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EFFECT OF SUPERPLASTICIZER ON MECHANICAL PERFORMANCE OF CONCRETE MADE WITH CIGARETTE BUTTS

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Abstract — Cigarette butts are among the most extensively littered wastes in the world. About 1.3 billion smokers worldwide produce trillions of cigarette butts every year. Discarded cigarette butts leach toxic chemicals and heavy metals into the environment, polluting water and soil. The aim of this research is to confine cigarette butts within concrete to eliminate its hazardous effects on the environment. However, the inclusion of cigarette butts in concrete may lead to poor mechanical properties and durability. A high-range water-reducing admixture (superplasticizer) has been used in concrete to compensate for the strength and durability loss. Cylindrical concrete specimens containing different percentages of cigarette butts (0%, 10%, 20%, and 30%) by weight of cement were prepared with and without a superplasticizer. The prepared specimens were tested to assess the mechanical performance of the concrete. It was observed that 10% inclusion of cigarette butts may be performed without significantly compromising the mechanical performance, and superplasticizer may be added to concrete to slightly enhance the mechanical properties.

***Keywords*:** cigarette butt, toxic chemical, environment, superplasticizer, mechanical performance

1.0 INTRODUCTION

Cigarette butts are linked with different types of environmental pollution posing significant health hazards to various living organisms [1–5]. It is the second most littered item in the world just after food wrappers [6]. The volunteers of International Coastal Cleanup collect huge amount of cigarette butts every year from the coastal line of different countries of the world (Fig. 1). Cigarette butts found on beaches may not originate from smoking directly on the shore. Instead, they are often discarded on sidewalks or tossed from vehicles in motion. Subsequently, these discarded butts find their way into street drains, eventually flowing into streams, rivers, and ultimately, the oceans [7]. Approximately 4.5 trillion discarded cigarette butts are believed to accumulate annually as litter and most of them end up in the ocean, making it the biggest man-made ocean contaminant [8]. Cigarette contains almost 4000 type of chemicals and about 50 of them are carcinogenic [1, 9]. When discarded, cigarette butts are carried to the aquatic environment and leach toxic chemicals [10, 11]. Discarded cigarette butts contain left-over unsmoked tobacco which eventually pollutes the environment [3]. Cigarette butts consist of as many as 12,000 cellulose acetate fibers and are mostly non-biodegradable [7]. Cellulose acetate is photodegradable and over time, ultraviolet rays will fragment cigarette butts into smaller pieces, yet the source material remains, essentially becoming dispersed in water and soil [12–14]. Cigarette butts may leach many toxic chemicals like heavy metals, nicotine, ethylphenol, formaldehyde etc. to the environment [15–17]. Studies indicate that cigarette butts release nicotine, arsenic, polycyclic aromatic hydrocarbons, and heavy metals into the environment which are discarded on road-side [18].

Instead of ending up in landfills, majority of cigarette butts find their way to nearby water bodies. Even if cigarette butts are collected properly, it is not economically feasible or sustainable to landfill them because of high treatment cost [19]. Confining cigarette butts in concrete may be a practicable solution, rather than landfilling or discarding them into the environment.

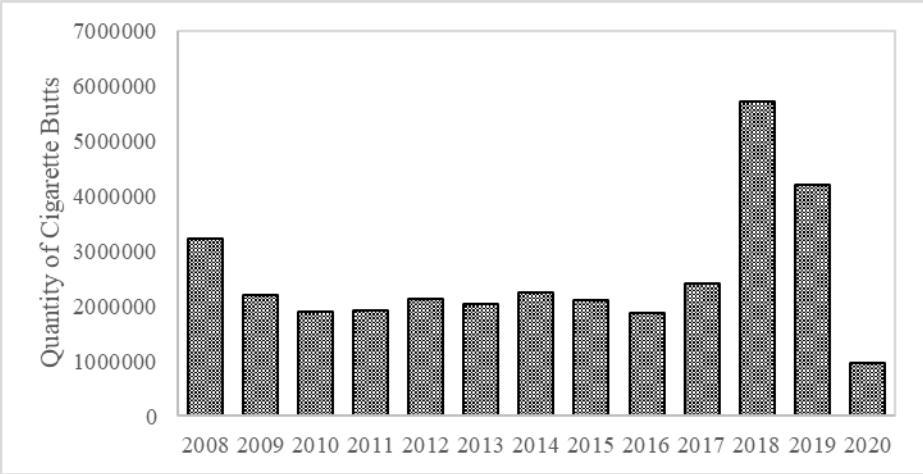


Figure 1 Cigarette butts collected globally in International Coastal Cleanup, 2008-2020.
Source: Ocean Conservancy, 2020

