

EFFECT OF METAKAOLIN ON THE PROPERTIES OF COCONUT SHELL CONCRETE

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ABSTRACT. This paper presents the strength behaviour of coconut shell (CS) concretes by using the partially replacement of Natural Coarse Aggregate (NCA) with CS and Ordinary Portland Cement with metakaolin (MK). Nine different concrete mixtures are made by replacing 0%, 10% and 20% of NCA with CS and 0%, 10% and 20% cement with MK respectively. M30 grade of concrete is designed as per standard specification IS: 10262-2009 to achieve the target mean strength 39.9 MPa for a tolerance factor of 1.65. The mix proportion 1: 1.52: 2.82 are used for the experimental works with w/b 0.43. For fresh concrete properties, slump test is carried out. For hardened concrete properties, compressive strength, split tensile strength and flexural strength tests, are carried out. The results indicate that upto 10% partially replacement of NCA with CS and 10% partially replacement of cement with MK gives the optimized compressive strength.

Keywords: Coconut shell (CS), Metakaolin (MK), Compressive strength, Flexural strength, Split tensile strength, Workability

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INTRODUCTION

In the construction industry, the price of architecture resources plays a vital role using different architecture materials. By means of waste resources in concrete has given a believable environment. Waste has been used to achieve its low density and strength and also to achieve thermal filling light weight concrete. Coconut shell (CS) is a waste material from agriculture which is available in lively in steamy area like Asia, America and Africa which are used conveniently as less strength that proves as light weight concrete aggregate. Engineering properties of CS as aggregate in concrete proves as light weight aggregate. Kaolin clay is the raw material in the manufacture of Metakaolin (MK). Highly pure kaolinitic clays can be blazed at comparatively low temperature 600-700°C to stay silica and alumina in irregular state, and then abraded to particles smaller than 2 microns (μ). The material is a highly awake pozzolan of bright white color. That is substantially appropriate for use in architectural concrete.

In the recent past many researchers have studied the physical and mechanical characteristics of coconut shell aggregate and its influence on properties of both fresh and hardened concrete. [1] Anwar et al. (2016) studied the waste CS may be utilized to replace NCA. M20 grade of concrete was produced by replacing NCA at 0%, 5%, 10%, 20%, 30%, 40% and 50% by weight with CS. Total sixty three cubes were cast and their compressive strength was evaluated at 7, 14 and 28 days. The results showed that CSC can be used in light weight concrete construction. Utilization of CS will not only be cost effective and Eco friendly, but also resolve the issues related to shortage of conventional material and problem of disposal of waste material. [2] Reddy et al. (2014) experimentally investigated the utilization of CS as coarse aggregate and concluded that addition of CS decreases the workability and addition of fly ash as cement replacement increases workability of CSC. The compressive strength and split tensile strength decreases with increase in CS replacement. [3] Ahlawat and Kalurkar (2014) found the possibility of generating M20 grade of concrete by partial replacement of aggregate by CS. 45 no of cubes were casted. Percentage of replacement by CS varies 2.5%, 5%, 7.5%, 10%. Compressive strength found out 19.71, 19.53, 19.08, 18.91 N/mm² at 28 days of curing. Workability and compressive strength had been checked at 7, 14 and 28 days. As the percentage of replacement increased the compressive strength gets reduced. [4] Lenka and Panda (2017) investigates the fresh, hardened and durability properties of conventional concrete (CC) and self-compacting concrete (SCC) by partially replacing cement with MK in different percentages (5-20%). In hardened concrete compressive, split tensile and flexural strength test carried out at an age of 7, 28 and 90 days with constant (w/b) 0.43%. The authors concluded that optimum replacement level of MK for cement was 10%, which increased mechanical properties and robustness properties of concrete. [5] Kim et al. (2012) experimentally investigated the impacts of MK on lightweight concrete according to various types of fine aggregate. Three types of fine aggregate used for this purpose, two of them were by-product of power plant i.e. bottom ash and other one was artificial expanded shale. MK was added to each fine aggregate at cement substitution of 0%, 5%, 10%, 15% and 20% by weight. The feasibility of concrete decreased with increased replacement of MK and type of fine aggregate. [6] Paiva et al. (2012) presented an introduction of MK can have a strong effective on fresh and hardened properties of concrete. High range water reducer admixture (HRWRA) was used to cause deflocculating of particles of MK, leading to better efficiency, improved workability and performance. When HRWRA was used dispersion of MK agglomerate was more effective and this reflects on hardened and fresh state properties. The present paper focuses on the influence of MK and CSA on fresh and hardened properties of CSC.

