

Experimental evaluation of mechanical properties of roller compacted concrete incorporated with processed bagasse ash and triangular polyester fibers

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Abstract: Roller compacted concrete (ROCC) has extensive uses in various industrial and heavy-duty pavement design applications which accommodates lower-speed traffic. This study aims to assess how processed bagasse ash (BA) and synthetic fibers i.e. Triangular polyester fibre (TPF) affect the mechanical performance characteristics of ROCC combinations. One of the key considerations for mix design is the ideal water content value for each ROCC mixture's maximum dry density. The impact of using processed sugarcane bagasse ash with 15%, 30%, and 45% by cement weight as a partial substitute to OPC and triangular polyester fibres as 0.25%, 0.50%, and 0.75% per 1 m³ on the ideal water content and mechanical properties were examined in this experimental work. It has been observed that the performance of various ROCC mixtures (compression, flexure, split tensile, impact and abrasion strength) with addition of TPF decline marginally as a result of the increased water requirement. To meet the requirements for strength and workability, mixtures with 30% processed bagasse ash in place of cement and Triangular polyester fibers after 90 days of curing age should be given consideration in mix design for sustainable construction. an NDT, Ultrasonic pulse velocity test has been conducted to validate the experimental results of compressive strengths of different ROCC mixes which replicate the ROCC with 30% replacement of processed bagasse ash along with fibres would be the optimal solution for sustainable construction practices.

Keywords: ROCC, Processed Bagasse ash, TPF, optimum water content, maximum dry density, mechanical properties

1. Introduction

Roller compacted concrete (ROCC) is a zero-slump concrete mixture made up of ingredients like cement, aggregates, and water without any reinforcement [1]. “Steel wheel vibratory rollers compact the layers, and rubber tyre rollers may be used for final compaction. For the pavement to have a hard, long-lasting surface, it is cured using after or another method” [1]. It is typically laid using an asphalt paver and compacted using vibratory roller compaction machinery [1,2]. As received or processed bagasse ash is used as pozzolanic material as like fly ash, GGBS etc. These industrial waste products make cement cost effective without compromising with quality. Usually, an asphalt concrete paving machine is used to place it in layers that are not thicker than 10 inches (254 mm) [2]. “It is relatively new, and the technology is still developing, and it is utilized for pavements and dam construction” [2,3]. In a mixing facility, the ROCC ingredients are combined to create a heterogeneous mass with a consistency akin to zero slump concrete or wet gravel [3]. Bagasse, a byproduct of the sugar industry, is the source of bagasse ash. “The sugar mill burns the by-product of the sugar business so that it can be used for various purposes”, As the flexural qualities, split tractable and compressive properties increase in fiber content, they fairly extend [4-7]. ROCC has been used in the construction of numerous significant pavement projects in North America over the past ten years,



and the pavements' overall performance has been positive. To get the optimal water content, wet density and dry density of ROCC easy and accurate method i.e. Nuclear Density Gauge can be used [8]. The microstructural characterization of both rice straw ash and sugarcane bagasse ash exposed the dumbbell shaped silica-storage structures called phytoliths [9]. ROCC exhibits high flexural, shear and bond strengths and high resistance to reflection cracking [9]. As received or processed bagasse ash is used as pozzolanic material as like fly ash, GGBS etc. These industrial byproducts make cement cost effective without compromising with quality [10]. Additionally, a number of European nations as well as Australia are beginning to embrace roller-compacted concrete pavements. "Using ROCC has several benefits, such as more rapid pavement deployment and cost savings due to the building process" [11]. Steel reinforcement, forms, and dowels are not used in ROCC pavements. When compared to the price of concrete pavements that are built the old-fashioned way, this also yields considerable reduction in the cost. The two main areas of engineered construction that use roller-compacted concrete are pavements and dams. Only the application of ROCC in pavements are covered in this work. Traffic is typically intended to flow directly on the final surface of ROCC pavements. Typically, no wearing course is utilized, although occasionally, a hot mix asphalt overlay is applied for rehabilitation or smoothness. ROCC pavements often do not have transverse or longitudinal contraction joints for crack management. Numerous applications have made use of ROCCP. These include bulk commodity (coal, timber chips) storage areas, vehicle parking lots, military vehicle roads and parking sections, log sorting yards, lumber storage, forestry and mining transport roads, container intermodal yards, and, to a lesser degree, municipal streets, secondary highways, and aircraft parking ramps or areas. Although cement is abundantly used binding ingredient in the civil engineering construction practices, its manufacturing severely harms environment. hence it is necessary to substitute it partially by supplementary cementitious materials in cement concrete applications. In small quantities, it serves as a substitute for cement. Bagasse ash can be used as an additional cementitious material to improve flowability and yield stress while lowering the amount of superplasticizer needed [12,13].

This research work focuses on development of sustainable fiber reinforced ROCC with processed bagasse ash and its experimental evaluation with due consideration to optimal water content, maximum dry and wet densities, percentage compaction, and mechanical properties with different proportions of TPF as secondary reinforcement and cement substituted with processed BA in different percentages.

2. Materials and Methodology

2.1 Materials

Researchers have been articulated diverse views on ROCC mix designs procedure, primarily due to differences in consistency and gradation compared to normal concrete. The design of ROCC mix is closely tied to its mechanical properties, durability, and suitability for pavement applications. In this experimental work, the materials used for ROCC specimens included cement, water, aggregates, Processed Bagasse ash (BA) manufactured by sieving, heating and grinding the received bagasse ash, workability agents, and TPF, all sourced locally. The OPC 53 grade cement has been used, which conforms to specified standards [14,15] properties of the cement and processed Bagasse ash are presented in Table 1. For the aggregates, well graded fine aggregates finer than 2.36 mm size were utilized, along with crushed natural gravels with 20 mm and 10 mm nominal sizes. A mix of coarse aggregates 20 mm, 12.5 mm, and 6 mm are combined with natural sand were used to get the appropriate grading as specified in existing literature. The properties of the TPF, which was produced in India, are presented in Table 2. Since TPF reduces optimal moisture content in concrete and ROCC inherently has limited workability, processed Bagasse ash has been added partially to enhance workability of the mix.

