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Research paper

Mechanical Characterisation of Coconut Shell Concrete with Quarry Dust and Saw Dust as Fine Aggregate Using Coconut Fibre

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Abstract

This research investigates the mechanical properties of quarry dust and sawdust as fine aggregate in coconut shell concrete. The mechanical properties of concrete are increased by the addition of fibres and it is added in various percentages (1%, 2%, 3%, 4%, 5%). The tests was conducted with both controlled and coconut shell concrete and found optimized value of sawdust replacement to be 5%. For coconut shell concrete, fibres with aspect ratio 66.67 and for controlled concrete, fibres with aspect ratio 83.34 were used based on previous optimisation of fibre research. Compressive test results shows that coconut shell sawdust concrete with 2% of fibre yields maximum strength whereas in coconut shell quarry dust concrete maximum strength was attained with 4% of fibres. The results obtained were utilized for other experimental tests (split-tensile, flexural, impact and bond strength) which in turn compared with controlled concrete with fibres and coconut shell concrete with fibres.

Keywords: *Controlled concrete, Light weight concrete, Coconut shell concrete, Sawdust, Coconut fibre, compressive strength*

1. Introduction

In developing countries like India, there was a lot of solid waste produced by the industries. Fly ash, Rubber, Glass, Coconut Shell, and many other agricultural wastes are researched as an alternate for replacing coarse aggregates. Light Weight concrete has density less than 2000 kg/m^3. Research has been going on to make light weight concrete by replacing fine and coarse aggregate with natural ingredients.

With the similar property and behaviour to sand, studies show quarry dust has good strength as replacement of sand in concrete [7]. From past 40 years sawdust was being used in concrete, but not widely, even though sawdust has the low-compressive strength it can make to perform well in certain floor and wall applications [12]. Due to its better heat preservation and heat insulation property and has low bulk density, also lowers the pollution in the environment this has more advantages than traditional concrete [24].

As over 960million tones of solid waste are being produced annually from the industries, mines, municipals, agricultural & other process as a by-product. Out of this 350million tones was organic waste from agricultural sources; 290million tones are inorganic waste from industrial & mining sector. Sugarcane baggage, wheat straw and husk, paddy, wooden mill waste, vegetables wastes, cotton stack coconut husk, etc., all these wastes are being produced from agricultural sources. Out of this coconut shell was the promising material that can be used as a replacement for concrete materials. The coconut production in India was reported as more than 12million tones [6-10]. So, using both the materials that are damaging the environment can use as a replacement to the traditional materials and can possibly reduce the pollution in the environment which the world is facing.

2. Material Properties

The concrete mix M25 was designed according to IS 10262(2009) and the mix ratio for controlled concrete 1:2.22:2.60:0.55 and for coconut shell concrete 1:1.47:0.65:0.42

2.1 Sawdust

The sawdust was a fine powder collected from various hardwoods and softwoods such as Oak, Mahogany, Mulberry and Axle wood by cutting then in the saw-mill. The powder was collected and stored in a waterproofing bag such that to avoid the effect of fungus [12]. The collected sawdust was dipped in water for 4 to 5 hrs before the concrete preparation.

2.2 Quarry Dust

Quarry dust passing through 4.75 mm sieve was used as fine aggregate, for Controlled concrete and CSC [7]. The specific gravity of quarry dust is 2.487 and fineness modulus is 3.9

2.3 Coconut Fibre

It is a naturally occurring fibre which is extracted from the husk of coconut. It is used in many applications like floor mats, brushes, door mats and mattresses, but the brittle nature of the fibre made it to attract concrete research workers to make concrete strong in tension. The fibre used in this project has the diameter 0.6 mm. The length of the fibre was optimized in the previous study as 50mm for CC and 40mm for CSC and used in this experiment. Thus cut down fibre was added to concrete at 1%, 2%, 3%, 4%, 5% and 6% by volume of concrete.

3. Test Results and Discussions

The main theme of this research work is to investigate on the mechanical properties of concrete. These tests determine the properties of controlled concrete and coconut shell concrete, replacing fine aggregate partially with sawdust and quarry dust with addition of fibre.