EXPERIMENTAL STUDY

Test Method

The experimental program consists of testing the hardened coconut shell concrete specimens. The hardened concrete specimens consists of 150×150 mm concrete cubes for compressive strength, 150×150 mm by 500 mm prisms for flexural strength and 100×200 mm cylinders for split tensile strength.

Materials Used and Properties

The cement used for the present work is Ordinary Portland Cement (OPC 43 grade). The physical property of cement specified by Bureau of Indian Standard Specifications (BIS) IS 8112:1989 [7] and also the experimental values obtained from the present study are presented in Table 1. The natural sand of zone II (IS 383-1970) [8] is used as fine aggregate, which is passing through IS 4.75 mm sieve. Natural coarse aggregate used in the present study is 20 mm downgraded satisfying the grading requirements of BIS (IS 383-1970) [8]. The properties of fine aggregate and coarse aggregate are presented in Table 2. Particle size gradation curve of NFA and NCA is shown in Figure 1 and 2.

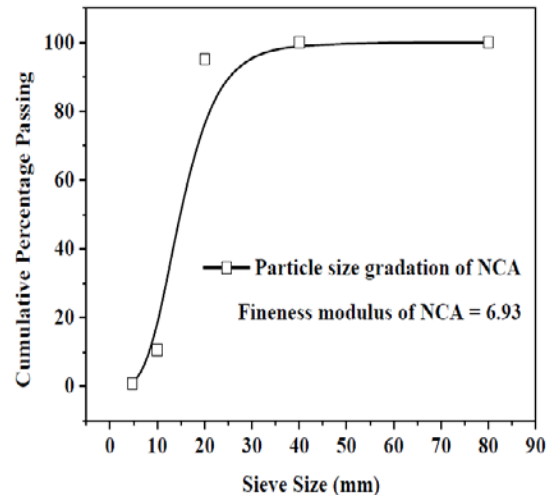
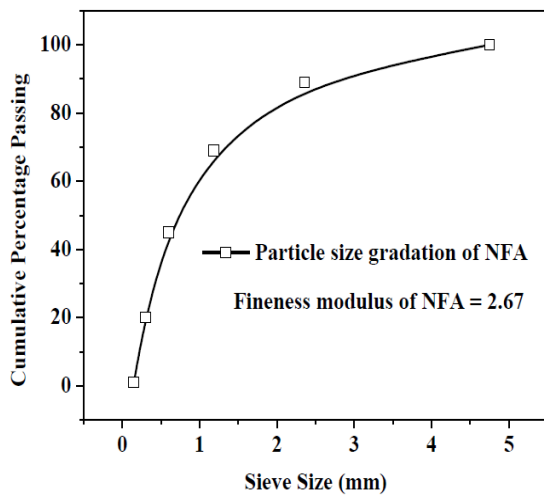


Figure 1 Particle size gradation curve of NFA Figure 2: Particle size gradation curve of NCA

Coconut shell is a waste material from agriculture which is available in lively in steamy area like Asia, America and Africa which are used conveniently as less strength that proves as light weight concrete aggregate. Firstly the coconut shell is dehydrated in water before concrete making. Though it is a light weight aggregate it consumes more water. This type of concrete gives excellent strength property like flexural and ductility. Coconut shell was accumulated from the marketplace and compressed into small-scale pieces by mechanical machine. Coconut shell which is (≥ 4.75 mm < 10 mm) 50% and (≥ 10 mm < 20 mm) 50% was used. The specific gravity of Coconut shell is 0.98. Figure 3 show the coconut shell aggregate (CSA) of size (≥ 4.75 mm < 10 mm) and Figure 4 show the coconut shell aggregate (CSA) of size (≥ 10 mm < 20 mm).