Table 1. Chemical composition (% by mass) and physical properties of cement and processed bagasse ash

Chemical composition	Cement	Processed Bagasse ash	Physical properties	Cement	Processed Bagasse ash
Silicon dioxide (SiO ₂), %	24.61	72.11	Blaine fineness (m ² /kg)	281	318
Aluminum oxide (Al ₂ O ₃), %	5.45	5.87	Specific gravity	3.15	2.42

Calcium oxide (CaO), %	62.74	4.60	Soundness: mm	2.5	3.2
Ferric oxide (Fe ₂ O ₃), %	4.35	4.52	Setting time: min Initial	81	-
Magnesium oxide (MgO), %	0.11	<0.05	Final	379	-
Moisture Content, %	-	0.32	Compressive 3 day Strength:(Mpa) 7 days 28 days	38.75 40.24	-
Sulfur trioxide (SO ₃), %	2.96	0.39		57.13	-
LOI, %	3.15	3.6	Chloride content, %	-	0.017

Table 2. TPF Properties

Length (mm)	Melting Point (°C)	Diameter (Micron)	Resistance to alkalis, salts, and acids	Ability of electrical conductivity	Tensile strength (N/mm ²)	Colour
12	240-260	30-35	High	Limited	434	White

Table 3. Laboratory Trials for Optimum water content and MDD value of ROCC mixture using modified proctor test apparatus

% Water Content	38%	39%	40%	41%	42%
Volume of mould (cm ³)	902.75	902.75	902.75	902.75	902.75
Wt. of mould (gm)	4630	4630	4630	4630	4630
Wt. of mould + compacted concrete (gm)	6780	6860	6840	6850	6800
Wt. of compacted concrete (gm)	2150	2230	2210	2220	2170
Bulk density (kg/m ³)	2381	2470	2448	2450	2403
Water content fraction	0.38	0.39	0.40	0.41	0.42
Maximum dry density (kg/m ³)	1720	1777	1748	1737	1692



Figure 1. Modified Proctor test setup

2.2 Mix Proportions

ROCC mix design has been carried out according to IRC SP 68[16,17]. Laboratory trials had been conducted to decide optimum moisture content and corresponding maximum dry density using modified proctor test [18] as given in Table 3. This study investigates the effects of varying processed bagasse ash contents, which are utilized in 15%, 30%, and 45% by cement weight. Three TPF volume fractions 0.25%, 0.50%, and 0.75% were added to the mixes. It was found that whereas TPF tends to decrease the workability of roller-compacted concrete, bagasse ash increases it due to pozzolanic action. The slump cone test (SCT) revealed that the ROCC mixtures, which were created with the ideal water-to-cement ratio, produced concrete that was non-workable and had 0% slump. To determine how consistent the combination is, moisture testing is usually carried out using accepted techniques. The Slump Cone Test, which is frequently combined with in-place density testing, was used to evaluate the workability of roller compacted concrete. The SCT is a rapid and frequent process that is usually carried out either after compaction is finished or after the initial compaction to get finished concrete layer for testing. Each work shift should begin with a test of the aggregate moisture content, and batch numbers should be adjusted as necessary if any changes are seen. To evaluate the concrete's workability, the SCT was used in this study to calculate the dry density, % compaction, and optimum moisture content (OMC). ASTM provides an outline of the SCT technique [19]. This technique computed the maximum dry density by compacting ROCC mixes with water contents. The mixes' water contents were adjusted based on the ideal moisture content values.

Fresh ROCC mixes were used to prepare 150 mm cube samples, 150 x 150 x 700 mm beam samples, and 150 mm diameter by 300 mm high cylindrical samples. To accomplish proper compaction, a vibrating table was utilized. For the cube, beam, and cylinder samples to be uniformly compacted before being assessed to ascertain their ultimate characteristics, the vibrating table was necessary. Table 4 gives an overview of the M40 concrete mix proportions employed in this work.

Table 4. Material quantities per cum for different ROCC Mixes for M40 grade

Mix ID	Cement (kg)	Bagasse ash (kg)	Water (kg)	Aggregate		Fine Agg. (kg)	W/(C+B)	Slump (mm)	Vebe time (Second)
				6 to 12.5 mm	12.5 to 19 mm				
CM	374	-	124	475	712	873	0.332	11	22
B15-F0	317.9	56.1	122.5	475	712	873	0.327	14	20
B30-F0	261.8	112.2	119.5	475	712	873	0.312	18	17

B45-F0	205.7	168.3	120	475	712	873	0.320	20	13
B0-F0.25	374	-	128	475	712	873	0.395	12	24
B0-F0.50	374	-	133.5	475	712	873	0.342	10	26
B0-F0.75	374	-	137.5	475	712	873	0.368	8	30
B15 -F0.25	317.9	56.1	124	475	712	873	0.332	14	19
B15-F0.50	317.9	56.1	127	475	712	873	0.340	13	20
B15-F0.75	317.9	56.1	134	475	712	873	0.358	11	22
B30-F0.25	261.8	112.2	120	475	712	873	0.321	16	17
B30-F0.50	261.8	112.2	121.5	475	712	873	0.325	15	19
B30-F0.75	261.8	112.2	126	475	712	873	0.337	13	21
B45- F0.25	205.7	168.3	118.8	475	712	873	0.318	18	15
B45 -F0.50	205.7	168.3	118.9	475	712	873	0.318	16	16
B45- F0.75	205.7	168.3	119.8	475	712	873	0.320	14	19

2.3 Experimental Work

2.3.1 Compressive Strength

A digital hydraulic uniaxial compression testing machine (CTM) with a 2000 kN capacity has been used to test the specimens in accordance with IS: 516-1959[20]. The specimens measure 150 × 150 × 150 mm. Continuous application of the compressive load at a steady pace rate of 1.3 kN/s will continue till the specimen's resistance to the rising load fails and no further load can be supported. There will be a record of the specimen's maximum load. By dividing the greatest force placed on the specimen during the test by the cross-sectional area of specimen, the measured compressive strength of the specimen has been determined.

2.3.2 Flexural Strength

ROCC specimens measuring 150 × 150 × 700 mm was casted and Two point loading flexural test was conducted using a 1000 kN hydraulic universal testing machine in compliance with IS:516-1959[20]. The maximum load that may be applied before the specimen fails was noted. A compressive load will be administered at a steady rate of loading until the specimen fails.

2.3.3 Split tensile Strength

The split tensile strength has been conducted according to IS:5816-1999 [21] on cylindrical specimens of size 150 mm diameter and 300 mm length using CTM of 2000 kN capacity and strength is calculated by the equation given below.

$$\sigma_{st} = \frac{2P}{\pi DL} \quad (1)$$

2.3.4 Impact test program and procedures

The ROCC Mixes' impact resistance is assessed in compliance with ACI Committee 544.2R-89. In order to accomplish this, 150X64 mm discs that had been cut using a cutter from 150X300 mm cylindrical specimens were cast, set on a base plate with four positioning lugs, and repeatedly hammered. The blows were delivered by a 4.45

kg hammer that was frequently dropped from a height of 457 mm while a 635 mm steel ball was positioned in the middle of the disc's upper surface. It was noted how many blows were needed to cause the first noticeable crack and eventual failure.

The first crack strength in each test was determined by counting the number of blows required to appear the first visible crack (N1), and the failure strength was determined by counting the number of blows required to completely failure of the disc (N2).

