Experimental mix design approach of reactive powder concrete to recognize compressive strength through non-destructive test

To cite this article: Hemantkumar G Sonkusare *et al* 2021 *J. Phys.: Conf. Ser.* **1913** 012149

Experimental mix design approach of reactive powder concrete to recognize compressive strength through non-destructive test

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Abstract. Rapid industrialization in concrete industry dominates the infrastructural development globally. Where, the crowded places, old structures, monuments gets maintain and rehabilitate to strengthen then we use high grade concrete. For this purpose we use reactive powder concrete and without destroying the structure know its strength parameters. This investigation mainly focus on mix proportion of different ingredients of reactive powder concrete and check the freshly prepared specimen for non destructive test as per codal provision. Ultrasonic pulse velocity test gives the idea about the uniformity of material, dense particle and homogeneity.

Higher the pulse velocity or wavelength which passes through specimen higher is the compression strength. In this examination specimen were prepared from silica fumes, silica sand and steel fiber to achieve the durability. Here, RPC M30 and RPC M60 cubes were prepared and tested after 3, 7, 14, 28 and 90days. The specimen was cured and age by accelerated curing and conventional curing to see increment in compression strength. The accelerated curing temperature was kept 600C with relative humidity 60% and conventional curing at 250C i.e. on room temperature ±20C. In reactive powder concrete there is a less cement use because of silica fume which was again by product of SiO2 i.e. silicon dioxide. This is resulting into less significant greenhouse effects to improve sustainable development goal.

This paper gives sufficient idea about the wavelength and its characteristics. Uses of silica sand in study of RPC and structural changes occur in compression strength. In this paper linear relationship was establish with the help of regression analysis for compactness of material and studying the wavelength. The R2 value is ranges 0.8 to 0.99 means the relationship was good and material is homogeneous. Plasticizer and water cement ratio plays an important role in case of workability and cement binder ratio.

Keywords: Non-destructive test, Wavelength, Accelerated curing, Compression strength, (RPC) Reactive powder concrete,

1. Introduction

(RPC) Reactive powder concrete is a complex material gives a higher strength which is not possible in high performance concrete, less permeable [18]. A UHPFRC is a super-strong novel material who absorbs the energy. If we improve the microstructure of RPC through heat of hydration process then blend of complex material increases by pressing the thickness [17]. Cast in situ or precast material

NDT is extensively used for the assessment of its mechanical features[5]. The partial replacement of zircon sand sillimanite used as filler material and high alumina cement is also possesses good performance in temperature up to 600^{0}C in place of silica fumes [4]. The NDT results can be explore through by preparing a mathematical model of the RPC. [1]. Cement Industry facing a wide problem of cost price hiking in daily basis, entire globe also faces same problem so partial replacement of silica fume is one of the excellent solution to the natural resources. Due to optimization of material can achieve the high strength as well as durable structure. Utilization of pozzolanic material like silica fume, GGBFS eliminates the coarser material from RPC and hence, achieves the homogeneity of structure. Further addition of optimum percentage of super plasticizer one can reduce the w/c ratio hence, we total controlled on creep and shrinkage [2]. Thus RPC is a combination of higher strength and higher shear capacity with lesser the load of structure resulting dead load reduction and can increase the shape for high rise structure. The insertion of steel fibers in RPC lengthened the response towards first crack and braking point failure of structures since; in earthquake zone we can achieve the loss of life.

2. Methodology of Reactive Powder Concrete

All information is gathered from past literature and different Indian standard codes to identify the various properties of material.

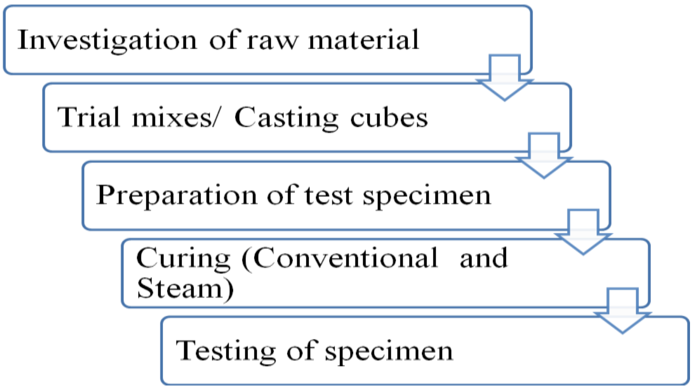


Figure 1. Methodology of experimental set up for RPC

3. Experimental Investigation of RPC

This investigation was divided into two parts first is material characteristics and second analysis by non destructive test [25], [26] and [27]. The age development through accelerated curing and conventional curing[9], room temperature 25^{0}C ±2^{0}C and accelerated curing was established on 60^{o}C and 60% relative humidity later to established up to 90days age of curing[11] .

Table 1. Properties of Silica Fumes, and cement (Chemical, Physical)

S. No.	Ch-symbol	Oxide composition Chemical Composition (%)	Si Fumes	Cement (C)
1	CaO	Calcium oxide	0.2	62.98
2	SiO_2	Silicon Dioxide	93	20.24
3	Al_2O_3	Aluminum Trioxide	2	4.61

4	Fe_2O_3	Ferric Oxide	0.5	2.74
5	K_2O	Potassium Oxide	1.0	0.27
6	Na_2O	Sodium Oxide	0.4	0.13
7	MgO	Magnesium oxide	1.6	2.39
8	SO_3	Sulphate	0.5	2.24
9	L.O.I	Loss of Ignition	2.6	3.29
10	Ins. Res.	Insoluble residue	-	0.86
11	LSF	Lime saturation factor	-	96.12
12	FL	Free lime	-	1.3
13	SM	Silica ratio	-	2.75
14	Cl	Chlorides	-	1.68
		Physical composition		
1	F	Fineness(by Residue on 45µs)	7.5%	396(m^2/kg)
2	Sp. Gr.	Specific Gravity	2.3	-
3	Sp. Sur	Specific Surface	15 (m^2/gm)	-
4	F	Bulk Density	650(kg/m^3)	-