Table 1 Physical properties of cement

CHARACTERISTICS	VALUE OBTAINED EXPERIMENTALLY (OPC)	VALUE SPECIFIED BY IS 8112-1989 (OPC 43 GRADE)
Fineness (m ² /kg)	340	225 (min)
Normal consistency, %	32.5	NA
Initial setting time, minutes	121	30 (min)
Final setting time, minutes	410	600 (max)
Specific gravity	3.15	3.15
Compressive strength, MPa		
(a) 3 days	30	23 (min)
(b) 7 days	43	33 (min)
(c) 28 days	51	43 (min)

Table 2 Properties of coarse and fine aggregates

CHARACTERISTICS	VALUE OBTAINED EXPERIMENTALLY AS PER IS: 383-1970	
	Natural fine aggregate	Natural coarse aggregate
Specific gravity	2.68	2.78
Bulk density (kg/m ³)	1535	1422
Abrasion value (%)	-	47.46
Impact value (%)	-	29.63
Crushing value (%)	-	24.50
Flakiness Index (%)	-	21.18
Water absorption (%)	0.80	0.21
Fineness modulus	2.67 (Zone II)	6.93



Figure 3 CSA (size ≥ 4.75 mm < 10 mm)



Figure 4 CSA (size ≥ 10 mm < 20 mm)

Metakaolin is refined kaolin clay type, which create an amorphous alumino silicate by fired (calcined) carefully under controlled conditions, which is reactive in concrete. The particle size of MK is smaller than cement particles, but not as fine as silica fume. Metakaolin is ordered from Golden Micro chemicals, supplier of minerals and extenders, Thane,

Maharashtra, India shown in Figure 5. The various physical properties of MK are represented in Table 3 and chemical compositions of MK are shown in Table 4.



Figure 5 Metakaolin samples

Table 3 Physical properties of MK

PROPERTIES	VALUE
Oil absorption (%)	60±5
Brightness	85±1
Ph of 10% solution	6±1
Moisture (%)	0.50
Particle size	
Average (d50)	1±1
<10 Microns (%)	95±2
>2 Microns (%)	80±1
Residue on 400	Nil
Bulk density (gms/lit)	320±20
Specific gravity	2±0.1

Table 4 Chemical composition of MK

OXIDES	AVERAGE (%)
Al ₂ O ₃	36.3
SiO ₂	52.8
MgO	0.81
Fe ₂ O ₃	4.21
K ₂ O	1.41
CaO	< 0.10
LOI	3.53

Mix Proportions

In this study, CS is taken as the replacement of Natural Coarse Aggregate and MK as the replacement of Cement. The mix design was targeted for M30 grade concrete with water to binder (w/b) 0.43 to achieve target mean strength [9]. Nine different concrete mixes were prepared. First three specimens were prepared with replacement of aggregate with CS 0%, 10% and 20% and without replacement of cement with MK (CSC0M0, CSC10M0 and CSC20M0) was treated as the coconut shell concrete. Second three specimens were prepared with replacement of aggregate with CS 0%, 10% and 20% and with replacement of cement with MK 10% (CSC0M10, CSC10M10 and CSC20M10). Third three specimens were prepared with replacement of aggregate with CS 0%, 10% and 20% and with replacement of cement with MK 20% (CSC0M20, CSC10M20 and CSC20M20). The mix specimens were immersed in curing tank for 7, 28 and 90 days. The detail mix quantity along with their identification is selected according to their replacement as given in Table 5. The detail mix quantity per m³ of concrete is presented in Table 6.