2.3.5 Abrasion test program and procedures

The abrasion test was performed on 71 ± 1.5 mm cubical specimens in accordance with Turkish standard standards TS:699-1987 (IS:1237, 2012 and IS:9284, 1997) [22]. Before the test, specimens were dried at 50 degrees Celsius in an oven until they reached a constant weight. In this investigation, Bohme abrasion test equipment was employed.

3. Test Results and Discussion

3.1 Moisture content and densities

Table 5 displays the optimal water content (w), maximum wet and dry density, and compaction values for each mixture made with modified proctor test. A polynomial function was used to determine the relationship between the ideal mixture's dry density and suitable water content., Figure 1 shows the experimental setup for determination of OMC and MDD of each mix.

In this procedure, ROCC mixes which have exhibited optimal results are compared to the relationship between the optimal moisture content and the maximum dry density depicted in figure 2a) to d). These figures illustrate how increasing the water content to the optimal value first increases the dry density of ROCC., after that, when the water content rises, the dry density drastically decreases. The addition of processed bagasse ash to ROCC mixes decreased the OMC for all mix proportions as compared to control mix, as shown in table 5. Optimum moisture content-maximum dry density relationship of different proportion of fiber with and without processed BA are shown in figure 3 and figure 4. As the processed bagasse ash fineness increased, so did the mixes' water requirements for the desired workability. figure 5 describes Moisture content-dry density relationship of mixture B-0,15,30 and 45% and F0 and figure 6 describes for mixture F-0.25, 0.50 and 0.75%.

Table 5. Optimal water content, wet and maximum dry densities of ROCC Mixes

Mix ID	w opt. (%)	Maximum wet density (r_w) Kg/m ³	Maximum dry density (r_d) Kg/m ³	Slump mm	V-B time (Second)
CM	5.230	2374	2374	11	21
B15-F0	5.077	2381	2381	14	19
B30-F0	4.924	2391	2391	18	17
B45-F0	4.970	2385	2385	20	13
B0-F0.25	5.360	2391	2370	12	25
B0-F0.50	5.496	2374	2365	10	27
B0-F0.75	5.693	2368	2359	8	31
B15 -F0.25	5.139	2429	2377	14	20
B15-F0.50	5.149	2422	2375	13	21
B15-F0.75	5.550	2421	2373	11	22
B30-F0.25	4.982	2446	2384	16	19

B30-F0.50	5.040	2438	2382	15	21
B30-F0.75	5.252	2430	2375	13	23
B45- F0.25	4.990	2441	2376	18	17
B45 -F0.50	4.980	2434	2380	16	18
B45- F0.75	5.020	2422	2375	14	16

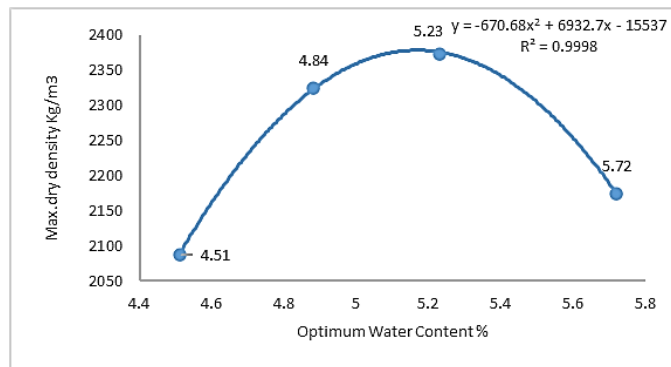


Figure 2 a). Moisture content-dry density relationship of mixture B0-F0 (CM)

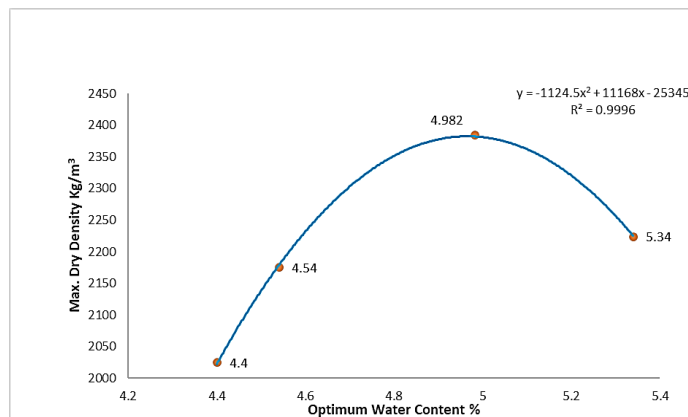


Figure 2 b). Moisture content-dry density relationship of mixture B30-F0.25

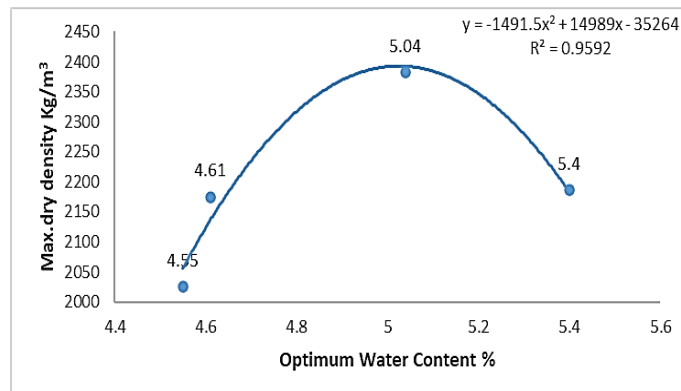


Figure 2 c). Moisture content-dry density relationship of mixture B30-F0.50

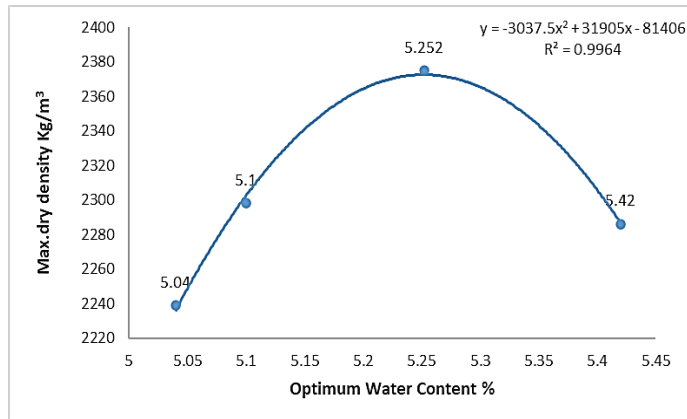


Figure 2 d). Moisture content-dry density relationship of mixture B30-F0.