Table 2. Properties of Admixtures

S. No.	Technical data	Mineral
1	Appearance	White fluid (liquid)
2	Relative density	1.14+0.02
3	Air Entrainment	Max 1% over control
4	Chloride content	<0.1%
5	PH	>6.00
6	Toxic effect	Non Toxic
7	Dosage	200 ml to 400 ml per bag of 50 kg cement
8	Water Reduction	20% above
9	Shelf Life	1 year in closed and properly stored container

3.1. Specimen Preparation

The preparation of blend for control mix is having w/c ratio 0.4 given in table 3. Ordinary Portland cement type- I fulfilling the codal provision of IS 1489 (Part 1): 1991 (Reaffirmed 2005).Locally available natural river sand (Specific gravity 2.57, Fineness modulus 2.6 zone II) & l quarry crushed aggregate (maximum size of 20mm) were used as fine and coarser aggregate respectively. The cube specimen was used having size 150x150x150mm. After casting of cubes shall be kept in laboratory for 24 Hrs then removed and curing by two methods up to 3, 7, 14, 28 and 90days [10]. Rate of heat of hydration was kept minimal with the help of accelerated curing to increase chemical attack and aggressive environments affect so here silica fume act as a pozzolanic material. Table 1 shows the chemical and physical engineering properties of material which further taken into account for analysis of RPC M30 and RPC M60 [14], [19].

Table 3. Mix Design Approach of RPC 30 & RPC 60 (CM)

Mix	Cement (Kg/m³)	% Replacement (silica sand)	Silica fume (Kg/m³)	Natural fine aggregates (Kg/m³)	Coarse aggregates (Kg/m³)	Superplasticizer (Kg/m³)	Water (Kg/m³)
CM 30	394	0	0	731	1137	20	0.4
CM 60	800	375	0	855	0	30	0.36

Table 4. Structure of Reactive powder concrete (RPCM 30 & RPC M60)

Mix	Cement (Kg/m³)	Silica fume (Kg/m³)	Silica fume (Kg/m³)	Natural fine aggregates (Kg/m³)	Coarse aggregates (Kg/m³)	Superplas-ticizer (Kg/m³)	Water (Kg/m³)
SF (10%)	353.6	39.4	39.4	731	1137	20	141.44
SF (12%)	346	47	47	731	1137	20	138.4
SF (14%)	338	55	55	731	1137	20	135.2
SF (16%)	330	63	63	731	1137	20	132
SF (18%)	323	70	70	731	1137	20	129.2
SF (20%)	315	78	78	731	1137	20	126

Mix	Cement (Kg/m³)	Silica fume (Kg/m³)	Silica sand (Kg/m³)	Natural fine aggregates (Kg/m³)	Coarse aggregates (Kg/m³)	Superplas-ticizer (Kg/m³)	Water (Kg/m³)
SF (10%)	800	39.4	375	855	0	30	290
SF (12%)	720	47	375	855	0	30	290
SF (14%)	704	55	375	855	0	30	290
SF (16%)	688	63	375	855	0	30	290
SF (18%)	672	70	375	855	0	30	290
SF (20%)	656	78	375	855	0	30	290

This protocol was maintained while developing The RPC solid blend. Initially break all the agglomerates of silica and cement for homogeneous mix in dry state. Add this agglomerates on aggregate fine and coarse. Mix this solid blend until the uniform color throughout i.e. Homogeneous mix for 1-2 minutes. Pour 75% of water into this uniform mixture as per the mix design criterion 3 minutes. Now insert the addition of steel fibers 1.5% as per the quantity 5 minutes. Pour the remaining water and admixtures 8 minutes so that requirement of water gets fulfilled. After that mix consistently and casts the specimen 30 minutes [24].

A cube having size 150 × 150 mm structure was utilized to cast the RPC models for the fundamental of compressive quality. After age of curing these cubes are aged for a period of 3, 7, 14, 25, and 90days [20]. The cubes were available after the period and test under compression machine having 2000kN capacity and then check its wavelength through ultrasonic pulse velocity test equipment [11], [16].

3.2. Investigational assessment and relationship

RPC M30 and RPC M60 results were examined for the following engineering properties at the age of 3, 7, 14, 25, and 90days as discussed: (1) Various mechanical properties and compressive strength of the specimen, Pulse velocity as per the codal provision IS [7],[25] and [6]. Linear regression models was established between pulse velocity (m/sec) and (km/sec) and compression strength of the specimen.

4. Outcome and conversation

4.1. RPC engineering property

The RPC Compressive strength has been carried out with two varying conditions first is destructive process and another is nondestructive process which shown in table No. 4, 5, 6, and 7. RPC Specimen

The compressive strength has been carried out under two different conditions which are shown in figure 2, 3,4 and 5[8] [9]. The results in table 4, 5, 6, and 7 are indicates the wavelength i.e. speed and time relation for a specimen. In results it is clearly indicates that the ultrasonic pulse velocity ranges from 3.9 to 4.8 for conventional curing. But for steam curing this value ranges from 4.1 to 4.9 means the steam curing gives more dense and compact member. [12], [13 &[15]. It was observed that previous literature [21] and other also it was observed silica fume gives results in 14% to 25% optimum. In this analysis first 10% add silica dose in lateral increment 2% is increased to watch the close observation on addition of ingredients.

