Effect of Sugarcane Molasses as an admixture on fresh and hardened properties of concrete

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Abstract
The sugar industry serves as the cornerstone of agriculture in Solapur district, boasting an impressive 44 sugar factories. Solapur district also stands as the leading producer of sugarcane in India. Within the sugar production process, cane molasses emerges as a local byproduct, alongside bagasse, pressed mud, and mud-laden wastewater. Molasses, one of the four types of sugar byproducts, contributes to the increased fluidity of fresh concrete and effectively retards the hardening time of cement paste. For the purposes of this study, molasses obtained from sugar refineries was utilized. The addition of molasses in varying dosages (0.25%, 0.50%, 0.75%, and 1.25% by weight of cement content) had a pronounced impact on both the initial and final setting times of concrete. Workability tests were conducted on freshly mixed concrete that incorporated these four different molasses dosages. Compressive strength tests were carried out on hardened concrete blocks after 7 and 28 days, along with flexural and split tensile strength tests. Comparisons were made between the control mix and the concrete mixtures containing molasses. The results indicated a slight increase in the strength of the concrete with molasses as it aged, except for the early stages of development. This suggests that the presence of molasses in concrete has the potential to enhance its long-term strength and durability.
Keywords: *Admixture, Molasses, Workability, Slump, Compressive strength, Flexural and Split tensile strength.*

1. Introduction

Solapur, a city located on the border of Maharashtra, Karnataka, and Telangana, is a bustling hub with eight national highways connecting it to various regions. Efforts are currently underway to develop these national highways by constructing concrete pavements. As part of this development, researchers have explored the utilization of local byproducts in the concrete used for local infrastructure. Concrete is widely employed in the civil industry for construction purposes. However, there are instances where concrete cannot be used due to its quick setting time. To address this issue, retarders, which are admixtures with different properties, are incorporated into the concrete mix to enhance its setting time. In this study, we will explore the use of molasses, a byproduct of the sugar industry, as a water-reducing and time-retarding admixture in concrete. Molasses is derived from sugarcane and is the residue that floats on the surface of boiling sugar juice during the sugar production process. When sugar is extracted from the sugar juice, a certain amount of sugar remains in the waste liquid material, known as molasses. As sugar contains carbohydrates, it functions as a retarder, slowing down the hydration process in cement. [1-2]

The impact of sugarcane molasses on the initial properties of concrete is a key topic of discussion. It has been observed that sugarcane molasses can improve the workability of concrete by acting as a plasticizer, reducing its water content while maintaining or even increasing its flowability. This improvement in workability can simplify the compaction and placement processes during construction activities. Additionally, the use of sugarcane molasses as an admixture in concrete has demonstrated potential advantages, such as enhanced freeze-thaw resistance, self-healing capabilities, and improved workability. Moreover, the inclusion of molasses as an admixture can also help reduce the porosity of concrete, ultimately enhancing its strength and durability. This phenomenon is attributed to the prolonged setting time of the concrete mix, which is influenced by the quality of water added to the mixture. Thus, replacing a significant portion of traditional admixtures with molasses in large-scale concrete production can offer substantial benefits in terms of cost-effectiveness, energy efficiency, durability, and overall ecological and environmental advantages. [3-4]

One of the key advantages of molasses is its ability to retard the setting time of fresh concrete due to the presence of sugar. This characteristic allows for more flexible handling and placement of the concrete during construction, providing workers with ample time to ensure proper compaction and finishing. The exploration of molasses as a water-reducing and time-retarding admixture in concrete offers promising prospects for the construction industry. The use of sugarcane molasses can improve the workability, freeze-thaw resistance, and self-healing properties of concrete. Additionally, it can contribute to the reduction of porosity, enhancing the strength and durability of concrete structures. Furthermore, the widespread adoption of molasses as an admixture in concrete production would yield significant economic, energy-efficient, and environmentally friendly outcomes. With its retarding effects on setting time, molasses presents a valuable solution for overcoming the limitations associated with quick-setting concrete. [5]

2.Materials

2.1 Sugarcane Molasses

Sugarcane molasses, a viscous and adhesive substance, comprises a diverse array of components, including sugars, minerals, organic acids, and trace elements. The specific composition of molasses can vary depending on its source and the process by which it is produced. Sucrose, glucose, and fructose are responsible for the sweet taste of molasses, while minerals like potassium, calcium, and magnesium contribute to its nutritional value. These constituents play a pivotal role in the interaction between molasses and the concrete matrix. [6] The physiochemical properties of the sugarcane molasses obtained from "Utopian Sugars Limited, Solapur" are outlined in Table 1