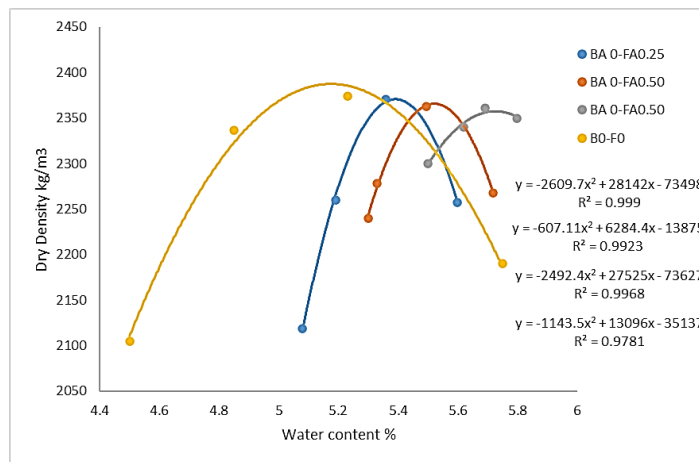


Figure 3. Moisture content-dry density relationship of mixture B0-F0, B0-F0.25, B0-F0.50 and B0-F0.75

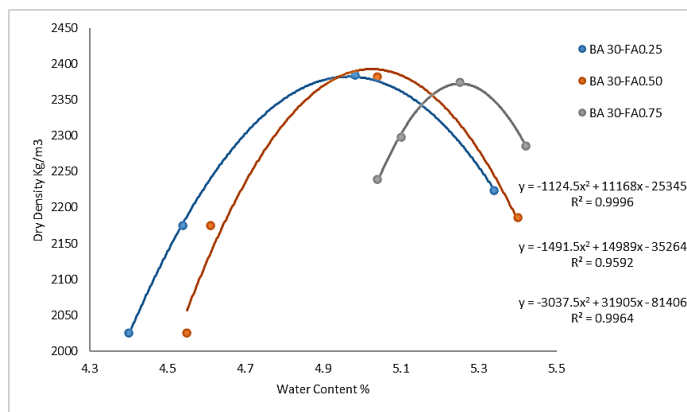


Figure 4. Moisture content-dry density relationship of mixture B30-F0.25, B30-F0.5 and B30-F0.75

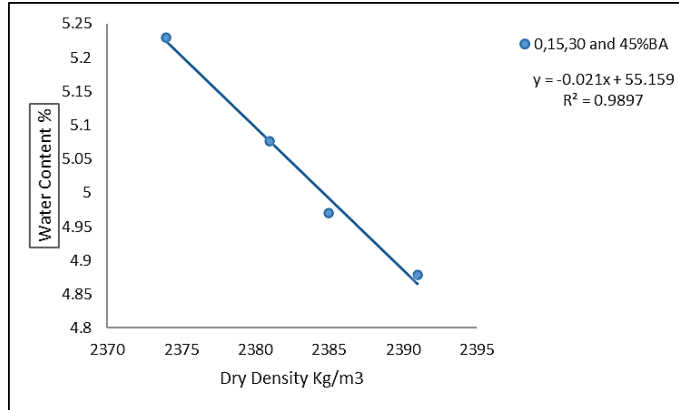


Figure 5. Moisture content-dry density relationship of mixture for B-0,15,30 and 45% and F0

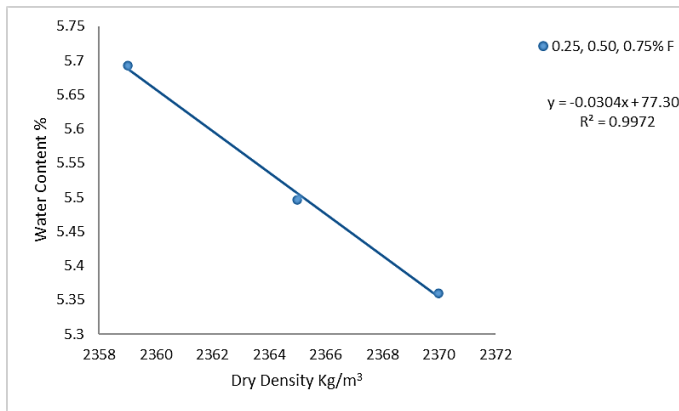


Figure 6. Moisture content-dry density relationship of mixture F-0.25, 0.50 and 0.75%

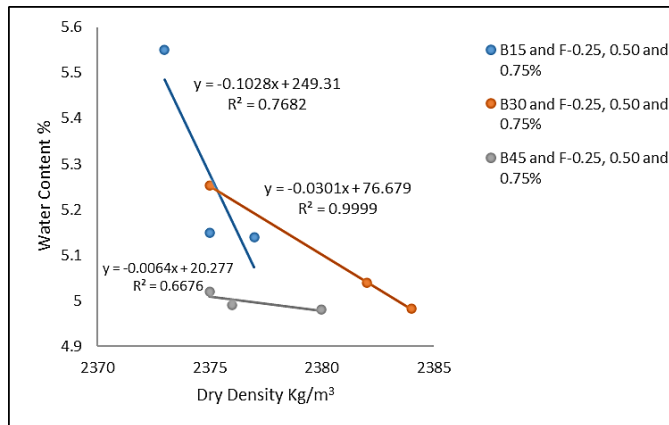


Figure 7. Moisture content-dry density relationship of mixture for All ROCC Mixtures

The following linear Relationship is established between optimal moisture content and TPF content

$$OMC_{TPF} = OMC_{ROCC} + 0.52TPFD \quad (2)$$

$$OMC_{BA} = OMC_{ROCC} - 1.02 \times 10^{-2} BAC \quad (3)$$

Where, OMC_{TPF} is the optimum water content of TPF_{ROCC} in %, OMC_{BA} is the optimum water content of BA in %, OMC_{ROCC} is the optimum moisture content of ROCC, and TPF is the fiber dosage per $1m^3$ in percentage, BAC is the bagasse ash content in % by cement weight as a partial cement replacement.