Inclusion of recycled materials in concrete usually degrades its quality, resulting in low mechanical strength [20–23]. The use of cigarette butts in concrete may not be an exception to the expected behavior of concrete. Mohajerani et al. [24] incorporated cigarette butts into asphalt concrete by varying the amount of cigarette butts and classes of bitumen, and found that the asphalt mix produced satisfactory results for light, medium, and heavy traffic conditions. Tao et al. [25] conducted a study on the uniaxial compressive strength of concrete containing cigarette butts and discovered that as the amount of cigarette butts in the concrete increased, the strength of the concrete decreased consistently, while the ductility increased. Mohajerani et al. [26] proposed the incorporation of cigarette butts into clay bricks as a potential solution for their disposal and suggested a 1% cigarette butts content in the bricks. High range water reducing admixture like superplasticizer (SP) can produce self-compacting concrete with low porosity and high density without compromising workability and can enhance mechanical performance of concrete [27–31]. Nevertheless, if the concrete's strength does not diminish significantly, it could be employed in applications where low strength concrete is suitable. In this context, effect of SP on mechanical performance of concrete containing cigarette butts have been studied and presented in this research.

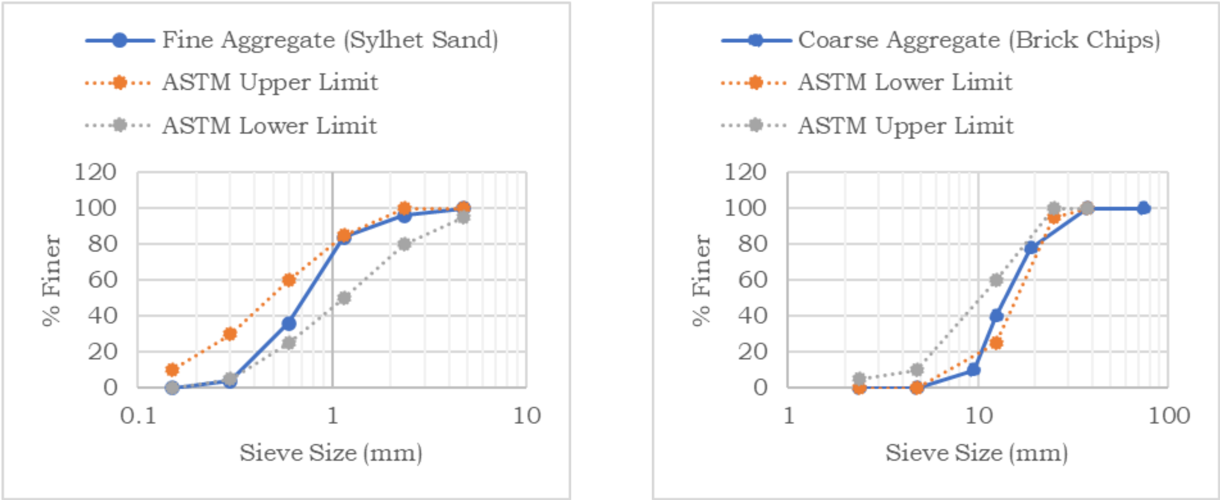
2.0 MATERIALS AND METHODS

2.1. Cement

PCC has been utilized as binder having local specifications of BDS EN 197-1:2003 CEM II/B-M (S-V-L) 42.5 N. No test was conducted to assess the quality of the used cement.

