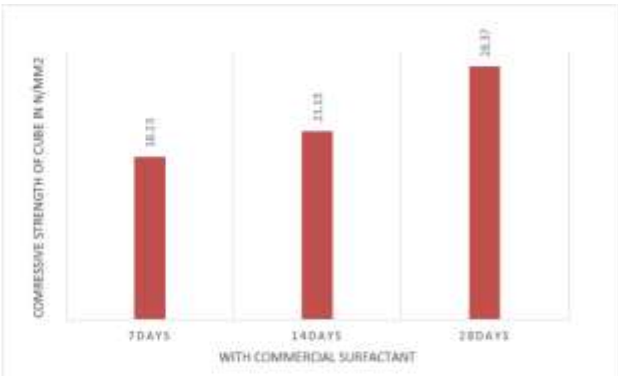
Gravity of cement) * 1000
450.53/3.15 *1000=0.143m3
Volume of water = (mass of water / specific gravity of water) * 1/1000
202.74/1 * 1/1000 = 0.202m3
Volume of all aggregate = ((1 –0.01) -(0. 143 + 0. 202))
= 0.64m3
Mass of CA = 0.64* volume of CA * sp. Gravity of CA
= 0.64 * 0.6 * 2.67*1000
= 1073.28kg/m3
Mass of FA = 0.64 * 0.4 * 2.795*1000
= 715.52m3
Cement = 450.53 kg/m3
Water = 202.74 kg/m3
CA = 1073.28 kg/m3
FA = 715.52 kg/m3
According to water/cement ratio 0.45, the ratio for Cement: F.A: C.A,
Mix-proportion: -1: 1.58: 2.38
.

4.RESULTS

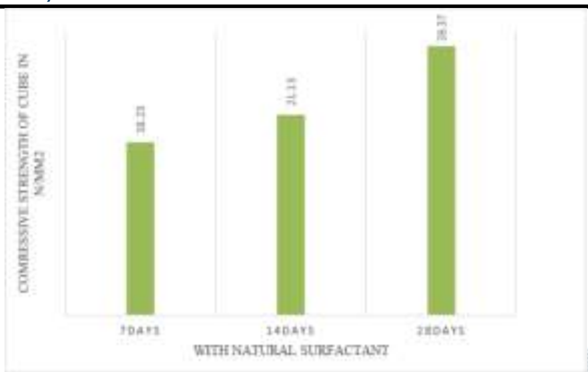
COMPRESSIVE STRENGTH

The compressive strength results presented in Table 4.1. The compressive strength increased with addition of surfactant. The maximum compressive strength for natural and commercial surfactant had shown slightly higher strength. It is observed that both with and without surfactant achieved their design strengths at 28 days. It can be seen from the table that surfactant content increases the 28 days compressive strength increases to 28.37 N/mm.

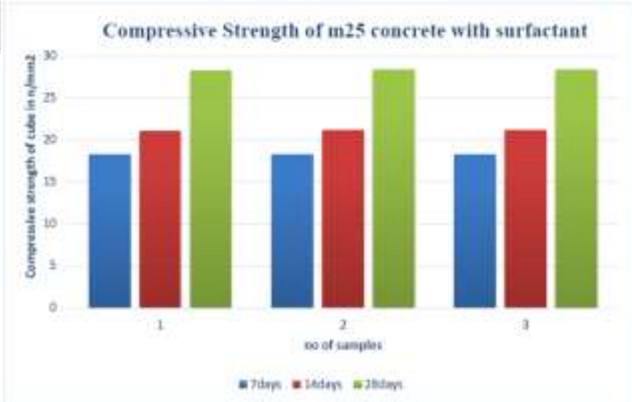
(Fig 4.1) column graph of compressive strength of concrete without surfactant



(Fig 4.2) column graph of compressive strength of concrete with commercial surfactant



(Fig 4.3) column graph of compressive strength of concrete with natural surfactant



(Fig 4.4) comparative graph of compressive strength of normal concrete natural and commercial surfactant-based concrete.

CONCLUSION

In this study, surfactants exhibited three distinct interactions with cement paste: (1) precipitation, reducing foamability; (2) adsorption onto cement grain surfaces; and (3) no interaction. Surfactants significantly influence the rheology of cement paste.
At low concentrations (below the critical concentration, *C_{Crit}*), surfactant molecules adsorb head-on, with hydrophobic tail interactions increasing the yield stress. At higher concentrations (*C* > *C_{Crit}*), large surface agglomerates form, causing a sharp drop in yield stress due to steric hindrance.
For cement foam production, using surfactants in the low concentration range (*C* < *C_{Crit}*) is beneficial. The increased yield stress improves foam stability, while hydrophobized cement grains enhance film stabilization at air–water interfaces.

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