3.2 Mechanical Properties

3.2.1 Compressive Strength

The compressive strength test results for ROCC, ROCC with BA, ROCC with fibers, and processed BA-TPF combinations at 7d, 28d, and 90d of curing are displayed in Table 6 and figure 8. According to test results for concrete mixed with BA, the strength of 7d and 28d is achieved primarily due to hydration of cement, whereas long-term strength is achieved by the addition of processed BA. The most significant increase in the compression strength of treated BA concrete mixtures at 90 days over 7 days and 28 days strength over reference mix is undoubtedly due to the pozzolanic reactivity of bagasse ash. As the BA concentration rises from 0% to 45%, the concrete mix's compression strength drops from 31 to 19 MPa after 7 days and from 39 to 30 MPa after 28 days. When bagasse ash content rises to B30, the concrete mix's 90-day compressive strength increases; when bagasse ash content falls to B45, it decreases. The table illustrates how the compressive strength rises from 47 to 51 MPa. Table 6 shows the compressive strength of the concrete mix including TPF. After 7, 28, and 90 days, the compressive strengths of ROCC and TPFROCC were seen to vary between 31 and 24 MPa, 40 and 30 MPa, and 47 and 36 MPa, respectively. The higher the TPF concentration, the lower the compressive strength of the TPFROCC mix. Because the strength of the TPFROCC mixture decreases as the TPF concentration rises, table 4 illustrates that the ideal w/c increases. The compressive strengths of the ROCC mixes with processed bagasse ash and TPF are presented in table 6. The final outcome demonstrates the unique features of processed BA and TPF influence the ideal weight-to-cement ratio. The ideal water content rises when the bagasse ash percentage reaches 30% and falls as the TPF percentage rises. It can boost the strength of the ROCC mix and combine bagasse ash and TPF for the best w/c ratio management. In this control mix, the strength of all the TPFROCC with 0.25, 0.50, and 0.75% mixture and processed bagasse ash added in 15, 30, and 45% increases after 90 days. TPF with bagasse ash's 7d and 28d compressive strengths ranged from 29 to 18 MPa and 30 to 25 MPa, respectively, depending on the mixture's strength proportion. The same combinations showed an increase in 90d compressive strength, ranging from 41 to 52 MPa. In general, ROCC must have a 28-day compressive strength of 30 to 35 MPa. After 28 days, the TPF0.25%-BA30 mixture with a w/c ratio of 0.366 and the TPF0.50%-BA30 mixture with a w/c ratio of 0.370 had respective compressive strengths of 35 and 33 MPa. ROCC that contains 30% BA and 0.25% to 0.50% TPF must therefore be designed in order to meet the ROCCP strength criterion. According to IRC: SP:62-2014 and ACI 325.10R-95, mixes are considered satisfactory when the compressive strength of ROCC at 28 days is at least 30 MPa.

Table 6. Mechanical properties for different mix proportions

Mix Design ID	<u>Compressive Strength</u>			<u>Flexural Strength</u>			<u>Split tensile Strength</u>		
	<u>MPa</u>			<u>MPa</u>			<u>MPa</u>		
	7 days	28 days	90 days	7 days	28 days	90 days	7 days	28 days	90 days
CM	31	40	47	2.4	4.1	4.4	2.8	3.0	3.1
B15-F0	28	32	49	2.1	4.0	4.7	2.5	2.9	3.2
B30-F0	25	36	51	1.6	4.4	5.2	1.8	3.1	3.5
B45-F0	19	30	40	1.6	3.8	4.3	2.0	2.7	3.2
B0-F0.25	29	30	45	3.2	4.7	5.3	3.4	3.9	4.3
B0-F0.50	28	29	41	3.3	5.4	5.7	3.7	4.0	4.5
B0-F0.75	24	30	36	4.1	5.6	5.9	3.4	3.9	4.2
B15 -F0.25	29	30	44	3.3	4.8	5.3	3.4	3.7	4.5
B15-F0.50	28	28	43	3.4	5.3	5.7	3.8	3.9	4.7

B15-F0.75	25	29	40	4.1	5.7	5.8	3.4	3.6	4.1
B30-F0.25	24	35	52	3.5	5.4	5.3	3.5	4.2	4.6
B30-F0.50	22	33	49	3.6	5.5	5.7	3.7	4.3	4.7
B30-F0.75	20	29	45	3.7	6.0	6.1	3.9	4.5	4.8
B45-F0.25	19	29	41	3.6	5.2	5.5	3.8	4.1	4.9
B45-F0.50	20	30	40	3.6	5.7	6.0	4.2	4.3	5.0
B45-F0.75	18	25	37	3.7	6.0	6.3	4.3	4.5	5.1

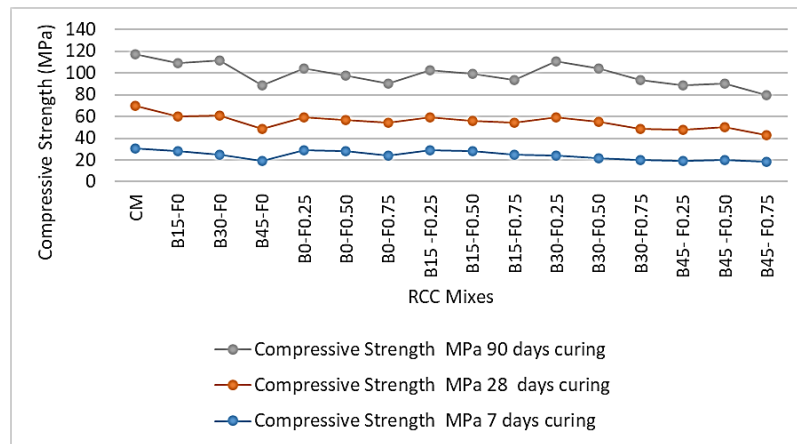


Figure 8. Compressive strength of ROCC Mixes

3.2.2 Flexural Strength

The experimental findings of the effects of TPF and processed bagasse ash in varying proportions are shown in Table 6 and figure 9. The table shows that as the amount of bagasse ash increases; the flexural strength falls in 7d and 28d curing. The control mix BA0's 7-day flexural strength is 2.4 MPa; in contrast, BA30's flexural strength drops to 1.6 MPa. The control mix BA0 has a 28-day flexural strength of 4.1 MPa, which rises to 4.4 MPa when BA30 is used, and falls to 3.8 MPa when BA45 is used. Concrete mixtures with 15–30% processed bagasse ash had greater strength at 28d and 90 days of curing age than the ROCC control mixture. The ROCC mixture containing 30% processed BA has flexural strength of 5.2 MPa after 90 days of curing age. When TPF was added to ROCC control mixtures at 0.25%, 0.5%, and 0.75% per 1 m³, the flexural strength values are shown in table 6. at 90d of water curing, the strengths of ROCC and TPFROCC ranged from 5.3 to 5.9 MPa. The TPF content increases in ROCC mixtures flexural strength and decreases with no fibers [25, 26] When TPF is added, the specimen's ductility and energy-absorbing ability both rises. Table illustrates how the TPF content affects the flexural strength for each mixture's varying bagasse ash content. As is the case with combinations comprising BA0% and BA15%, the flexural strength of the fiberless mixtures is less impacted by TPF with different concentrations. Applying TPF at 0.25%, 0.5%, and 0.75% improves the flexural strength of BA30-containing ROCC composites. It is evident that 0.75% TPF is stronger when combined with BA0%. Mixtures satisfy ACI 325.10R-95 and IRC: SP: 62-2014 standards for ROCC's compressive strength at 28 days, which must be at least 3.5 to 7 MPa.