Table 5 Details of concrete mix proportion along with identification

CONCRETE MIX PROPORTIONS	MIX IDENTITY
C 100% + MK 0% + CA 100% + CS 0% + FA 100%	CSC0M0
C 100% + MK 0% + CA 90% + CS 10% + FA 100%	CSC10M0
C 100% + MK 0% + CA 80% + CS 20% + FA 100%	CSC20M0
C 90% + MK 10% + CA 100% + CS 0% + FA 100%	CSC0M10
C 90% + MK 10% + CA 90% + CS 10% + FA 100%	CSC10M10
C 90% + MK 10% + CA 80% + CS 20% + FA 100%	CSC20M10
C 80% + MK 20% + CA 100% + CS 0% + FA 100%	CSC0M20
C 80% + MK 20% + CA 90% + CS 10% + FA 100%	CSC10M20
C 80% + MK 20% + CA 80% + CS 20% + FA 100%	CSC20M20

Table 6: Details of mix quantity per m³ of concrete

MIX IDENTITY	CEMENTIOUS MATERIALS PER m ³ OF CONCRETE				NFA (kg)	Water (lit)
	Cement (kg)	MK (kg)	NCA (kg)	CS (kg)		
CSC0M0	434.32	0	1226.30	0	660.90	186.76
CSC10M0	434.32	0	1103.61	122.63	660.90	186.76
CSC20M0	434.32	0	981.04	245.26	660.90	186.76
CSC0M10	390.88	43.43	1226.30	0	660.90	186.76
CSC10M10	390.88	43.43	1103.61	122.63	660.90	186.76
CSC20M10	390.88	43.43	981.04	245.26	660.90	186.76
CSC0M20	347.45	86.86	1226.30	0	660.90	186.76
CSC10M20	347.45	86.86	1103.61	122.63	660.90	186.76
CSC20M20	347.45	86.86	981.04	245.26	660.90	186.76

Mixing, Casting and Curing

At first the weight of all materials was taken. The materials were placed in a concrete mixer in an order of NCA, NFA, OPC, CS and at last MK. It was thoroughly mixed in dry condition until the mixture becomes homogeneous. The mixing procedure is same for all the cement paste. The specified amount of water was measured for the particular mix then added during mixing. After mixing the concrete, workability of fresh concrete was measured immediately by slump test. Then the test samples were cast in steel mould of $150 \times 150 \times 150$ mm and compacted by using needle vibrator and after 24 hours the mould was removed. Thereafter the specimen cured under tap water for 7, 28 and 90 days. An appropriate environmental condition was provided by the curing objective within a concrete structure i.e. temperature and humidity.

TEST RESULTS AND DISCUSSIONS

Fresh Concrete Test Results

The fresh concrete test was conducted to know the workability of concrete. Workability of the fresh concrete was measured by means of the slump test which is done immediately after the mixing. For different concrete mix aggregate was partially replaced with CS and cement was partially replaced with MK and the variation of slump value is represented in Table 7. It is observed that as CS increases in the concrete mix, the slump value of the concrete mix decreases. Further, by the addition of MK, in the CS concrete mix, the slump value comparatively increases with respect to the concrete mix without addition of MK. It indicates that CS decreases the workability of CSC mix, whereas MK increases the workability of the concrete mix. The same observation is carried out by (Smita and Panda 2017) for MK based concrete.