Table 1: Physiochemical Properties of Molasses

No.	properties	Sugarcane molasses
1	Colour	Dark brown
2	Specific gravity	1.34
3	Total solids	80.23%
4	Chloride content	1.8
5	PH	4.5
6	Appearance	Syrupy liquid

Fig 1: sample of sugarcane molasses

2.2 Cement: Ordinary Portland Cement 53 Grade (conforming to IS 12269)

Ordinary Portland Cement of 53 grade, which meets the requirements specified in IS 12269, is employed as the primary binder in the concrete mixture. This type of cement is widely utilized in the construction industry due to its excellent strength and durability properties. [7]

2.3 Aggregate

- **Fine Aggregate:** Crushed sand is utilized as the fine aggregate in accordance with the specifications outlined in IS 383:2016. The use of crushed sand ensures that the concrete mix meets the required grading and quality standards for optimal performance.
- **Coarse Aggregate:** Coarse aggregates ranging from 10mm to 20mm in size are used in compliance with the guidelines presented in IS 383:2016. These aggregates provide the necessary structural stability and strength to the concrete.

2.4 Water:

Potable water, in accordance with the specifications set forth in IS 456:2000, is employed for both the mixing and curing processes. The quality of water used in concrete production is crucial to maintain the desired chemical reactions and overall integrity of the final product. It is important to note that the addition of sugarcane molasses to the concrete mixture offers several benefits. The unique composition of molasses, including its sugars, minerals, and organic acids, contributes to enhanced workability and prolonged setting time of the concrete. This, in turn, facilitates better compaction and placement during construction activities. Furthermore, the presence of molasses can lead to improvements in the freeze-thaw resistance and self-healing capabilities of the concrete, thereby enhancing its durability and longevity. [8-9]

The materials used in this study include sugarcane molasses, which possesses various components that positively impact the concrete mixture. Ordinary Portland Cement 53 Grade, crushed sand as the fine aggregate, and coarse aggregates in the specified size range ensure the desired strength and quality of the concrete. Potable water is utilized for the mixing and curing processes, adhering to the recommended standards. The incorporation of sugarcane molasses, along with the other materials, contributes to the improved performance and characteristics of the final concrete product. [10-11]

3. Experimentation work on concrete

Every mix is tested for fresh properties slump and compaction factor of concrete. Further, more the hardened properties density, compressive strength, flexural strength, split tensile strength are also studied. Major Infrastructural development is carried out with M20 grade of concrete locally. Several trials have been made for proportioning of M20 grade of concrete. The following is the final concrete mix proportion.

Table 2 Mix proportion for M20 grade of concrete

W/C ratio	Cement	Fine Aggregate	Coarse Aggregate	Water	Mix proportion
0.51	352.54 kg/m³	813.02 kg/m³	1230.20 kg/m³	190 kg/m³	1:2.18:3.30

4. Results and Discussions

Fresh Properties of concrete

The fresh properties of concrete were evaluated based on the experimental results. It was observed that as the percentage of admixtures increased, the slump and compaction factor of the concrete also increased. The workability of the concrete was assessed using the slump cone test and compaction factor test. The slump test measures the consistency and workability of the concrete. It involves filling a slump cone with the freshly mixed concrete and then removing the cone. The amount of settlement or "slump" of the concrete is measured, indicating its workability. The results showed that as the percentage of admixtures increased, the slump of the concrete increased as well. This indicates that the addition of admixtures, such as sugarcane molasses, improves the workability of the concrete, making it easier to handle and place during construction activities. Similarly, the compaction factor test evaluates the ability of the concrete to be compacted effectively. It measures the degree of compaction achieved by the concrete when it is subjected to standard compaction procedures. The higher the compaction factor, the better the workability of the concrete. The experimental findings demonstrated that the addition of admixtures resulted in an increase in the compaction factor of the concrete. This suggests that the use of sugarcane molasses as an admixture enhances the ease of compaction, allowing for improved consolidation and density of the concrete. The results of the slump cone test and compaction factor test indicate that the inclusion of admixtures, specifically sugarcane molasses, positively affects the workability of the concrete. The increased slump and compaction factor values demonstrate improved consistency and ease of handling during construction. These findings support the potential benefits of utilizing sugarcane molasses as a water-reducing and time-retarding admixture in concrete, enhancing its fresh properties and overall performance.