4.2. Compressive strength of silica fume concrete

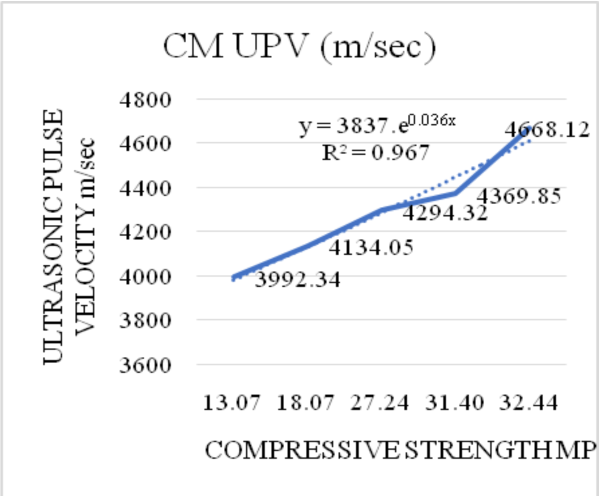
As per IS [7] the compressive strength test was carried out in a standard concrete cube of size150x150X150 mm. Compression testing machine capacity is 2000kN and it was work as a semi automatic and manual type. The reaction from Silica fume and silica sand is pozzolanic resulting into higher durability, and higher compact because of accelerated curing. [12] [15]. This kind of reaction is denser the microstructure throughout the specimen [21]. The quality of RPC M30 and RPC M60 slowly improve under conventional curing whereas steam curing suddenly increases the strength[13]. But long term effect cannot check because of this is a new material. So steel fibers were improves the compactness and sturdiness of the structural member [22][23].

Table 5. RPC M 30 Pulse Velocity in m/sec (Conventional Curing)

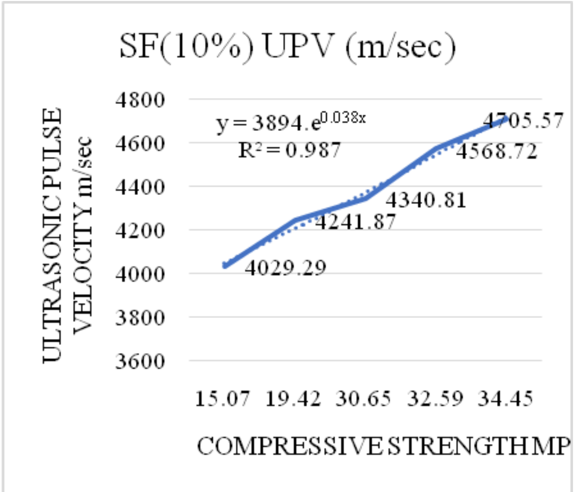
Mix Design	RPC M30 Ultrasonic Pulse Velocity in m/sec (Conventional Curing)				
	3rd Day	7th Day	14th Day	28th Day	90th Day
CM	3992.34	4134.05	4294.32	4369.85	4668.12
SF (10%)	4029.29	4241.87	4340.81	4568.72	4705.57
SF (12%)	4001.37	4314.36	4570.46	4693.97	4608.54
SF (14%)	3969.20	4127.62	4457.96	4565.93	4729.10
SF (16%)	4090.42	4276.41	4537.14	4641.39	4655.51
SF (18%)	4095.11	4392.96	4488.51	4549.21	4693.94
SF (20%)	4161.10	4339.28	4519.12	4655.78	4820.99

Table 6. RPC M 30 Pulse Velocity in m/sec (Steam Curing)

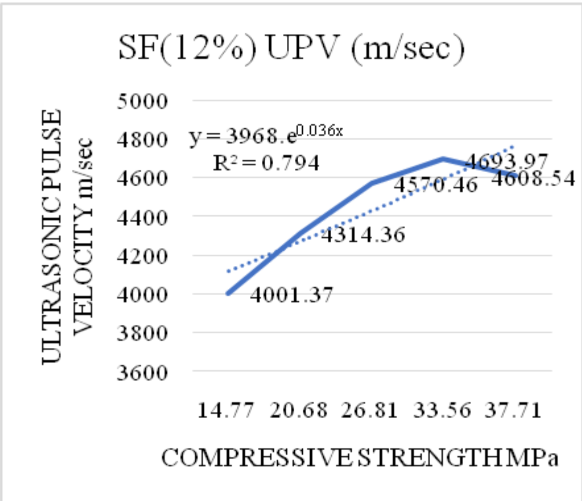
Mix Design	RPC M30 Ultrasonic Pulse Velocity in m/sec (Steam Curing)				
	3rd Day	7th Day	14th Day	28th Day	90th Day
CM	4182.40	4415.71	4605.42	4638.69	4765.56
SF (10%)	4211.94	4349.36	4513.90	4622.19	4732.74
SF (12%)	4177.56	4324.16	4560.25	4693.97	4867.07
SF (14%)	4184.66	4394.17	4592.81	4780.54	4870.71
SF (16%)	4368.33	4443.86	4628.44	4832.08	4887.54
SF (18%)	4155.52	4392.96	4478.58	4549.21	4714.70
SF (20%)	4144.72	4269.07	4438.63	4469.44	4570.43