2.2. Aggregates

River sand which is locally known as Sylhet sand, named after its source location, has been used as fine aggregate (FA). The fine aggregate comprises slightly coarser granules in size. Coarse aggregates (CA) are obtained by crushing clay bricks, resulting in brick chips. Fig. 2 illustrates the gradation of these aggregates, while Table 1 provides an overview of their physical properties.



(a) **(b)**

Figure 2 Gradation of (a) FA and (b) CA

Table 1 Physical Properties of FA and CA

Aggregate Type	FM	Unit Weight (kg/m^3)	Bulk Specific Gravity (OD)	% Voids	Absorption Capacity (%)
FA (Sylhet sand)	2.8	1560	2.38	33.7	5.26
CA (Brick chips)	7.72	1056	1.52	44.89	25.9

2.3. Cigarette Butts

Cigarette butts used in this research were collected from public places like streets, parks, lakes, road side tea stalls, smoking zone of restaurants etc. Cigarette butts were incorporated into the concrete in their untreated state, as any form of treatment would require additional expenses. The cigarette butts utilized in this study primarily consisted of cellulose acetate filters, tobacco, and paper. Fig. 3 shows the collected cigarette butts before being added into the concrete mix.

Figure 3 Untreated cigarette butts

2.4. Superplasticizer

In the concrete mix, a polycarboxylic ether based chemical admixture has been employed as SP having specifications conforming to ASTM C494, Type F & G.

2.5. Concrete Mixtures

Mix design was done for control specimen containing 0% cigarette butts targeting compressive strength of 20.7 MPa (3000 psi). Eight concrete mixes were prepared with different cigarette butts content (0%, 10%, 20%, and 30% by weight of cement) in concrete and 0.7% SP by weight of cement was added with half of the concrete mixes. Table 2 shows the quantity of different materials used in different concrete mixes. All mixtures had a consistent water-cement ratio.

Table 2 Constituent Materials for Concrete Mixes

	Concrete Mix	Cigarette Butts Content (%)	Cement (kg/m^3)	Water (kg/m^3)	FA (kg/m^3)	CA (kg/m^3)	Cigarette Butts (kg/m^3)	SP (kg/m^3)
Without Superplasticizer	1	0%	334	190	630	1195	0	0
	2	10%	334	190	630	1195	33.4	0
	3	20%	334	190	630	1195	66.8	0
	4	30%	334	190	630	1195	100.2	0
With Superplasticizer	5	0%	334	190	630	1195	0	2.338
	6	10%	334	190	630	1195	33.4	2.338
	7	20%	334	190	630	1195	66.8	2.338
	8	30%	334	190	630	1195	100.2	2.338

2.6. Test Methods

The compressive strength (CS) test conducted in this research adhered to the guidelines outlined in ASTM C39. The splitting tensile strength (STS) test was conducted in accordance with the procedures specified in ASTM C496. To calculate the static modulus of elasticity (MOE), the stress-strain diagram of the concrete cylindrical specimen was initially established. Subsequently, the static MOE for the concrete was determined by following the methodology outlined in ASTM C469. The strain rate for all the test was 1 mm per minutes. Fig. 4 illustrates the laboratory setup used for conducting the CS test, STS test, and MOE test.

(a) (b) (c)

Figure 4 Test setup for (a) CS test, (b) STS test and (c) MOE test

3.0 RESULTS AND DISCUSSION

3.1. Effect on Workability of Fresh Concrete

Slump test was conducted for fresh concrete having different percentages of cigarette butts content with and without superplasticizer as per ASTM standard requirements of specifications C143/C1443M. Table 3 shows the slump value for different concrete used here.

Table 3 Results of Slump Tests on Various Concrete Mixtures

	Concrete Mix	Cigarette Butts Content (%)	Slump (mm)
Without Superplasticizer	1	0%	87.5
	2	10%	12.5
	3	20%	0
	4	30%	0
With Superplasticizer	5	0%	100
	6	10%	30
	7	20%	25
	8	30%	12.5

Analyzing the slump test results, it is observed that the workability of concrete decreased significantly due to the addition of cigarette butts in concrete. Zero slump was obtained when 20% and 30% of cigarette butts were used in concrete. Cigarette butts are fibrous in nature and have irregular shapes and sizes, which can disrupt the flow of the concrete mixture. The presence of these irregular particles hinders the movement of the fresh concrete, making it more difficult to achieve proper compaction and placement. Furthermore, the low workability can be attributed to the high-water absorption exhibited by the fibrous filaments of cigarette butts. The workability of concrete slightly increased with the addition of superplasticizer in it. Minimum slump was obtained for 30% cigarette butts content for both with and without superplasticizer.