3.1 Compression Test

The internal resisting force of a body is determined using this test. The concrete specimens were casted to 100×100×100mm sized cubes, were allowed for curing and tested at the age of 3 day, 7 day and 28 day. The casting of specimens are done on both controlled concrete and coconut shell concrete with increasing percentage of fibre as 0%, 1%, 2%, 3, 4%, 5% and 6% and the results were shown in Table 1 and compared in Figure 1.

Table 1: Compressive strength of CC and CSC with added fibre

Mix	Sawdust %	Compressive Strength N/mm^2
		28th day
Controlled concrete with sawdust	0	30.1
	5	29.47
	10	25.9
	15	21.7
	20	18.47
Coconut shell concrete with sawdust	0	25.6
	5	25.23
	10	19.93

	15	16.5
	20	10.63

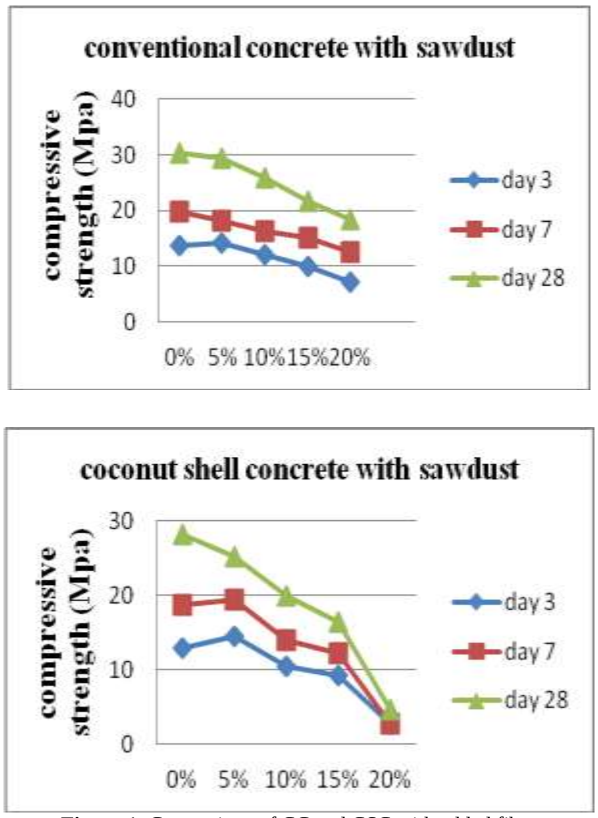

Figure 1: Comparison of CC and CSC with added fibre

The content of sawdust replaced in controlled and coconut shell concrete is in the percentage of 5%, 10%, 15% and 20% to the volume of fine aggregate. the results were shown in Table 2 and the comparison for CC and CCS in made in Figure 2.

Table 2: Compressive strength test results for partial replacement of sawdust in CC and CSC

Mix	Sawdust %	Compressive Strength N/mm^2		
		3rd day	7th day	28th day
Controlled concrete with sawdust	0	13.69	19.73	30.1
	5	14.23	18.17	29.47
	10	12.1	16.2	25.9
	15	9.93	15.16	21.7
	20	7.17	12.57	18.47
Coconut shell concrete with sawdust	0	14.23	19.6	25.6
	5	14.47	19.43	25.23
	10	10.53	14.03	19.93
	15	9.27	12.2	16.5
	20	4.67	8.67	10.63