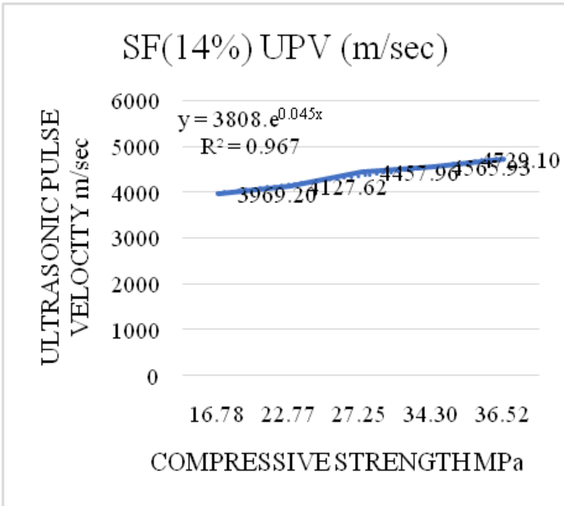
1. RPC M30 Control Mix Concrete



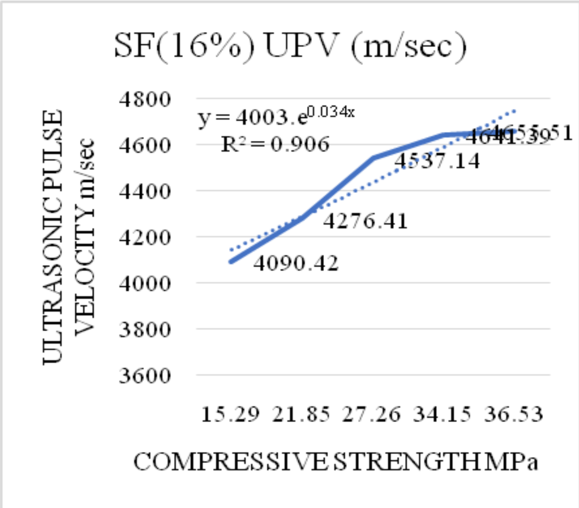
2. RPC M30 SF 10% Replacement



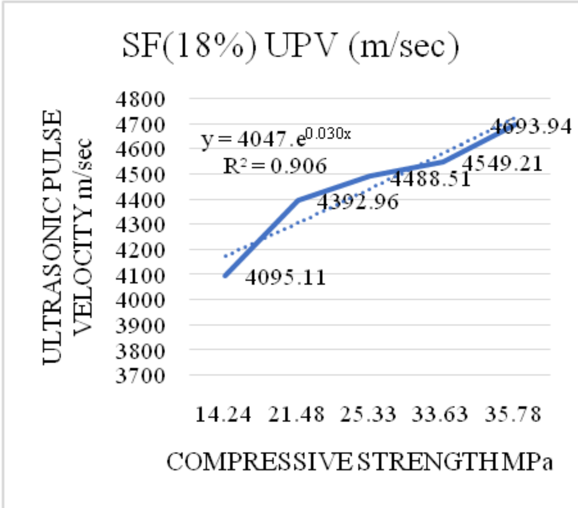
3. RPC M30 SF 12% Replacement



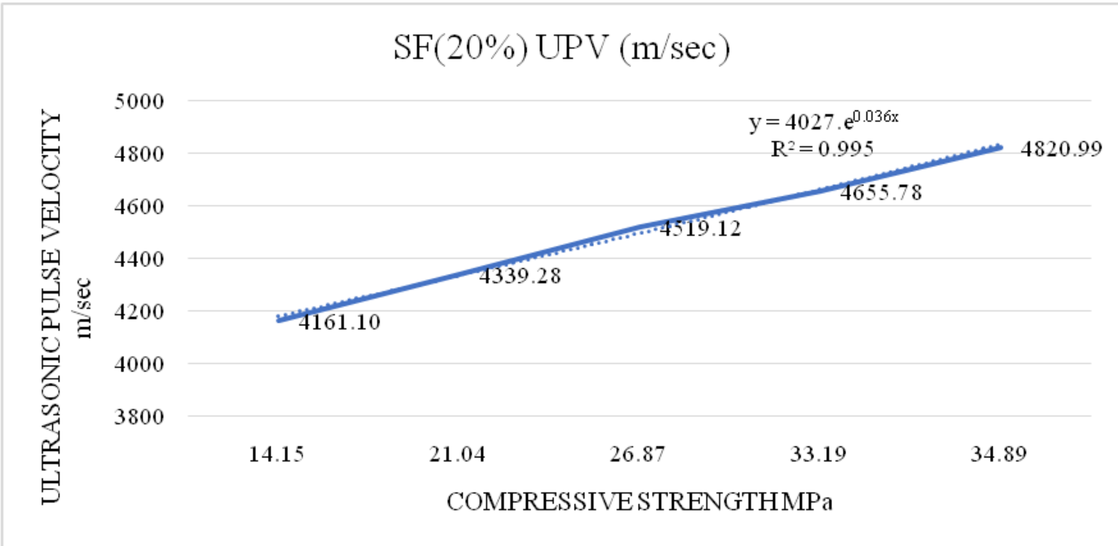
4. RPC M30 SF 14% Replacement



5. RPC M30 SF 16 % Replacement

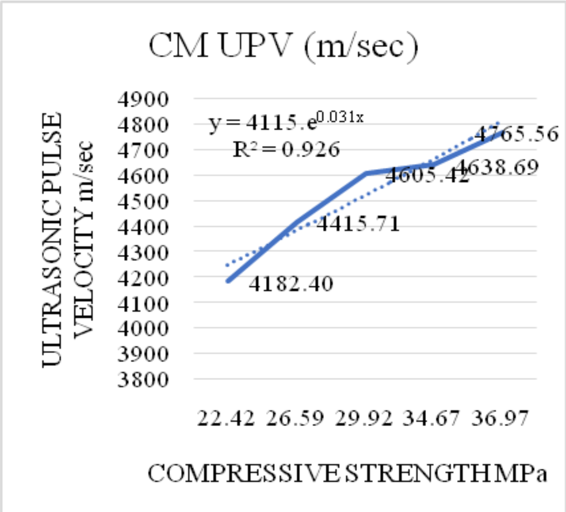


6. RPC M30 SF 18% Replacement



7. RPC M30 SF 20 % Replacement

Figure 2. RPC M 30 Linear Relationship of Compressive Stress and Ultrasonic pulse velocity of specimen (Conventional Curing).



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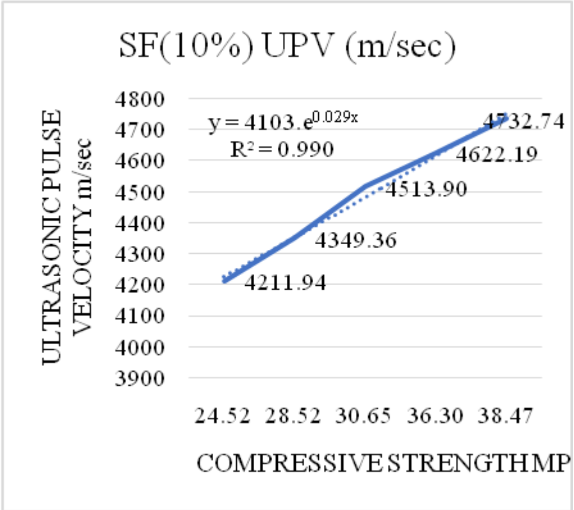