3.2. Effect on Compressive Strength of Concrete

SP was used in concrete to improve the physical and mechanical properties of concrete that was supposed to reduce due to the addition of cigarette butts. The effects of SP on CS of concrete containing different percentages of cigarette butts are summarized in Fig. 5. It is observed by analyzing the results that the compressive strength of concrete slightly increased due to the addition of SP in it. When SP was used, the CS of control specimen (concrete containing 0% cigarette butts) was increased by 4.39%. The CS of concrete having 10%, 20% and 30% of cigarette butts by weight of cement was increased by 7.61%, 7.89% and 22.4% respectively.

It is also observed that with the addition of cigarette butts in concrete, the compressive strength decreased, for both without and with superplasticizer. When 10% cigarette butts by weight of cement was added to concrete, the compressive strength decreased by 9.46% without superplasticizer. But 20% and 30% addition of cigarette butts reduced the CS of concrete significantly to 33.56% and 47.86% without superplasticizer. Similar trend was observed when superplasticizer was added to concrete. The CS of concrete decreased by 6.66%, 31.33% and 38.86% due to the addition of 10%, 20% and 30% of cigarette butts in concrete respectively.

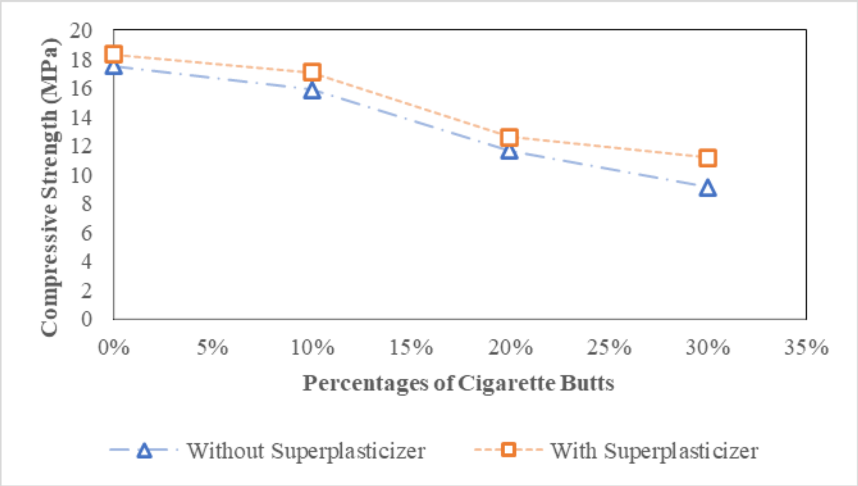


Figure 5 Effect of SP on CS of concrete containing different percentages of cigarette butts

3.3. Effect on Splitting Tensile Strength of Concrete

The effects of SP on STS of concrete having varying content of cigarette butts are summarized in Fig. 6. It is observed by analyzing the results that the STS slightly increased with the addition of SP. But the effect of SP diminished with the increase of cigarette butts content in concrete. When SP was used, the STS of control specimen (concrete containing 0% cigarette butts) was increased by 15.51%. The STS of concrete containing 10%, 20% and 30% of cigarette butts by weight of cement was increased by 11.38%, 4.49% and 2.87% respectively due to the addition of SP. Further analyzing the obtained results, it is seen that maximum STS was obtained when 10% cigarette butts were used in concrete, with and without SP.