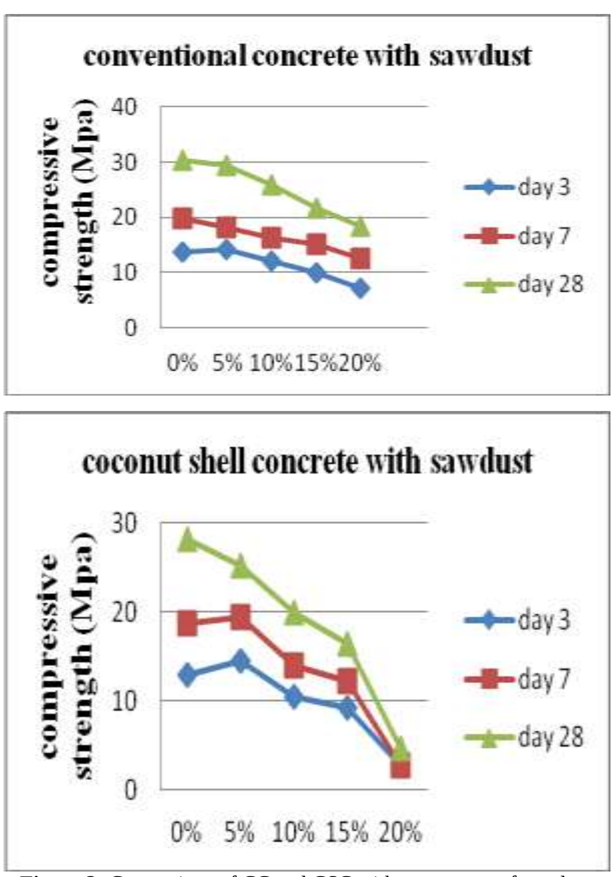

Figure 2: Comparison of CC and CSC with percentage of sawdust

From the above Table 2 and Figure 2 it was clear that 5% replacement of sawdust in controlled concrete as well as in coconut shell concrete gives better strength as 29.47Mpa and 25.23Mpa but lesser than the controlled and coconut shell concrete, in order to increase the strength fibre is added to it in the percentage of 1%, 2%, 3%, 4% and 5%. The test results were as shown in the Table 3 and comparison is made on Figure 3.

Table 3: Compressive strength of CCS and CCQ with addition Fibre

Mix	Fibre %	Compressive Strength N/mm^2		
		3rd day	7th day	28th day
Controlled Concrete with 5% Sawdust and addition of fibre	0	14.23	19.6	30.1
	1	12.76	15.73	29.1
	2	15.23	17	30.96
	3	14.3	19.73	34.43
	4	16.2	19.96	29.47
	5	9.83	11.93	13.23
Controlled Concrete with Quarry dust with fibre	**0**	**20.267**	**27.067**	**30.033**
	1	20.200	26.567	36.533
	2	22.833	28.933	38.567
	3	17.400	24.467	34.533
	4	16.900	24.033	32.767
	5	13.667	17.333	23.26

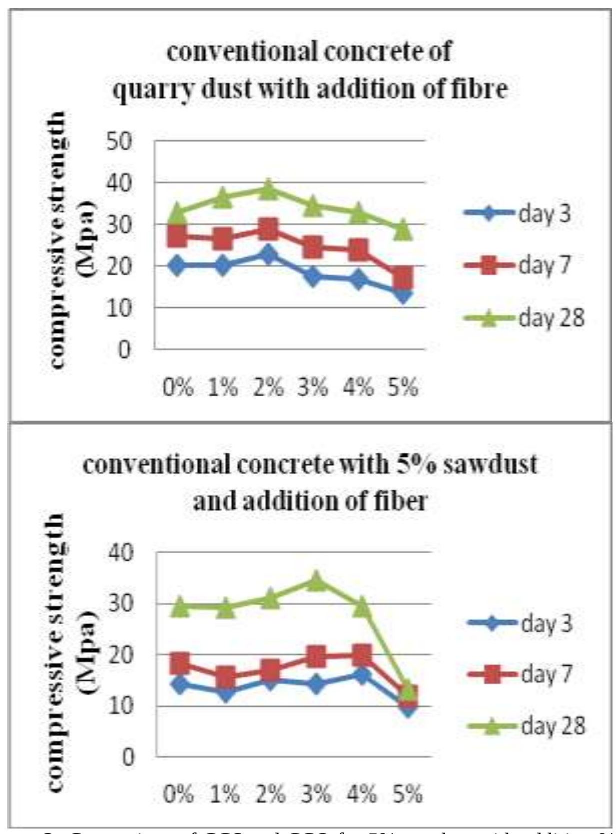

Figure 3: Comparison of CCS and CCQ for 5% sawdust with addition % of fibre

The above Table 3 and Figure 3 shows that compressive strength of concrete is more at addition 3% fibre in CCS and at addition of 2% of fibre in CCQ. The values are as 34.43Mpa and 38.567Mpa. In case of controlled concrete CCS shows good improvement when fibre is added to it comparing to 0% fibre. From this the optimum percentage of fibre to be continued for the Tensile, Flexure strength and Impact tests are arrived.