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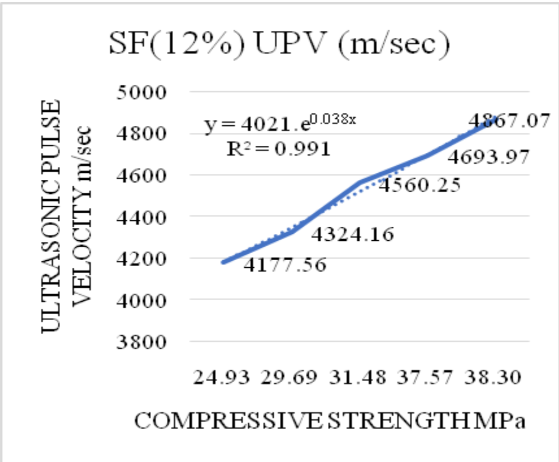

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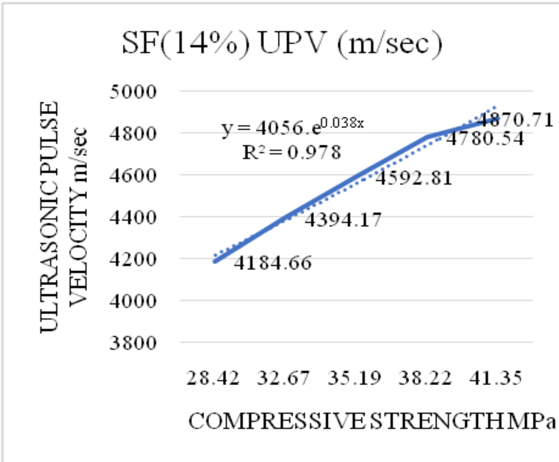

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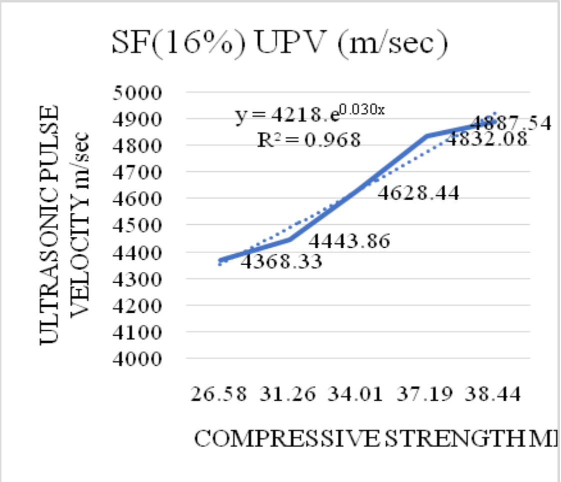

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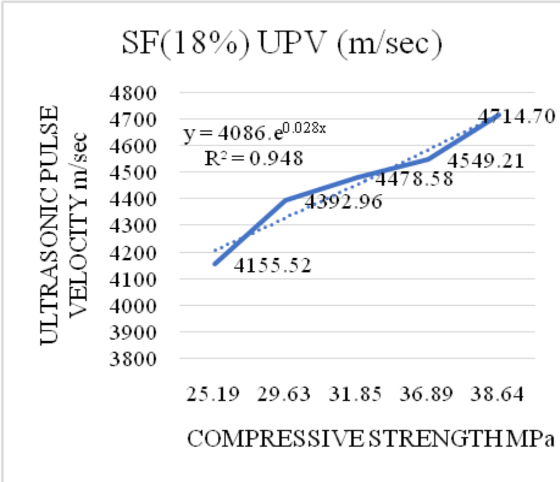

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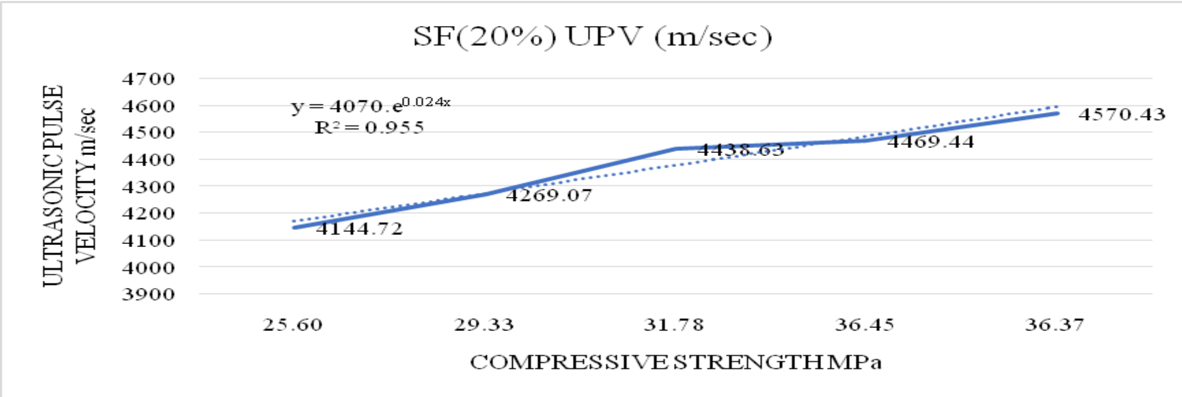


7. RPC M30 SF 20 % Replacement

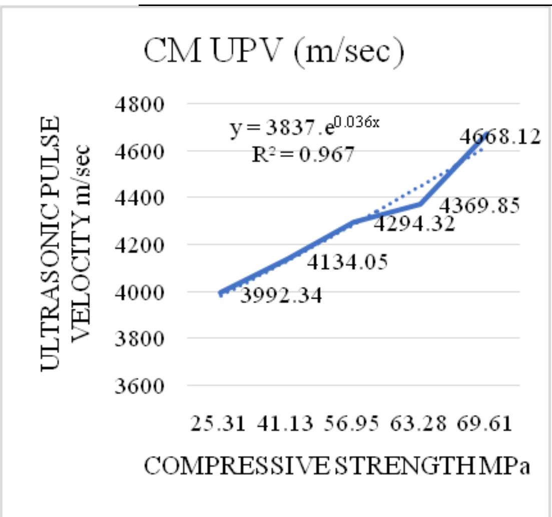
Figure 3. RPC M30 Linear Relationship of Compressive Stress and Ultrasonic pulse velocity of specimen (Steam Curing).