Table 3 Slump value and compaction factor

M20 Mix	Slump (mm)	Compaction Factor
Conventional	75	0.87
Molasses 0.25%	80	0.90
Molasses 0.50%	85	0.91
Molasses 0.75%	85	0.92
Molasses 1.25%	95	0.94

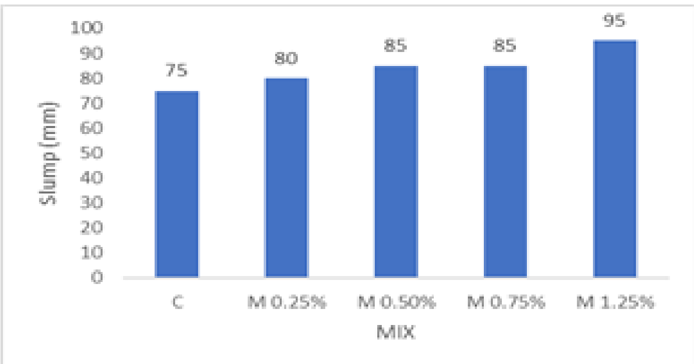

Fig 2: Slump of concrete

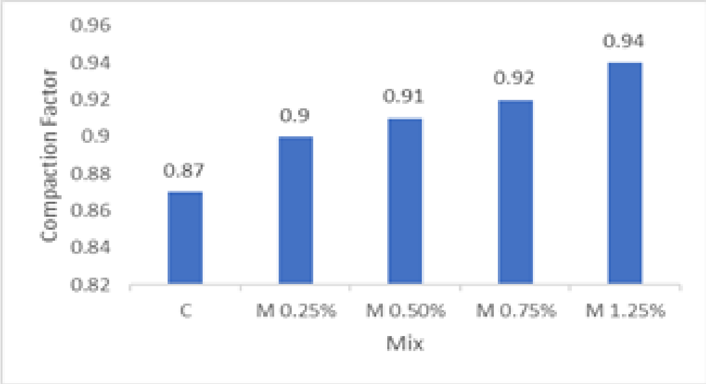

Fig 3: compaction factor of concrete

4.1 Discussion

4.1.1 Fresh properties

In this study, concrete mixtures were prepared with the addition of four different dosages of molasses at varying percentages: 0.25%, 0.50%, 0.75%, and 1.25%. The experimental results revealed that as the percentage of admixtures increased, the slump and compaction factor of the concrete also increased. The addition of molasses had a significant impact on the setting properties of the concrete, resulting in a noticeable collapse of slump during the experimentation.

To provide a clearer understanding of the results, the following observations were made:

1. From the conventional concrete mix to the inclusion of 0.25% molasses, there was a 7% increase in slump and a 3% increase in the compaction factor.
2. Increasing the molasses dosage from 0.25% to 0.50% resulted in a 6% increase in slump and a 1% increase in the compaction factor.
3. When the molasses dosage was further increased from 0.50% to 0.75%, there was no significant change in slump, but a 1% increase in the compaction factor was observed.
4. Finally, increasing the molasses dosage from 0.75% to 1.25% led to a substantial 12% increase in slump and a 2% increase in the compaction factor.
5. Overall, when comparing the conventional concrete to the molasses-added concrete at various dosages, there was a significant 26% increase in slump and an 8% increase in the compaction factor.

These findings highlight the influence of molasses on the fresh properties of concrete. The addition of molasses resulted in improved workability, as demonstrated by the increased slump and compaction factor values. The collapse of slump observed during the experimentation indicates that molasses influenced the setting time of the concrete. Overall, the results support the potential benefits of incorporating molasses as an admixture in concrete, enhancing its fresh properties and facilitating the construction process.

4.1.2 Hardened properties of concrete

Compressive strength:

This is a fundamental property that is widely used to assess the strength and load-bearing capacity of concrete. It quantifies the ability of concrete to withstand compressive forces and is typically determined through laboratory testing of concrete specimens, such as cubes or cylinders, under controlled conditions. In this study, concrete cubes with dimensions of 150 mm x 150 mm x 150 mm and cylinders with dimensions of 150 mm diameter and 300 mm height were cast and tested for compressive strength at different curing ages, specifically 7 and 28 days.