Table 7 Slump value of coconut shell concrete

MIX IDENTITY	WATER CEMENT RATIO	SLUMP VALUE (mm)	DEGREE OF WORKABILITY
CSC0M0	0.43	25	Low
CSC10M0	0.43	10	Very Low
CSC20M0	0.43	5	Very Low
CSC0M10	0.43	30	Low
CSC10M10	0.43	18	Very Low
CSC20M10	0.43	12	Very Low
CSC0M20	0.43	38	Low
CSC10M20	0.43	22	Very Low
CSC20M20	0.43	15	Very Low

Hardened Concrete Test Results

The cube, prism, cylinders were cast and cured properly for 7, 28 and 90 days in curing tank. To know the hardened concrete properties, the compressive strength, split tensile strength and flexural strength test were conducted. Then the hardened concrete test results of CSC and MK based CSC is presented in graphical representation.

Compressive Strength

A set of three concrete cubes were cast and tested each after 7, 28 and 90 days for each mix proportion. Figure 6 represents compressive strength versus age in days for all concrete mixes and Figure 7 show the graphical representation of compressive strength for different concrete mixes at different curing period. The compressive strength of all CSC mixes is compared with the control specimen CSC0M0. It is observed that the percentage increase in strength of CSC0M10 and CSC0M20 after 7 days, 8.01 and 1.63, after 28 days 27.82 and 9.32 and after 90 days 19.84 and 0.65 respectively. As CS and MK concerned, the compressive strength of all CSC mixes decreases as compared with control specimen. Minimum decrease in strength observed in CSC10M10 specimen i.e. 26.51%, 13.20% and 2.37% after 7, 28 and 90 days respectively. Maximum decrease in strength observed in CSC20M20 specimen such as 52.75%, 30.49% and 33.85% after 7, 28 and 90 days respectively. It is observed that, without CS and with MK, the compressive strength is higher in CSC0M10 specimen, whereas with CS and MK, the compressive strength is higher in CSC10M10 specimen.