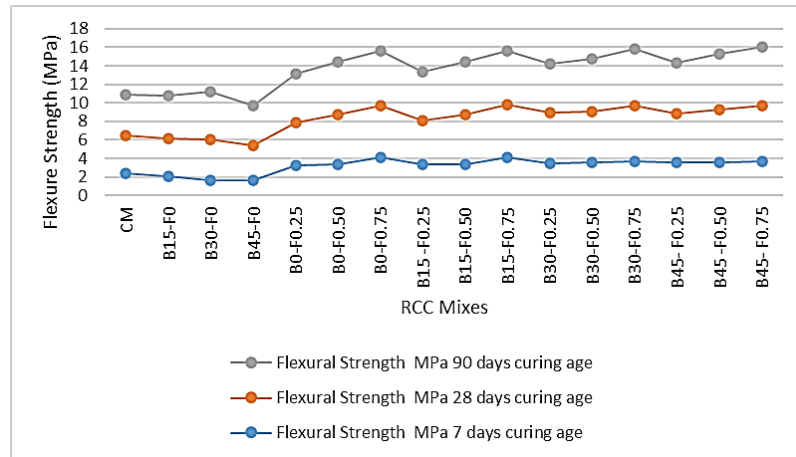


Figure 9. Flexural strength of ROCC Mixes

3.2.3 Split Tensile Strength

In the first 7d and 28d, the splitting tensile strength findings decrease as amount of processed bagasse ash content increases. When concrete mixtures containing 15 to 30 percent processed bagasse ash were aged for 28d and 90 days, their split strength was greater than that of the ROCC control mixtures. The outcome of adding 0.25%, 0.5%, and 0.75% TPF to the control mixture is displayed in table 6. The ROCC and TPFROCC samples' splitting tensile strength readings after 7 days of curing were found to vary between 3.4 and 3.7 MPa. In tests using control mixtures, the 28d and 90d curing splitting tensile strengths ranged from 3.9 to 4.0 MPa and 4.2 to 4.5 MPa, respectively according to a brittle behavior and samples with TPF exhibited ductile behaviour.

The results of adding fibers and treated bagasse ash in varying amounts to the control mixture are displayed in Table 6 and figure 10. The findings demonstrate that the splitting tensile strength of the fiberless mixes is not significantly impacted by BA% and B15% with 0.25% TPF. As bagasse ash and TPF levels rise, so enhances the 7, 28, and 90 days splitting tensile strength. The corresponding 7d, 28d, and 90d curing splitting tensile strengths ranged from 1.8 to 4.3 MPa, 2.7 to 4.5 MPa, and 3.1 to 5.1 MPa. The ACI states that ROCC combinations have a split tensile strength of 325.10R-95.

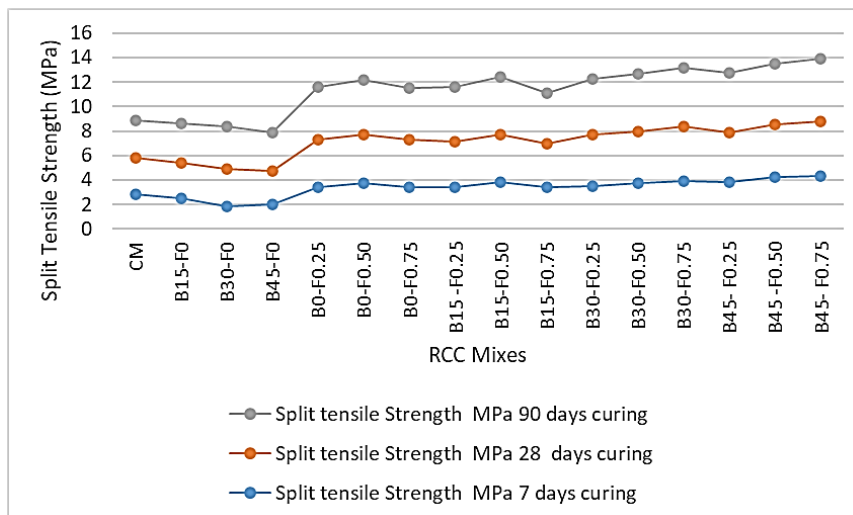


Figure 10. Split Tensile Strength of ROCC Mixes

3.2.4 Impact Energy Result and Discussion

The roller compacted concrete mix series' impact resistance performance is displayed in both Fig. 7 and Table 11. According to the results, the number of blows at the first crack (N1) and the number of blows for failure (N2) are given. Table 7 also displays the INFCB label, which indicates the % increase in failure crack blows.

Table 7. Test results for impact resistance of ROCC mix

Mix design ID	First crack strength (blows) N ₁	Failure strength (blows) N ₂	Blows Difference (N ₂ - N ₁)	Impact Energy KN-mm		INFCB (N ₂ - N ₁ / N ₁) X 100
				First crack Strength	Failure Strength	
CM	151	167	16	3044.52	3367.11	10.60
B15-F0	133	140	7	2681.59	2822.73	5.26
B30-F0	107	111	4	2157.37	2238.02	3.74
B45-F0	94	96	2	1895.26	1935.59	2.13
B0-F0.25	176	195	19	3548.58	3931.66	10.80
B0-F0.50	202	228	26	4072.80	4597.02	12.87
B0-F0.75	230	282	52	4637.34	5685.79	22.61
B15 -F0.25	163	180	17	3286.47	3629.23	10.43
B15-F0.50	180	199	19	3629.23	4012.31	10.56
B15-F0.75	193	228	35	3891.34	4597.02	18.13
B30-F0.25	157	169	12	3165.49	3407.44	7.64
B30-F0.50	170	186	16	3427.60	3750.20	9.41
B30-F0.75	181	204	23	3649.39	4113.12	12.71
B45- F0.25	88	94	6	1774.29	1895.26	6.82
B45 -F0.50	101	107	6	2036.40	2157.37	5.94
B45- F0.75	133	148	15	2681.59	2984.03	11.28

$$\text{Impact Energy, } U = \left(\frac{n \cdot m \cdot V^2}{2} \right) \quad (4)$$

$$H = \left(\frac{gt^2}{2} \right) \quad (5)$$

$$V = g \cdot t \quad (6)$$

$$m = \frac{W}{g} \quad (7)$$

where t is the time it takes for the hammer to descend from a height of 457 mm, g is the acceleration caused by gravity, n is the number of blows, and V is the hammer's velocity upon impact. H stands for fall height, m for hammer mass, and W for hammer weight. By changing the pertinent values in equation (4) [1]

$$457 = 9810t^2/2 \quad t = 0.3052 \text{ second and } V = 9810 \times 0.3052 = 2994.01 \text{ mm/second}$$

The impact energy per blow, U, of the hammer can be obtained by substituting the values in equation 4 as presented in table 7.