Table 4: Compressive strength test on CSSC and CSCQ with Coconut Fibre

Mix	Fibre %	Compressive Strength N/mm^2		
		3rd day	7th day	28th day
Coconut shell Concrete with 5% Sawdust and addition of fibre	0	14.23	18.17	25.6
	1	14	16.83	22
	2	21.33	26.13	33.32
	3	22.7	27.53	29.89
	4	17	20.12	26.033
	5	15.65	18.36	24.26
Coconut shell Concrete with Quarry dust	0	10.667	14.9	19.3
	1	13.133	14.867	20.033
	2	13.733	16.500	21.533
	3	14.533	19.133	23.967
	4	17.833	21.533	26.800
	5	13.667	17.333	23.267

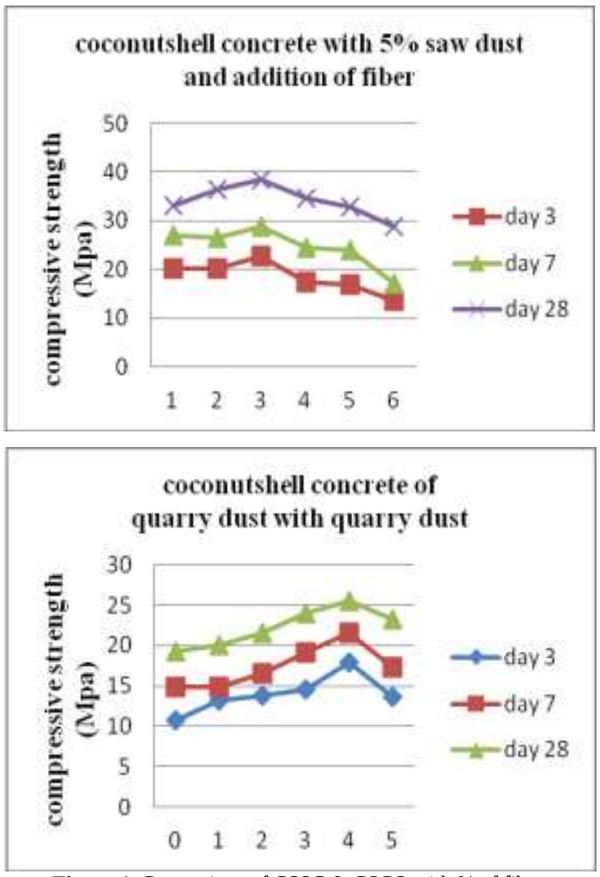

Figure 4: Comparison of CSSC & CSCQ with % of fibre

The Table 4 and Figure 4 shows that CSSC has a greater value of 33.32 Mpa at 2% of fibre while CSCQ has 25.50 Mpa at 4% of fibre. In case of coconut shell concrete CSSC shows good improvement when fibre is added to it in comparison to 0% fibre.

3.2 Split Tensile Test

This test is done on the concrete cylindrical specimens which are prepared in the steel moulds of size 100×200mm.The load is applied by placing the cylinder horizontally in the compression testing machine, load should be applies till a vertical crack develops across the diameter [11]. The value is about 0.05 – 0.12 times greater than the direct tensile strength. The results were shown in Table 5 & 6 and their variations are shown in Figure 5 & 6.

Table 5: Split tensile strength for beams of CC, CCF, CCS and CCQ with addition of fibre

M20	Fibre %	Split Tensile strength (N/mm^2)		
		3rd day	7th day	28th day
CC	0	2	2.96	3.7
CCF	3	2.95	3.28	4.3
CCSD	3	2.95	4.23	4.86
CCQD	2	2.28	3.68	4.04

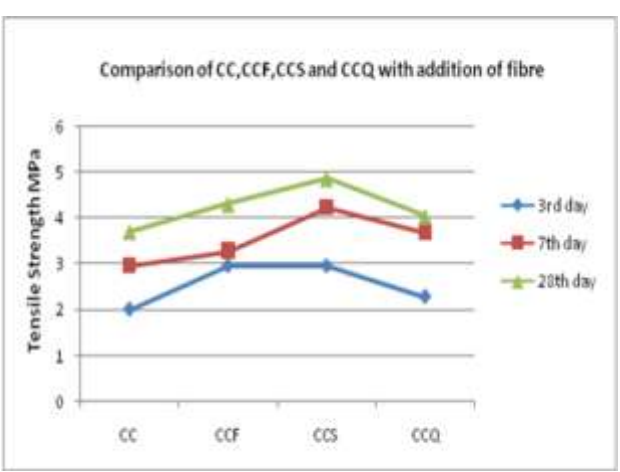

Figure 5: Comparison of CC, CCF, CCS and CCQ with addition of fibre.