Flexural strength

This is also known as the modulus of rupture, is a crucial parameter for evaluating the ability of concrete to resist bending or flexural stresses. This property is evaluated by subjecting beam specimens to bending loads, simulating the actual conditions experienced by concrete elements such as beams, slabs, and columns. By measuring the maximum bending moment and the corresponding deflection, the flexural strength of the concrete can be determined. This provides valuable insights into the structural performance and durability of concrete elements under varying loading conditions. [12]

Split tensile strength

Another important property that is assessed in this study is split tensile strength. This test indirectly measures the tensile strength of concrete by subjecting a cylindrical specimen to radial forces on its surface, resulting in the formation of a vertical crack along its diameter. The split tensile strength is then determined by measuring the maximum tensile stress at the point of failure. This property is of particular interest as it provides information about the ability of concrete to resist cracking and withstand tensile stresses, which are typically induced by external loads or temperature variations.

By evaluating the compressive strength, flexural strength, and split tensile strength of the concrete, a comprehensive understanding of its mechanical properties can be obtained. These properties play a vital role in determining the suitability and performance of concrete in various applications. They are essential for ensuring the structural integrity, durability, and safety of concrete structures. [13-15]

Table 4: 7 days compressive strength of concrete

M20 Mix	Compressive Strength
Conventional	19
Molasses 0.25%	15.31
Molasses 0.50%	13.89
Molasses 0.75%	10.21
Molasses 1.25%	5.35

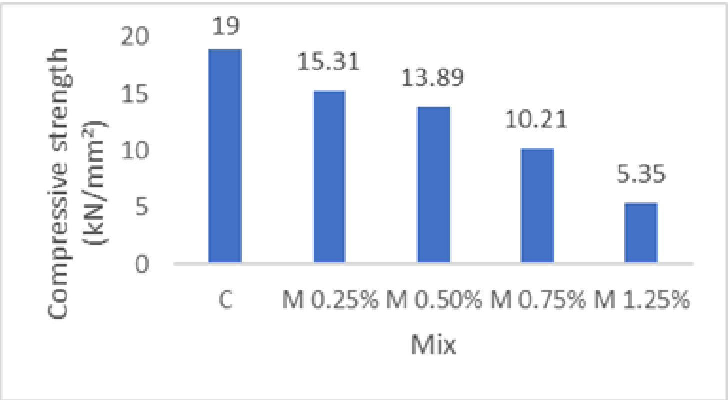

Fig 4: 7 days Compressive strength of cubes

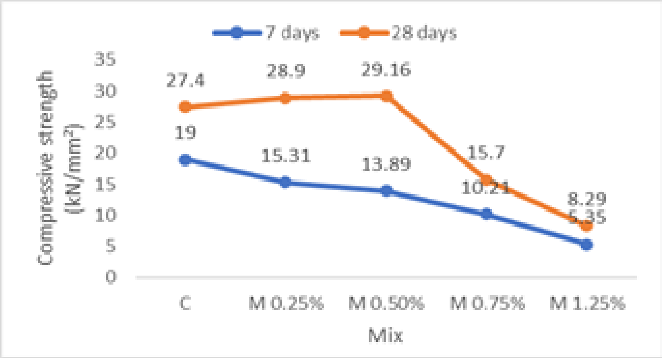

Fig 5: 7 and 28 days of compressive strength of cubes

Table 5: 28 days Compressive, Flexural and Split Tensile Strength of M20 grade of Concrete

M20 Mix	Compressive Strength		Flexural Strength	Split Tensile Strength
	Cubes	Cylinder		
Conventional	27.40	28.80	5.60	3.24
Molasses 0.25%	28.90	29.53	5.75	3.68
Molasses 0.50%	29.16	31.7	5.9	3.9
Molasses 0.75%	15.7	15	2.8	3.04
Molasses 1.25%	8.29	7.35	1.2	1.6