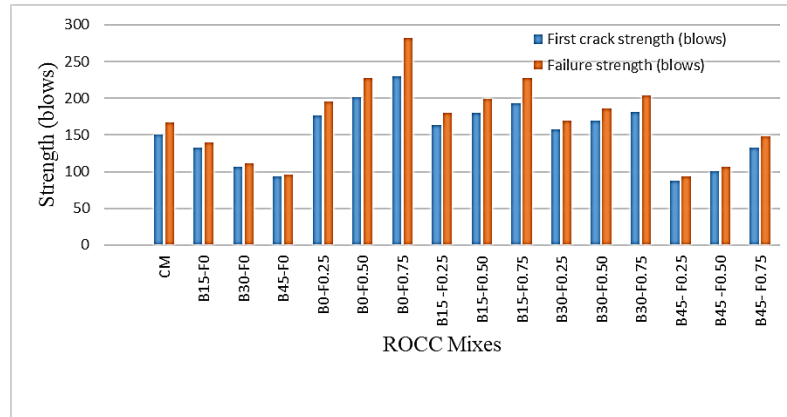


Figure 11. Strength versus different mix design of ROCC with fiber and bagasse ash

Experimental results show that adding TPF to the mixes increases N1 by 16.56%, 33.77%, and 52.30% when volume fractions of 0.25%, 0.50%, and 0.75% fibres are added, respectively. Mixtures including bagasse ash reduce N1 by 11.92%, 29.13%, and 37.75% at replacement rates of 15%, 30%, and 45%, respectively. However, adding 15% bagasse ash with fibre fractions of 0.25%, 0.50%, and 0.75%, respectively, raises N1 in combinations of bagasse ash and fibres by 8%, 18.06%, and 25.81%. When adding varying amounts of fibre, the value of N1 drops with 45% BA, while it rises by 10% and 17% for 0.50 and 0.75 percent TPF with 30% BA. The reason for this could be that the fibres in the specimens are better dispersed when bagasse ash is added. For N2 values, a similar pattern is seen. However, the inclusion of fibre filaments delays failure strength, as indicated by INFCBP values that show the capacity to absorb kinetic energy. The test results also in figure 11, reveal that adding processed bagasse ash (15, 30 and 45%) despite increment the strength, leads to higher brittleness. On the other hand, fibrous and almost bagasse ash fibrous specimens exhibit decreased start and crack propagation under impact stress. Lower ductility and higher paste strength can be achieved in BA mixtures when the water-to-cement ratio decreases. In N1 and N2, the rate of rise due to fibre or bagasse ash decreases significantly when 45% BA is added with fibre, even if N1 increases BA (15, 30 and 45%) with fibre (0.25%, 0.50% and 0.75%) mixes. When fibres are added, the INFCBP value rises by 12 compared to both BA-made and fiber-free examples. Table 7 illustrates how the number of blows for initial and ultimate strength has improved. Table 7 demonstrates that adding 0.25%, 0.50%, and 0.75% of fibres to plain concrete improves the number of blows for the first crack by 16.56%, 33.77%, and 52.30%, respectively.

3.2.5 Abrasion Test Results and Discussion:

Volume losses representing wear resistance data are tabulated in Table 8. The figure 12 shows that as the amount of processed bagasse ash in the mix grows, so does the mass loss. Mass loss and compressive strength are thought to be roughly inversely related.

Table 8: Wear resistance results in (cm³/50 cm²) for different curing age, bagasse ash and fiber volume fraction

Mix Design Code	7 days	Wear (cm ³ /50 cm ²)	% wear	28 days	Wear (cm ³ /50 cm ²)	% wear	56 days	Wear (cm ³ /50 cm ²)	% wear
CM	32	9.7	01	40	9.31	0.8	48	8.82	0.3
B15-F0	28	11.25	15	35	9.457	1.57	50	8.33	-5.96
B30-F0	25	12.28	25	38	9.359	0.52	52	8.085	-8.33
B45-F0	20	13.31	35	32	9.8	5.26	41	9.212	4.44
B0-F0.25	30	8.80	-10	32	8.33	-10.5	46	5.39	-38.9

B0-F0.50	28	8.54	12.5	31	8.085	-13.2	42	6.174	-30
B0-F0.75	25	8.28	-15.5	30	8.82	-5.3	37	7.35	-16.7
B15 -F0.25	31	10.78	10	34	8.575	-7.9	47	6.37	-27.8
B15-F0.50	30	10.29	5	32	8.624	-7.4	44	7.007	-20.6
B15-F0.75	25	9.31	-5	31	8.673	-6.8	41	7.399	16.1
B30-F0.25	24	11.76	14.8	36	7.84	-15.8	51	5.88	-33.3
B30-F0.50	22	11.27	15	34	8.085	-13.2	49	6.468	-26.7
B30-F0.75	21	10.192	4	31	8.183	-12.1	45	6.811	-22.8
B45- F0.25	20	12.74	30	31	11.27	21	42	8.526	-3.33
B45 -F0.50	21	11.76	20	29	10.78	15.8	40	8.379	-5
B45- F0.75	19	11.27	15	26	10.29	10.5	38	8.281	-6.1

Processed Bagasse ash helps to reduce the porosity of the paste increasing strength. It is known that bagasse ash possesses very low cementitious at early ages, however, with the development of cementing crystal at late ages. The volume loss due to abrasion is presented in figure 12. The abrasion loss of control mix, with fiber volume fraction, with bagasse ash and without bagasse ash with ROCC mix were found by volume respectively. The values at 15%, 30% and 45% bagasse ash ROCC mix volume loss were increased 16%, 26.59% and 37% respectively at 7 days curing. The values at 0.25%, 0.50% and 0.75% fiber ROCC mix volume loss were decreases 9.3%, 12% and 15% respectively as compared to plain ROCC at 7 days curing. The inclusion of TPF in the ROCC composites produces a compact, denser and stronger surface, which results in a higher resistance to abrasion.

It should be mentioned that non-fiber, simple mixes have relatively little hardness. A good correlation was found when mechanical characteristics and abrasion loss values were examined. The relation is exponential. resistance to abrasion is primary influenced by its compressive strength. In the case of mix 30% processed bagasse ash with 0.75% fibre ROCC polypropylene fibre reinforcement enhances both compressive strength and flexural performance. Additionally, there is a significant correlation between volume loss and the volume loss of fibre reinforced with bagasse ash on various curing days. The negative abrasion value indicates negligible wear and is attributed to surface polishing or minor measurement variation during the test. Table 8 shows the Relation between the abrasion resistance and the compressive strength of concrete at different cement substitute levels (0%, 15%, 30% and 45%) by mass with processed bagasse ash, regardless of age and different volume fraction (0.25%, 0.50% and 0.75%). This shows that beyond 15% cement replacement, the depth of wear decreases with increasing cement replacement upto 30% for the concrete compressive strength at 56 days curing. For example, a given compressive strength of 47, 49 and 51 MPa, and the depths of wear at 0%, 15% and 30% BA replacements were decreased by 5.96 and 8.33 % respectively. The abrasion-erosion resistance of 0.25%, 0.50% and 0.75% fiber reinforced concrete is decreased by 38.9%, 30% and 16.7% at 56 day curing age respectively. An abrasion loss of 0.75% TPF with processed bagasse ash 30% ROCC mixture is decreasing and most economical mix design as comparable to other mix design.