Table 6: Split tensile strength for beams of CSC, CSCF, CSSC and CSCQ with addition of fibre

M20	Fibre %	Split Tensile strength (N/mm^2)		
		3rd day	7th day	28th day
CSC	0	1.21	2.52	2.82
CSCF	3	1.77	2.98	3.6
CSCSD	2	1.89	2.97	3.19
CSCQD	4	2.04	2.55	2.62

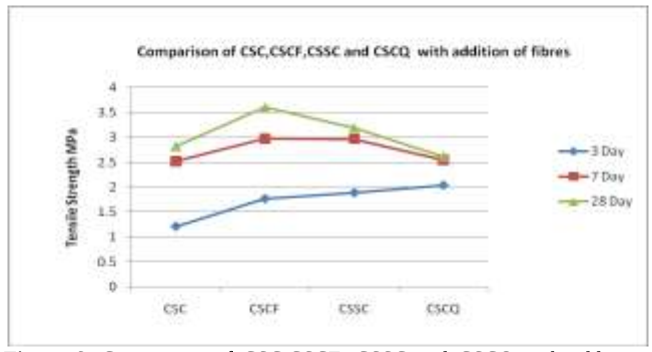

Figure 6: Comparison of CSC,CSCF, CSSC and CSCQ with addition of fibre

3.3 Flexure Test

The beam (100×100×500mm) was subjected to four point loading method. The test results were shown in Table 7, Figure 7 and Table 8, Figure 8.

Table 7: Flexure test on CC, CCS and CCQ with addition of fibre

M20	Fibre %	Flexure strength (N/mm^2)			28-day Comp strength N/mm^2	As per IS 456:2000 $0.7\sqrt{f_{ck}}$
		3rd day	7th day	28th day		
CC	0	1.93	2.42	3.81	29.4	3.795
CCF	3	2.95	3.56	5.1	43.8	4.632
CCSD	3	2.85	4.53	5.33	34.43	4.10
CCQD	2	2.27	3.47	4.67	38.567	4.347

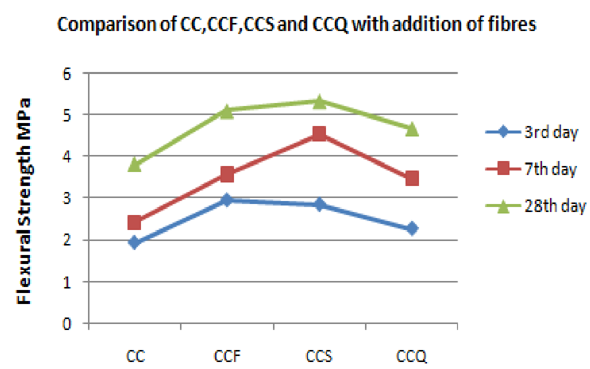

Figure 7: Comparison of CC, CCS and CCQ with addition of fibre

Table 8: Flexure test on CSC, CSSC and CSCQ with addition of fibre

M20	Fibre %	Flexure strength (N/mm^2)			28-day Comp strength N/mm^2	As per IS 456:2000 $0.7\sqrt{f_{ck}}$
		3rd day	7th day	28th day		
CSC	0	2.08	3.45	4.23	25.6	3.54
CSCF	3	2.54	4.12	5.7	30.01	3.834
CSSC	2	2.09	2.89	4.12	33.32	4.04
CSCQ	4	2.13	3.07	4	25.5	3.534