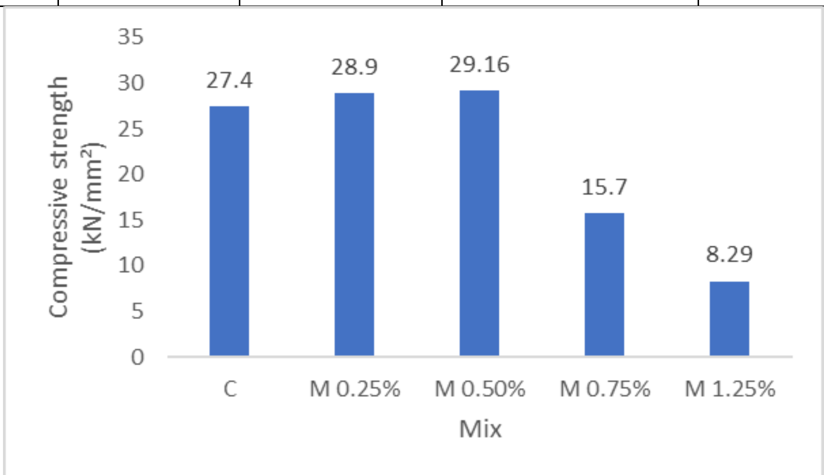

Fig 6 Compressive strength of cubes

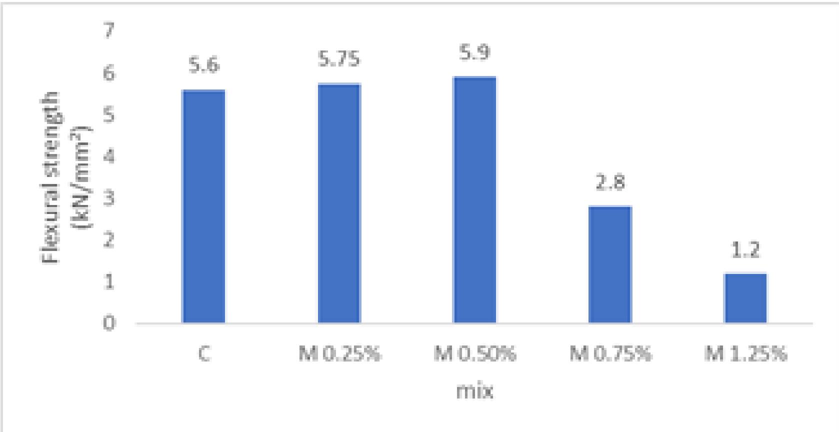

Fig 7 Flexural strength of beams

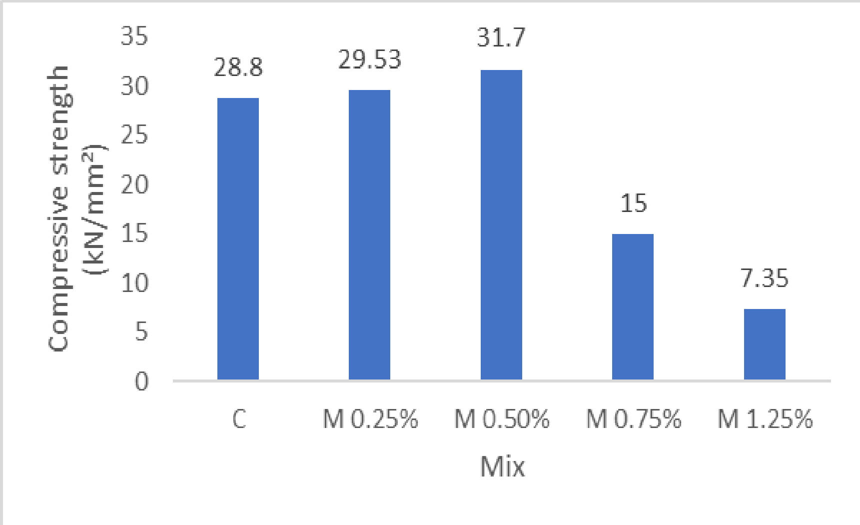

Fig 8 Compressive strength of cylinders

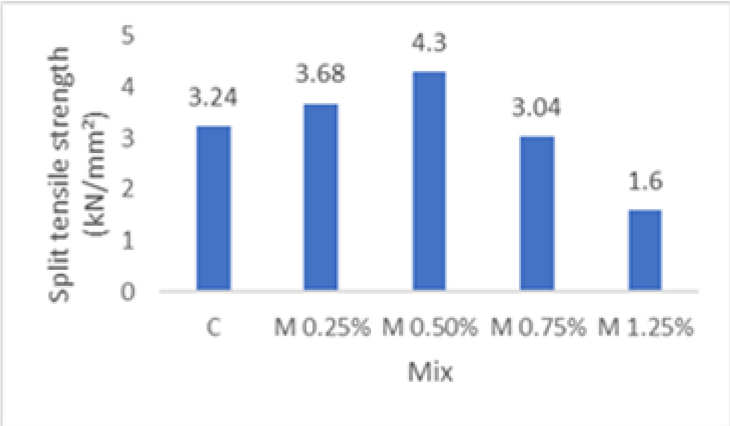

Fig 9 Split tensile strength of cylinders

The addition of molasses to the concrete during the experiment had a notable impact on the setting properties of the concrete, resulting in a visible collapse of the slump. After 24 hours, it became challenging to set the cube specimens, and demolding was delayed until 48 hours for samples containing 0.25% molasses or higher. The inclusion of molasses increased the initial and final setting time of the concrete. Furthermore, the organic compounds present in sugarcane molasses were found to possess air-entraining properties that improved the freeze-thaw resistance of the concrete. These compounds facilitated the formation of air bubbles, reducing potential damage caused by water expansion during freezing and subsequent contraction during thawing cycles. [16-18]

The compressive strength of the concrete specimens was evaluated at different curing ages (7 and 28 days) to determine the effect of molasses addition. The results are as follows:

1. For 7 days, the addition of 0.25% molasses led to a 19% decrease in the compressive strength of the cubes.
2. Increasing the molasses dosage from 0.25% to 0.50% resulted in a 17% decrease in the compressive strength of the cubes after 7 days.
3. The inclusion of 0.50% to 0.75% molasses resulted in a significant 29% decrease in the compressive strength of the cubes after 7 days.
4. When the molasses dosage was further increased from 0.75% to 1.25%, there was a substantial 47% decrease in the compressive strength of the cubes after 7 days.

For specimens cured for 28 days, the effects of molasses addition on various strength parameters were as follows:

5. The addition of 0.25% molasses resulted in a 6% increase in the compressive strength of the cubes, a 3% increase in the compressive strength of the cylinders, a 3% increase in the flexural strength of the beams, and a 13% increase in the split tensile strength of the cylinders.
6. Increasing the molasses dosage from 0.25% to 0.50% resulted in a 3% increase in the compressive strength of the cubes, a 7% increase in the compressive strength of the cylinders, a 4% increase in the flexural strength of the beams, and a 17% increase in the split tensile strength of the cylinders.