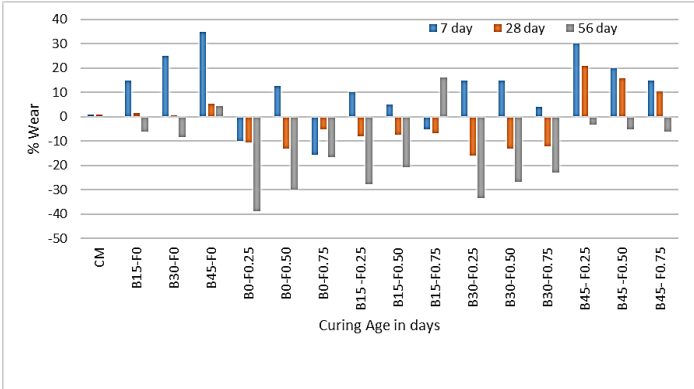


Figure 12. Comparison of wear and % fiber with BA for different ROCC mixes



Figure 13. Abrasion test on ROCC

3.2.6 Ultrasonic Pulse Velocity Test (IS 13311-Part-1)

It is conducted on concrete cube specimens of size 150 mm for different ROCC Mixes for 7dd, 28 and 90d curing age and results are shown in table 9. these results of NDT are compared with compressive strength obtained by destructive testing which is conducted under compression testing machine.

Table 9. Comparison between Ultrasonic Pulse Velocity Test Results and compressive strengths of ROCC Mixtures

ROCC Mix Design ID	Pulse Velocity (km/sec)			Concrete Quality Grading	Compressive strength (MPa)		
	7 days	28 days	90 days		7 days	28 days	90 days
CM	3.0	3.2	3.3	Medium	31	40	47
B15-F0	3.3	3.4	3.6	Medium	28	32	49
B30-F0	3.4	3.5	3.9	Good	25	36	51
B45-F0	3.3	3.4	3.6	Good	19	30	40
B0-F0.25	3.2	3.3	3.4	Good	29	30	45
B0-F0.50	3.5	3.6	3.7	Good	28	29	41
B0-F0.75	3.2	3.4	3.5	Good	24	30	36
B15 -F0.25	3.5	3.7	3.8	Good	29	30	44
B15-F0.50	3.7	3.8	3.9	Good	28	28	43
B15-F0.75	3.5	3.6	3.8	Good	25	29	40
B30-F0.25	4.3	4.1	4.2	Excellent	24	35	52
B30-F0.50	4.6	4.7	4.9	Excellent	22	33	49
B30-F0.75	3.7	3.8	3.9	Good	20	29	45
B45- F0.25	3.6	3.8	3.8	Good	19	29	41
B45 -F0.50	3.8	3.7	3.9	Good	20	30	40
B45- F0.75	3.7	3.8	3.8	Good	18	25	37

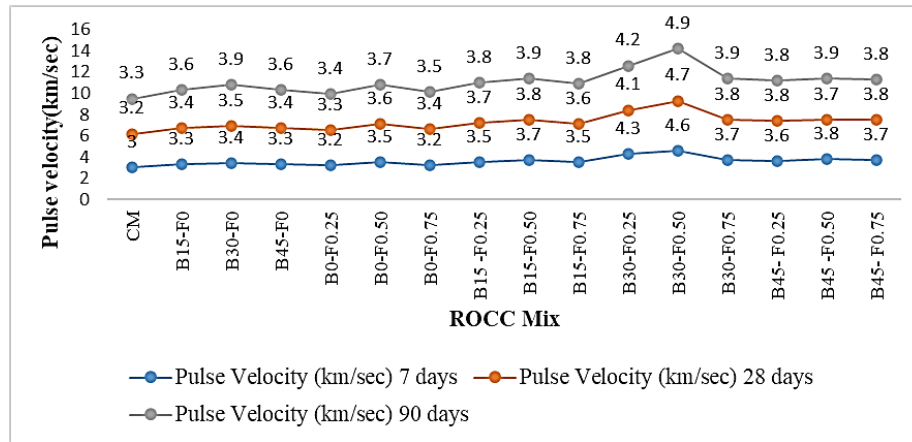


Figure 14. Ultrasonic Pulse velocity for different ROCC quality grading

The ultrasonic pulse velocities of the ROCC mixtures are presented in table 9. results increase from 7, 28 and 90 days with increasing bagasse ash and TPF. ROCC mixture grading quality varies between medium to excellent as per the guidelines of IS 13311-Part 1[23]. For ROCC mixtures B30-F0.25 and B30-F0.50 the concrete grading observed is excellent as pulse velocity varies between 4.2 to 4.9 km/sec at 90 days of curing age. From figure 13 it is observed that Compressive strengths of these mixtures are found to be optimum at 28 & 90 days respectively.

4. Conclusion

From this experimental work, the following conclusions has been drawn,

1. Due to the pozzolanic activity of processed BA, the mechanical properties of ROCC mixes containing 30% processed BA as a partial replacement for cement indicate a decrease in strength at 7 days of curing age and an improvement in strength and workability at 28 and 90 days. The optimal water content and water to cementitious materials (W/C+B) value of the mix are higher than those of the mixes without bagasse ash.

2.It is concluded that Water to cementitious materials ratio, i.e. W/(C+B) ratio, falls in the ROCC mix with fiber inclusion of optimal water content values. As the ratio falls, the peak compression strength marginally reduces, while the flexural strength of the ROCC mixes with TPF considerably increases. ROCC mixes can be effectively proportioned using processed BA30% and TPF as a secondary reinforcement, which enhances the mechanical properties at 28 and 90 days of curing.

3.The experimental outcomes shows that with processed BA 30% and TPF 0.75% volume fraction considerably acceptable in view of impact energy and economical mix design compared to FRC and plain concrete for sustainable construction.

4.The abrasion loss of processed BA30% and TPF 0.75% with ROCC mixture is decreasing and most economical mix design as comparable to other mix design.

5.Th comparison between ultrasonic pulse velocity and destructive testing shows that UPV provides a reliable, non-destructive indication of roller compacted concrete quality when processed bagasse ash and triangular polyester fibers are incorporated with 30% and 0.25% & 0.50% respectively.

6.It is concluded that without addition of retarders, average compressive strength of processed BA30% and TPF0.50% ROCC mixture increases by 61% from 7d to 28 d for time lapse of 0, 45, 90, 135 and 180 minutes and from 28 d to 90d it decreases by average 16%.

Disclosure Statement

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Notations:

ROCC-Roller Compacted concrete
BAC -Bagasse ash content (%)
OMC TPF-Optimum water content of TPF RCC (%)
OMCROCC- Optimum water content of ROCC (%)
TPFD -Fiber dosage per 1 m³ (%)
OMC BA- Optimum water content of BA (%)
r_w-Maximum wet density, Kg/m³
r_d- Maximum dry density, Kg/m³
CM-Control Mix
B-Bagasse Ash %
F-Fibers %

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