Table 7. RPC M 60 Pulse Velocity in m/sec (Conventional Curing)

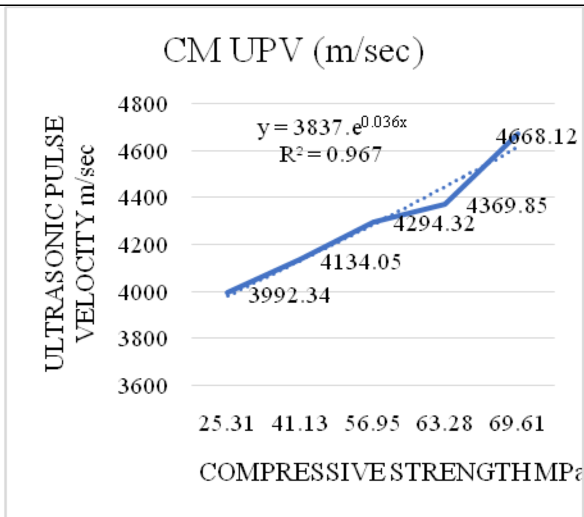
Mix Design	RPC M60 Ultrasonic Pulse Velocity in m/sec (Conventional Curing)				
	3^{rd} Day	7^{th} Day	14^{th} Day	28^{th} Day	90^{th} Day
CM	4048.46	4219.23	4273.51	4418.69	4748.02
SF (10%)	4086.13	4378.45	4532.41	4603.77	4885.51
SF (12%)	4206.35	4504.98	4587.72	4641.62	4695.00
SF (14%)	4154.63	4228.13	4452.77	4649.34	4733.30
SF (16%)	4085.34	4317.16	4417.65	4712.34	4742.37
SF (18%)	4129.73	4389.02	4448.62	4566.33	4734.67
SF (20%)	4208.39	4379.97	4504.48	4670.43	4777.89

Table 8. RPC M 60 Pulse Velocity in m/sec (Steam Curing)

Mix Design	RPC M60 Ultrasonic Pulse Velocity in m/sec (Steam Curing)				
	3rd Day	7th Day	14th Day	28th Day	90th Day
CM	4236.19	4298.87	4397.97	4524.96	4638.00
SF (10%)	4202.60	4308.86	4481.75	4635.30	4754.40
SF (12%)	4280.02	4320.58	4447.34	4584.51	4632.82
SF (14%)	4127.68	4229.00	4472.01	4607.34	4749.44
SF (16%)	4355.32	4432.24	4536.20	4669.31	4745.04
SF (18%)	4182.14	4359.35	4502.40	4610.92	4708.50
SF (20%)	4207.59	4282.76	4410.11	4533.46	4627.41



1. RPC M60 Control Mix Concrete



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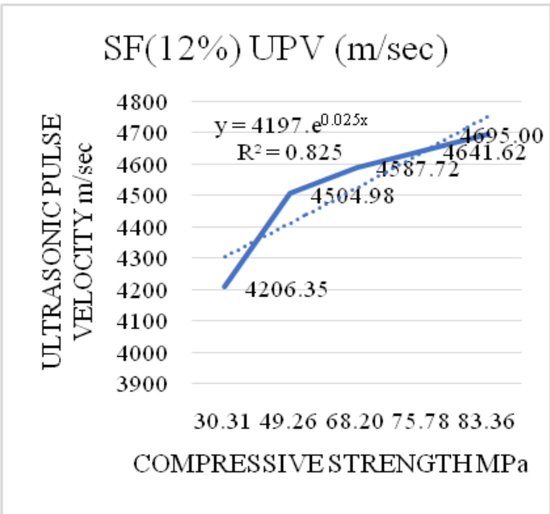
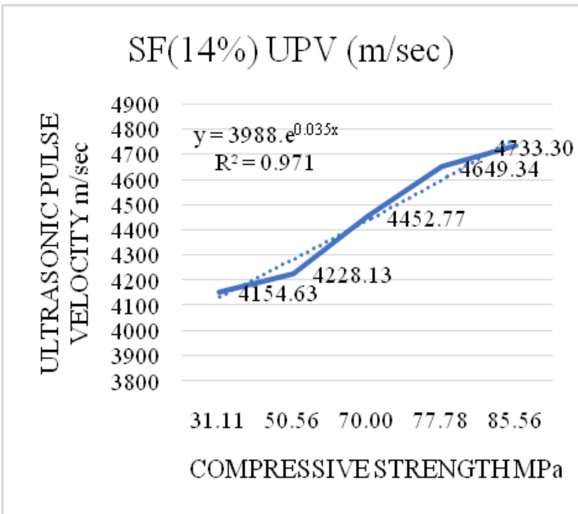
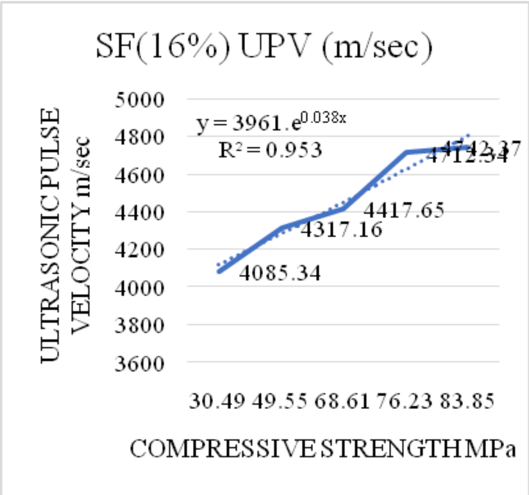