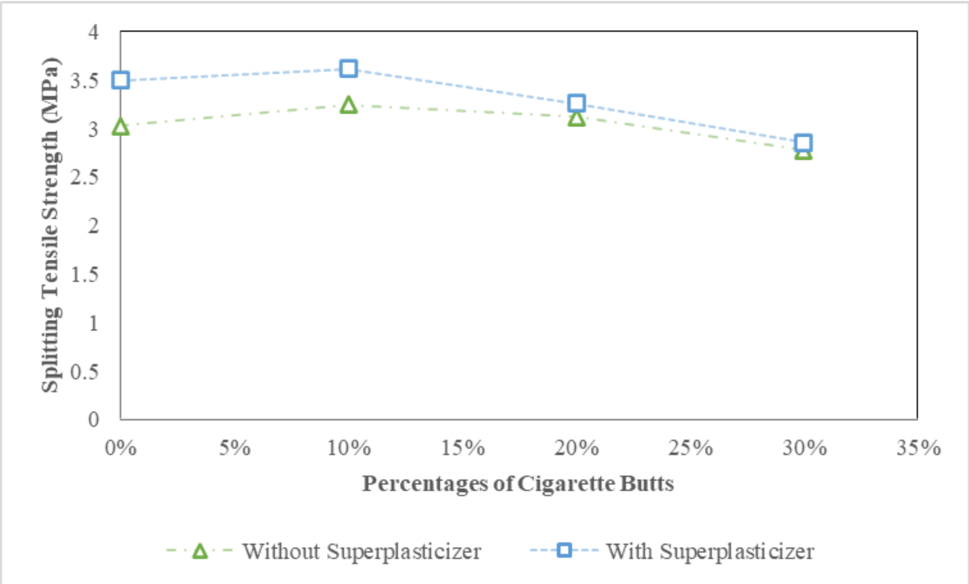


Figure 6 Effect of SP on STS of concrete containing different percentages of cigarette butts

3.4. Effect on Modulus of Elasticity of Concrete

The effects of SP on MOE of concrete containing different percentages of cigarette butts are presented in Fig. 7. It is observed that the MOE of concrete increased remarkably with the addition of SP. When SP was used, the MOE of control specimen (concrete containing 0% cigarette butts) was increased by 20.84%. The MOE of concrete containing 10%, 20% and 30% of cigarette butts by weight of cement was increased by 69.91%, 139.2% and 203.24% respectively.

The stress-strain diagram from which MOE obtained is graphically presented in Fig. 8 (a and b). It is seen that with the addition of cigarette butts in concrete, the MOE of concrete reduced significantly and the concrete showed more ductile behavior. The MOE of concrete without SP decreased by 63.8%, 81.09% and 89.61%, respectively for 10%, 20% and 30% addition of cigarette butts by weight of cement. Similar trend was also observed for concrete with SP. The modulus of elasticity of concrete with SP decreased by 49.1%, 62.58% and 73.93% respectively for 10%, 20% and 30% addition of cigarette butts by weight of cement.