7. The inclusion of 0.50% to 0.75% molasses led to a significant decrease in all strength parameters: a 46% decrease in the compressive strength of the cubes, a 52% decrease in the compressive strength of the cylinders, a 53% decrease in the flexural strength of the beams, and a 29% decrease in the split tensile strength of the cylinders.
8. Increasing the molasses dosage from 0.75% to 1.25% resulted in a 47% decrease in the compressive strength of the cubes, a 51% decrease in the compressive strength of the cylinders, a 57% decrease in the flexural strength of the beams, and a 47% decrease in the split tensile strength of the cylinders.

These findings demonstrate the influence of molasses addition on the compressive, flexural, and split tensile strength of the concrete at different curing ages. It is evident that higher dosages of molasses led to a reduction in strength properties, especially when the dosage exceeded 0.75%. However, at a lower dosage of 0.25%, some parameters showed an improvement in strength after 28 days of curing. These results provide valuable insights into the effects of sugarcane molasses as an admixture in concrete and highlight the importance of dosage control for achieving the desired strength characteristics. [19-21]

5. Conclusion

1. In early age of the concrete molasses delays in setting and hardening reveals delaying strength gaining in early age.
2. Molasses addition improves workability slightly however the slump of concrete is assured. The compressive strength is also increased marginally.
3. Flexural and Split tensile strength are significantly increased. The addition of 0.5% molasses has improved 5% flexural strength and 33% split tensile strength.
4. 0.75% and 1.25% addition of molasses leads to reduce cube and cylinder compressive strength drastically. Due to prolonged setting process of concrete the flexural and split tensile strength also reduced due to 0.75% and 1.25% addition.
5. Addition of 0.5% facilitates true slump medium workability. The cube and cylinder compressive strength also improved. The flexural and split tensile strength are substantially increased. It is suggested for 0.5% of molasses addition in concrete.

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