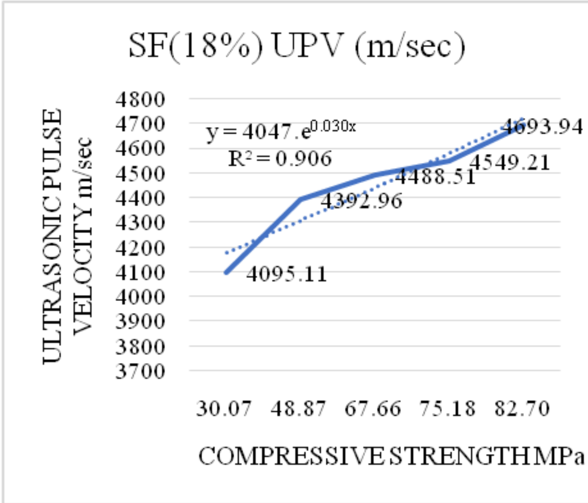
3. RPC M60 SF 12% Replacement



4. RPC M60 SF 14% Replacement



5. RPC M60 SF 16 % Replacement



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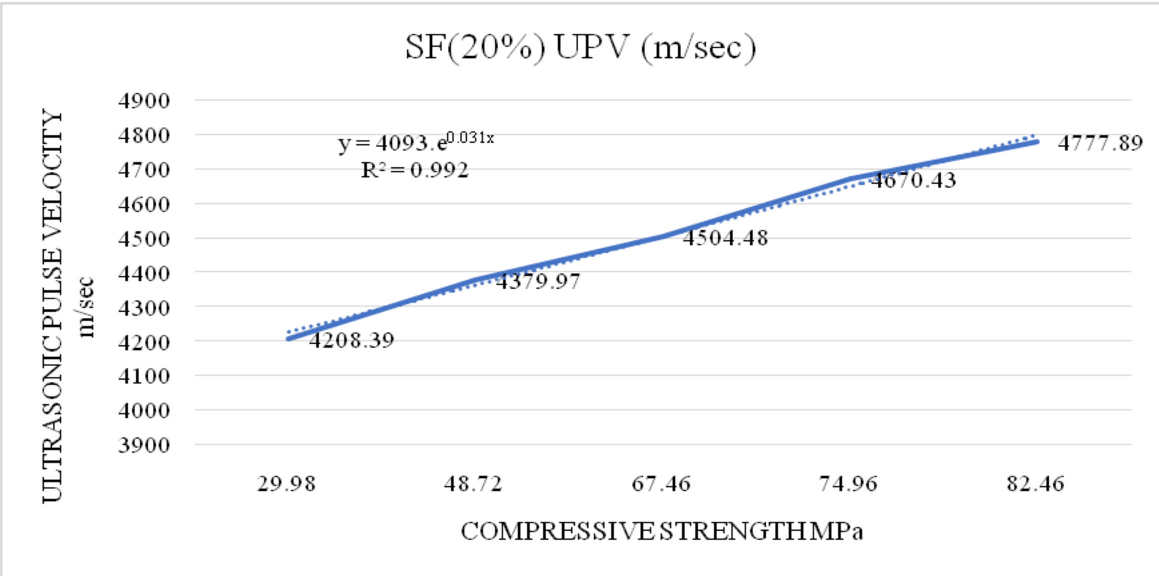
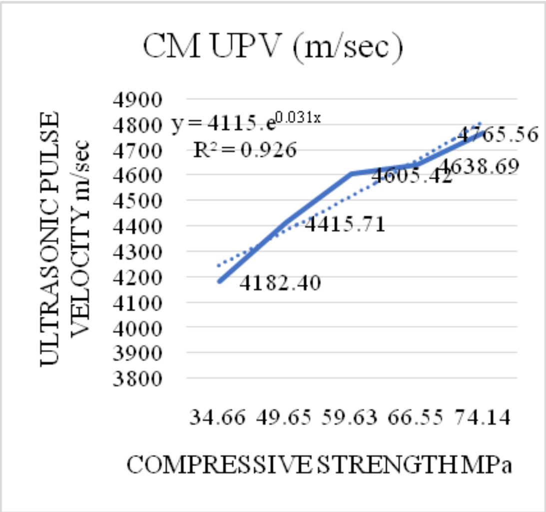


7. RPC M60 SF 20 % Replacement

Figure 4. RPC M60 Linear Relationship of Compressive Stress and Ultrasonic pulse velocity of specimen (Conventional Curing)



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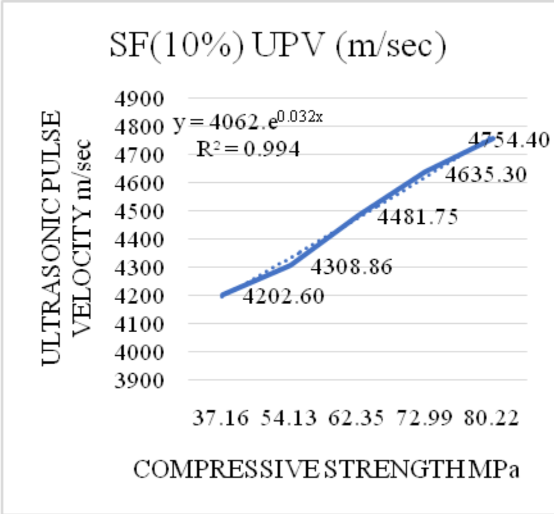
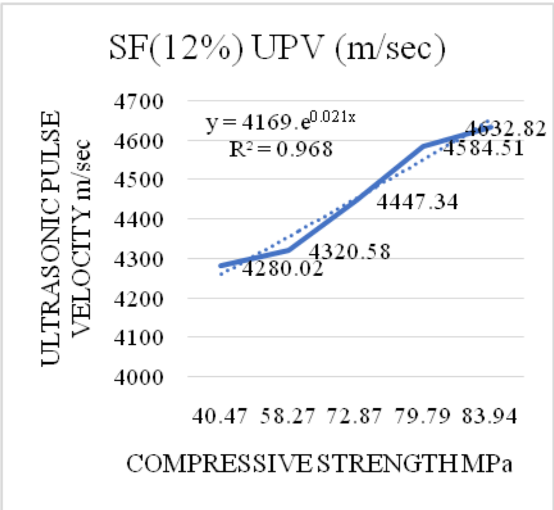