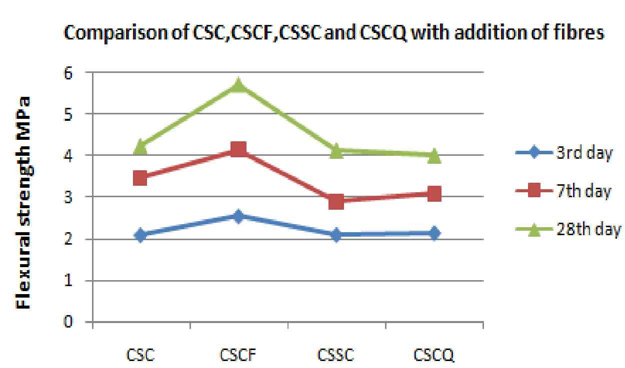

Figure 8: Comparison of CSC, CSSC and CSCQ with addition of fibre

3.4 Impact Test

It determines the resistance against sudden load applied on the concrete specimen. This is done on the specimen sizes 63.5×152.4mm as mentioned on ACI committee 544.1R-82. For a certain no. of blows the specimen starts fail by producing its initial crack to until it gets broken. The results of controlled concrete without fibre is shown in Table 9 and the variation is shown in Figure 9. The results of coconut shell concrete is shown in Table 10 and Figure 10. The results of controlled concrete is shown in Table 11 and Figure 11. The results of coconut shell concrete is shown in Table 12 and Figure 12.

Table 9: Impact test on CC, CCS and CCQ without fibre

Mix	Fibre %	Impact strength	
		No. of blows in 28 days	
		Initial crack	Final crack
CC	0	18	23
CCSD	0	19	23
CCQD	0	21	26

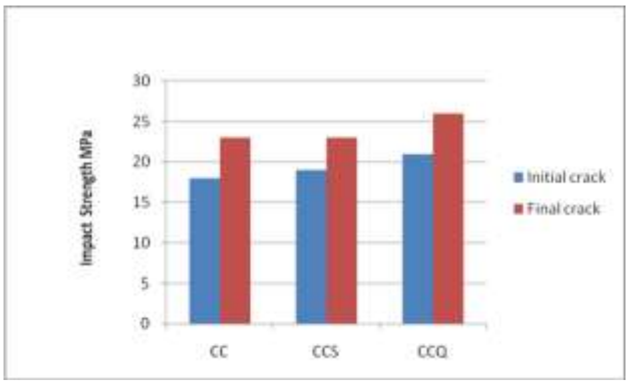

Figure 9: bar chart of CC, CCS, CCQ without addition of fibre.

Table 10: Impact test on CSC, CSSC and CSCQ without fibre

Mix	Fibre %	Impact strength	
		No. of blows in 28 days	
		Initial crack	Final crack
CSC	0	25	30
CSCSD	0	25	31
CSCQD	0	29	36

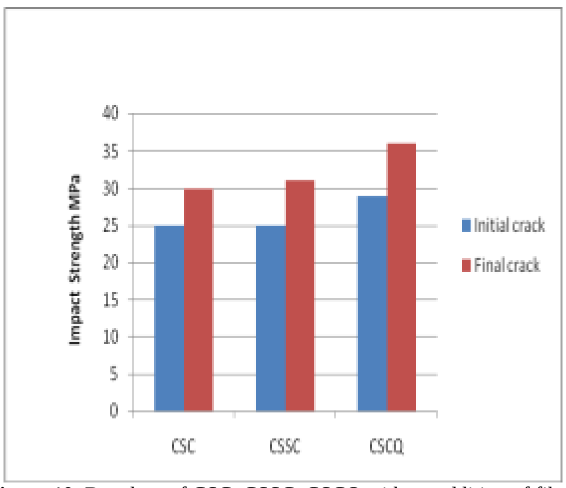

Figure 10: Bar chart of CSC, CSSC, CSCQ without addition of fibre

Table 11: Impact test on CC, CCS and CCQ with addition of fibre

Mix	Fibre %	Impact strength	
		No. of blows in 28 days	
		Initial crack	Final crack
CSC	3	128	192
CSCSD	2	104	139
CSC QD	4	119	146

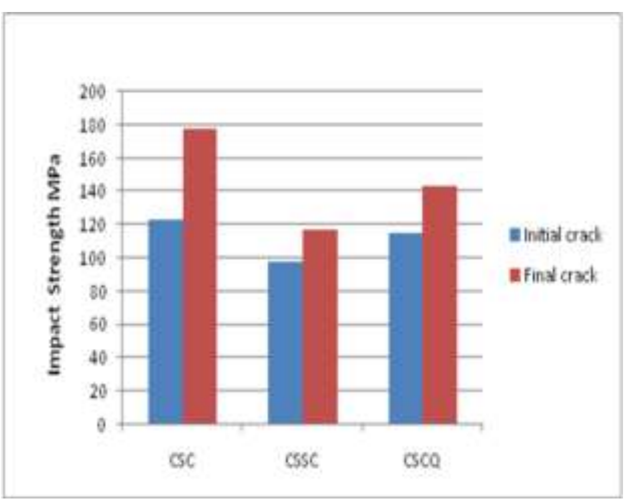

Figure 11: Bar chart of CC, CCS, CCQ with addition of fibre

Table 12: Impact test on CSC, CSSC and CSCQ with addition of fibre

Mix	Fibre %	Impact strength	
		No. of blows in 28 days	
		Initial crack	Final crack
CC	3	123	178
CCSD	3	98	117
CCQD	2	115	143