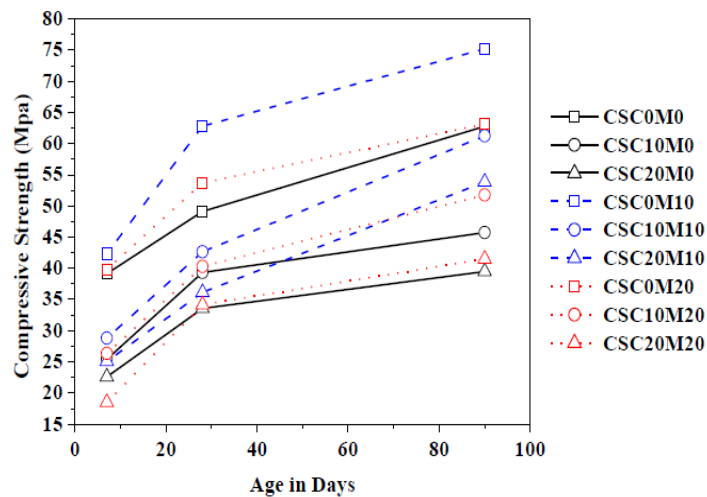


Figure 6 Compressive strength versus age in days

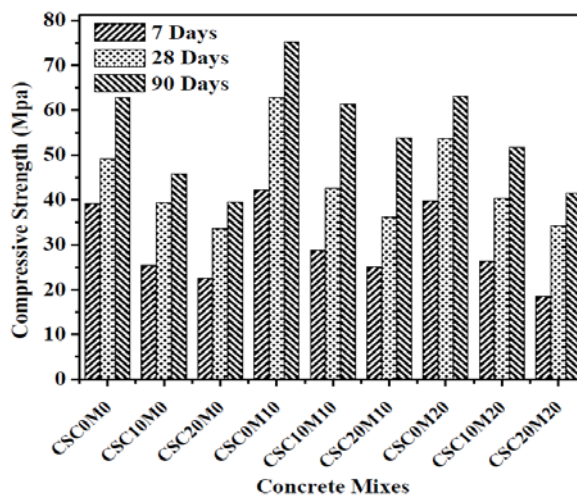


Figure 7 Compressive Strength versus Concrete Mixes

Flexural Strength

Figure 8 represents flexural strength versus age in days for all concrete mixes and Figure 9 show the graphical representation of flexural strength for different concrete mixes at different curing period. The flexural strength of all CSC mixes is compared with the control specimen CSC0M0. It is observed that the percentage increase in flexural strength of CSC0M10 and CSC0M20 after 7 days, 52.48 and 28.60, after 28 days, 31.76 and 20.00 and after 90 days, 33.28 and 24.49 respectively. As CS and MK concerned, the flexural strength of all CSC mixes decreases as compared with control specimen for 7 and 28 days and all most all mixes increases at 90 days (except CSC20M20). Minimum decrease in flexural strength observed in CSC10M10 specimen i.e. 3.07% and 12.77% after 7 and 28 days respectively and increases to 4.32% at 90 days. Maximum decrease in flexural strength observed in CSC20M20 specimen such as 25.76%, 26.72% and 15.70% after 7, 28 and 90 days respectively. It is observed that, without CS and with MK, the flexural strength is higher in CSC0M10 specimen, whereas with CS and MK, the flexural strength is higher in CSC10M10 specimen.

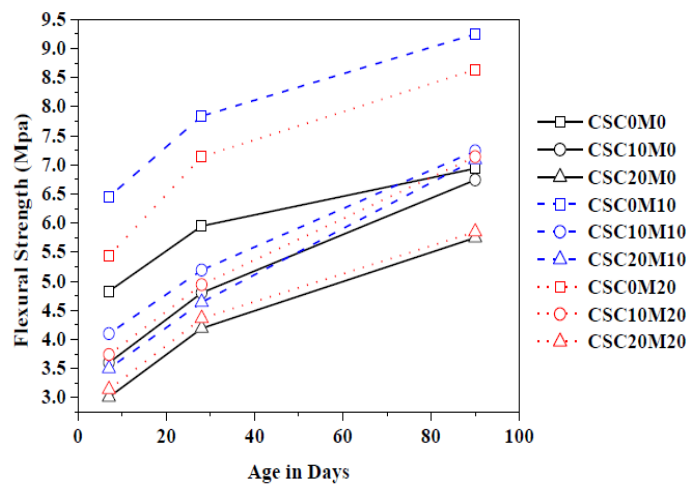


Figure 8 Flexural strength versus age in days

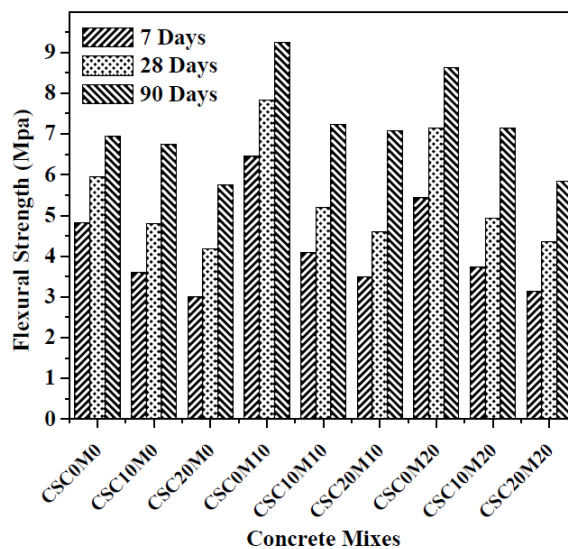


Figure 9 Flexural strength versus Concrete mixes

Split Tensile Strength

Figure 10 represents split tensile strength versus age in days for all concrete mixes and Figure 11 show the graphical representation of split tensile strength for different concrete mixes at different curing period. The split tensile strength of all CSC mixes is compared with the control specimen CSC0M0. It is observed that the percentage increase in split tensile strength of CSC0M10 and CSC0M20 after 7 days, 27.57 and 7.64, after 28 days, 10.21 and 5.46 and after 90 days, 5.54 and 1.38 respectively. As CS and MK concerned, the split tensile strength of all CSC mixes decreases as compared with control specimen. Minimum decrease in split tensile strength observed in CSC10M10 specimen i.e. 3.32% and 2.25% after 28 and 90 days respectively expect 7 day strength. Maximum decrease in split tensile strength observed in CSC20M20 specimen such as 11.16%, 9.18% after 28 and 90 days respectively expect 7 days strength. It is observed that, without CS and with MK, the split tensile strength is higher in CSC0M10 specimen, whereas with CS and MK, the split tensile strength is higher in CSC10M10 specimen.