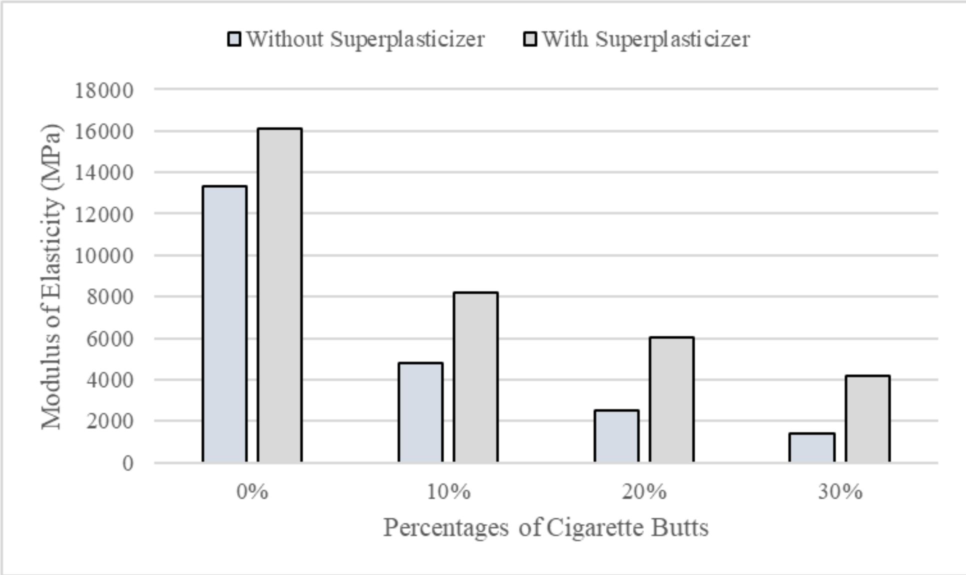
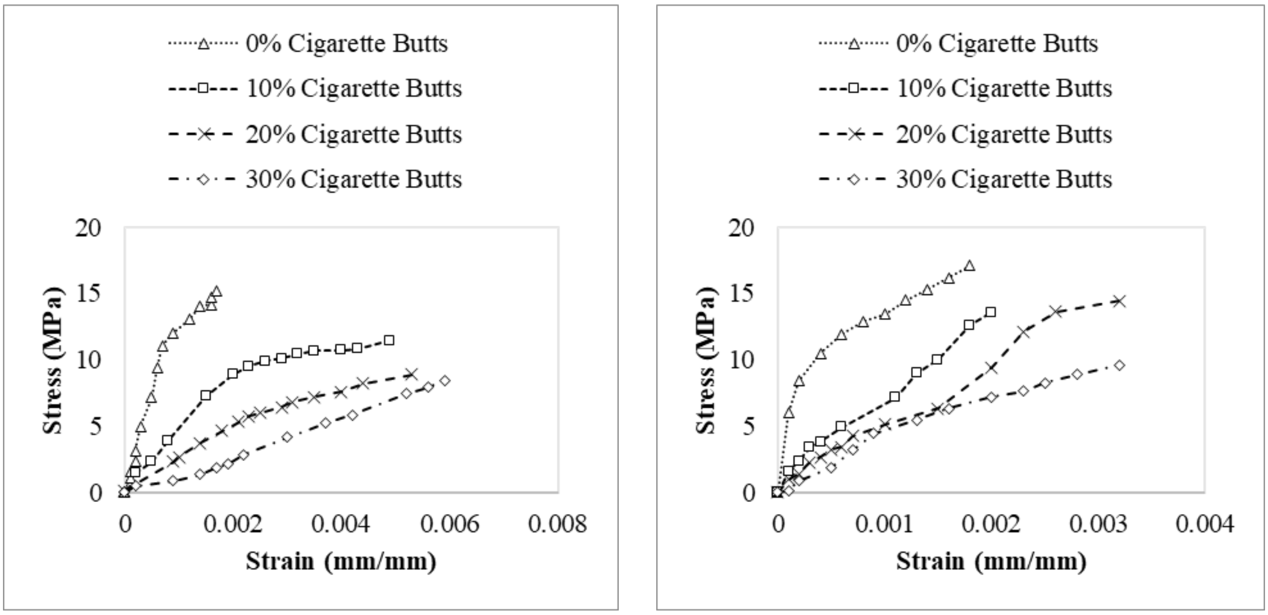


Figure 7 Effect of SP on MOE of concrete containing different percentages of cigarette butts



(a) **(b)**

Figure 8 Stress-strain diagram of concrete containing different percentages of cigarette butts (a) without SP and (b) with SP

The CS and MOE are two important mechanical properties of concrete that are often studied to understand its structural behavior. The relation between CS and MOE can be predicted by the proposed ACI relation. A liner relationship between CS and MOE of concrete containing cigarette butts has been established and is shown in Fig. 9 (a and b). It is observed that for concrete containing cigarette butts with and without SP, the ACI 318-19 relation overestimates the value of MOE. When cigarette butts are incorporated into concrete, their irregular shape, porous structure, and different material properties can introduce variations in the behavior of the composite material. These variations can affect the mechanical properties, including the MOE. The ACI 318-19 relation, which is based on conventional concrete, may not adequately consider these deviations and thus result in an overestimation of the MOE for cigarette butts concrete.