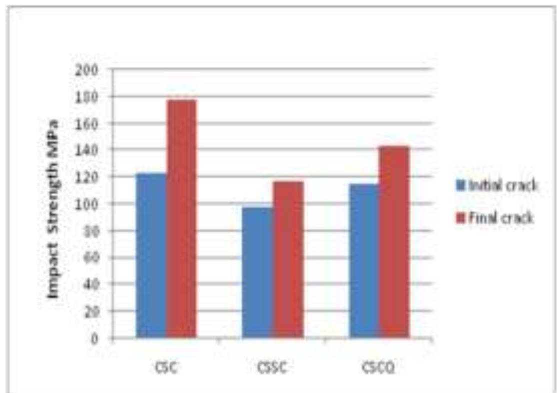

Figure 12: Bar chart of CC, CCS and CCQ with addition of fibre.

The impact test values are as show in the table 11 and table 12, the use of fibre has given improved values. This shows that fibre usage can withstand to sudden loading, hence it can be used in manufacturing of concrete for constructions as they experience impact loads and roller loads

4. Conclusion

4.1 Compressive Strength

The specimens with replacement of sawdust to fine aggregate shows a slight decrease in strength when compared with control concrete and coconut shell concrete, but the addition of fibre has improved results. At CCS with 3% fibre is 34.43Mpa (34.43Mpa – 14.4% increase when compared to CCS-without fibre) and CSSC with 2% fibre is 33.32Mpa (33.32Mpa – 30% increase when compared to CSSC-without fibre). CCQ with 2% of fibre has its maximum value of 38.567Mpa (38.567Mpa – 12.01% higher when compared to CCS with 3% fibre) and CSCQ with 4% fibre has its maximum value of 25.50Mpa (25.50Mpa – 23.4% lower when compared to CSSC with 2% fibre). This shows that for CCQ with 2% fibre is better than CCS and CSSC with 2% fibre is better than CSCQ with 4% fibre.

4.2 Split Tensile Strength

As the optimum percentage of sawdust, quarry dust and addition of fibre are used for the cylindrical specimens, it showed better increment results from the table 12 & 13. The split tensile strength of CCS with addition of 3% fibre is 4.86Mpa (4.86Mpa – 52% higher when compared to CSSC with addition of 3% fibre is 3.19Mpa). CCQ with addition of 2% of fibre is 4.04Mpa (4.04Mpa – 54% higher when compared to CSCQ with addition of 4% of fibre is 2.62).The tensile resistance of concrete specimen is determined using split tensile test, here the test results have attained greater improvement in tension.

4.3 Flexure Strength

The flexure strength of CC with 3% of fibre is 5.1 Mpa and is better when compared to all other replacements made CCS at 3% addition of fibre is 5.33Mpa and CCQ at 2% is 4.67 Mpa(5.33Mpa – 14.13% higher when compared to CCQ with 2% of fibre added) and for CSC with 3% of fibre is 5.7 Mpa and is better when compared to all other replacements made on CSC for CSSC at 2% addition of fibre is 4.12Mpa and for CSCQ at 4% is 4.0. From the obtained results it is clear that in both cases replacement of sawdust at 5% added with fibre is better than the replacement of quarry dust added with fibre. The modulus of rupture or bending strength shows that CCS and CSSC have the ability to withstand the fracture strength better than CCQ and CSCQ.

4.4 Impact Strength

The impact value of CC with 3% gives initial and final crack at 128 and 192. CCS 3% gives initial and final at 104 and 139 and for CCQ with 2% gives 119 and 146.In CSC with 3% gives 123 and 178 and CSSC 2% gives 98 and 170 and CSCQ with 4% gives 115 and 143. Comparing these values CC and CSC with fibre gives more impact strength.

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