2. RPC M60 SF 10% Replacement



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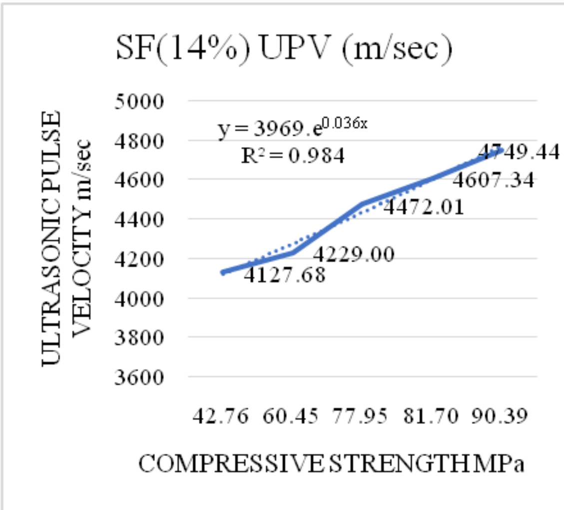

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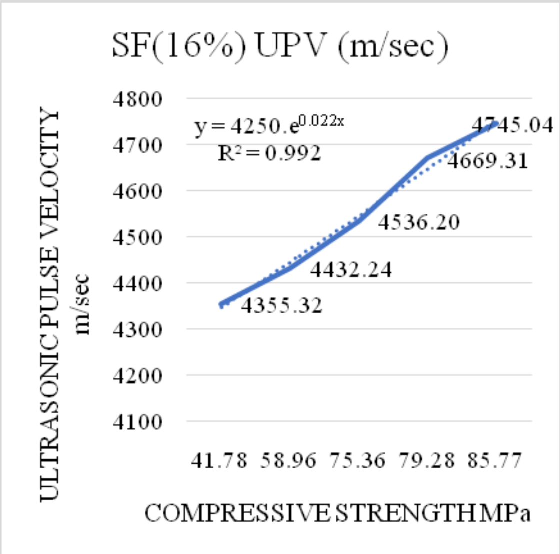

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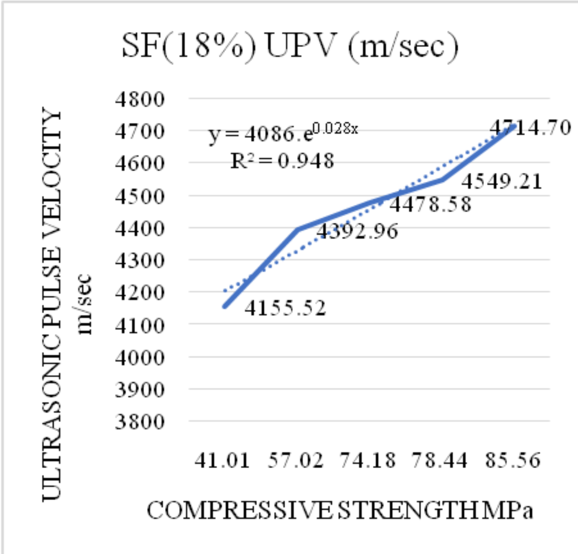

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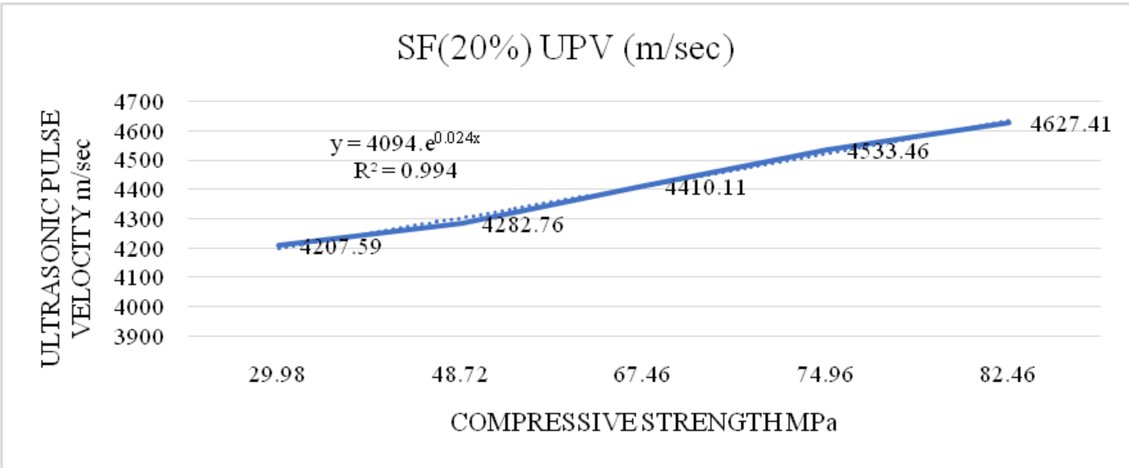

7. RPC M60 SF 20 % Replacement

Figure 5. RPC M 60 Linear Relationship of Compressive Stress and Ultrasonic pulse velocity of specimen (Steam Curing)

5. Conclusions

This paper investigates the RPC behavior in relation with destructive and non destructive test. Looking to the societal impact and sustainable development goal use minimum natural resources and use by product.

In this paper results show that ultrasonic pulse velocity ranges from 3.9 to 4.8 m/sec hence the material is homogeneous as per the codal provision IS 13311(part1):1992.

Linear relationship between ultrasonic pulse velocity m/sec and compressive stress MPa The mix structure of cement showed up in composed works was difficult to achieve as a result of the deviations in constituent materials, especially from different geographical status.

Steam curing enhances the compactness of internal structure so wavelength passing time will decrease.

Partial replacement of silica fume and silica sand gives the optimum value on 14% and 6% for higher strength.

Steel fibers enhances the cracking pattern in specimen also stress strain curve longer period of time while using 1.5%

6. References

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