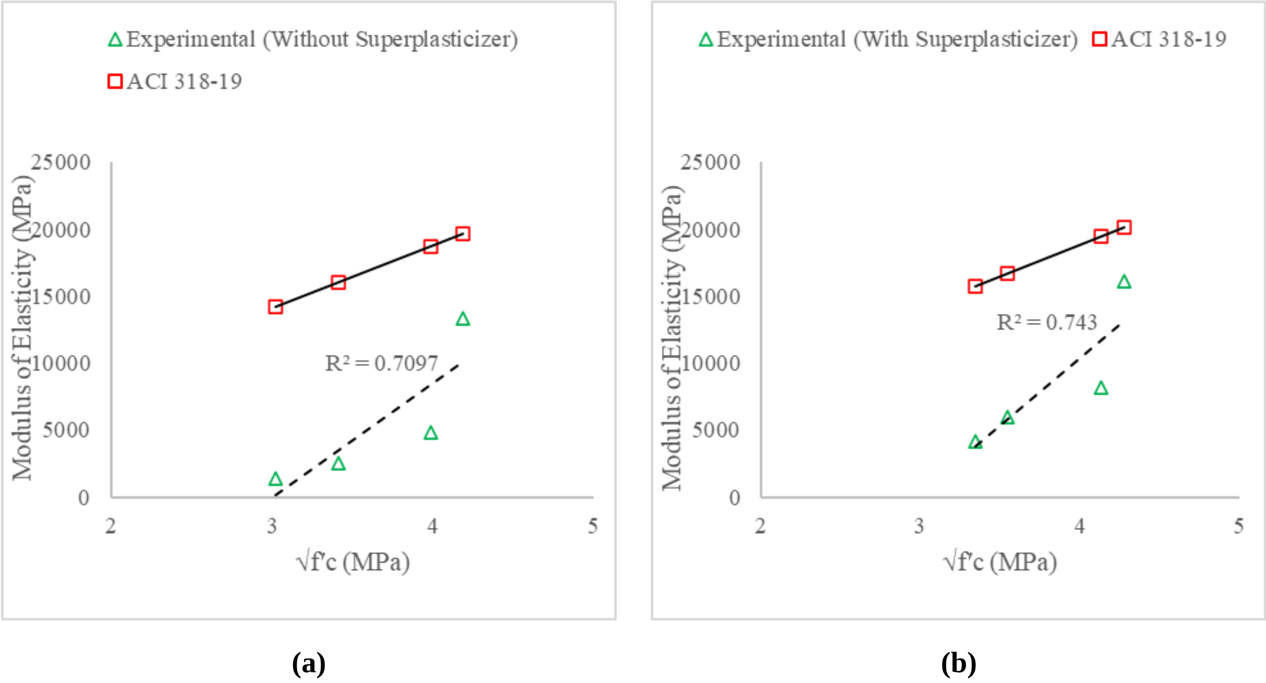


Figure 9 Relation between CS and MOE of concrete containing different percentages of cigarette butts (a) without SP and (b) with SP

4.0 CONCLUSION

Based on the experimental investigations conducted on the prepared concrete specimens, the following conclusions were drawn:

i) The workability of concrete decreases significantly with an increase in cigarette butt content. The workability slightly increased with the use of a superplasticizer.
ii) The compressive strength of concrete decreases with an increase in the cigarette butt content. It was observed that for 10% cigarette butt content, the compressive strength of concrete without superplasticizer decreased by 9.45%. The compressive strength decreased by 33.56 % %And for 20% and 30% cigarette butt contents, respectively. A similar trend was observed when superplasticizer was added.
iii) The maximum splitting tensile strength was obtained for 10% cigarette butt content for concrete with and without a superplasticizer. The splitting tensile strength decreased when 20% and 30% cigarette butts were used in concrete.
iv) With an increase in cigarette butt content in concrete, the ductility of concrete increases, but the modulus of elasticity decreases.
v) The obtained data suggest that 10% cigarette butts may be included in the concrete without significantly compromising its mechanical strength. The detrimental effect of the inclusion of cigarette butts in concrete can be overcome by adding a superplasticizer.

Conflict of Interest

The authors declare that they have no known competing financial interests or personal relationships that could have influenced the work reported in this study.

Acknowledgement

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