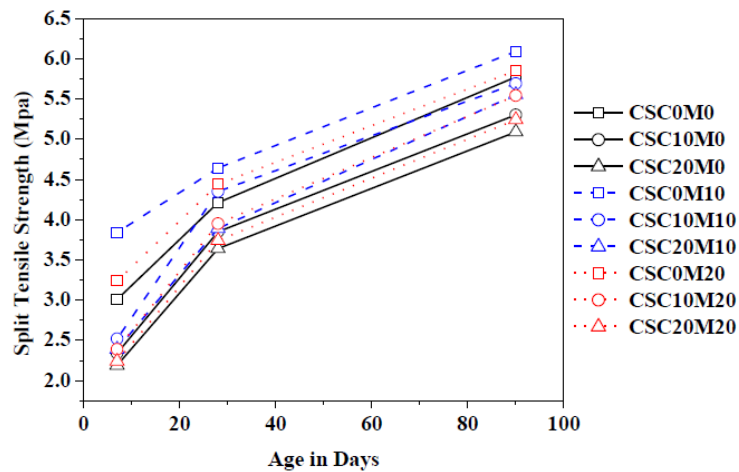


Figure 10 Compressive strength versus age in days

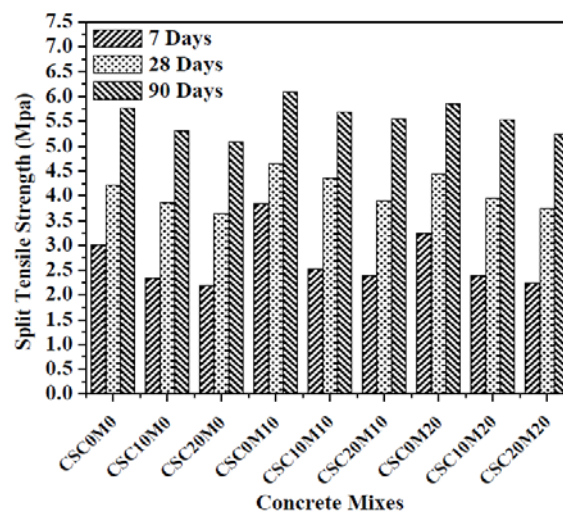


Figure 11 Split Tensile Strength versus concrete mixes

CONCLUDING REMARKS

- The increase in CS decreases the workability of concrete mix, whereas by the partially replacement of cement with MK, increases the workability of concrete mix in a constant w/b ratio.
- As curing time increases the compressive, flexural and split tensile strength of CSC and CSC with MK increases.
- The compressive strength, flexural strength and split tensile strength of CSC decreases with respect to control specimen.
- The compressive strength and split tensile strength of CSC with MK also decreases with respect to control specimen but the minimum decrease in strength is observed in CSC10M10 specimen.
- The flexural strength of CSC with MK also decreases with respect to control specimen but the minimum decrease in strength is observed upto 28 days, thereafter maximum gain in strength is observed upto 90 days.
- Minimum decrease in split tensile strength is observed in CSC10M10 specimen i.e. 3.32% and 2.25% after 28 and 90 days respectively expect 7 day strength.
- Without CS and with MK, the compressive, flexural and split tensile strength is higher in CSC0M10 specimen, whereas with CS and MK, the strength is higher in CSC10M10 specimen.

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