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Strength Analysis of Concrete Containing Crushed Rock Particles AS Partial and Total Replacement of Sand

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Abstract- In recent past, the demand for natural river sand has rapidly increased for constructional purposes. This high demand led to extraction of sand from river beds. Depletion of natural sand creates the environmental issues and hence sand excavating is restricted by government which resulted in shortage and substantial increase in its cost. In this context, there is a need to recognize reasonable elective material from mechanical waste instead of stream sand. The usage of squashed shake sand which is a waste material has been acknowledged as building material in numerous nations for as long as three decades. In this paper, attempt is being made to replace natural river sand partially and completely with stone dust. The cube compressive strength test and split tensile tests were conducted. Experimental investigations have revealed that the mechanical properties of concrete using stone dust are almost similar to the conventional concrete. Hence the detrimental effects on environment caused due to excessive mining of river sand can be minimized.

Key Words: Concrete, Compressive strength, Split tensile strength, Crushed rock powder

I. INTRODUCTION

Concrete is a composite material that comprises of a blend of cement, aggregates, and water, with or without admixtures, strands, or different cementitious materials. Aggregate is a general class obviously to medium grained particulate material utilized in construction, including sand, rock, squashed stone and geo-manufactured aggregates. Aggregates in concrete go about as auxiliary filler. Stream sand has been the most prominent choice for the fine total segment of concrete before, however abuse of the material has prompted ecological concerns. Because of extreme mining process, the accessibility of stream sand has gotten short in supply. This prompted to the search of alternate materials as ingredients of concrete that are in no way inferior to the conventional materials.

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In any case, there has been broad research on the elective materials reasonable to supplant sand in concrete. The need to discover substitution for sand emerges from the way that in many parts of the world, there is developing worry about the exhaustion of sand stores, ecological and financial dangers related with extraction of sand from waterway banks.

Some elective materials which have been utilized as fractional trade for sand incorporate fly ash, slag limestone, silica stone, furnace bottom ash and reused fine aggregate [1–3]. Among the numerous materials researched, squashed rock dust has all the earmarks of being the most appropriate on the grounds that it is accessible in huge amounts in many pieces of the world. The usage of squashed rock sand gives extra advantage to concrete. It is known to cause an expansion in the quality of concrete over that made with equivalent measure of ordinary waterway sand. Use of squashed rock powder alleviates pressure on sand as well as decreases the requirement for its dumping as quarry dust is viewed as a waste item in the quarries. Squashed rock sand is gotten during the devastating of large stone boulders into coarse aggregates. Around 20-25% of the crushed material squashed in a smasher unit for extraction of aggregates is left as fine residue and is viewed as waste. The utilization of quarry dust as a structure material has been acknowledged in the propelled nations in the previous three decades [4, 5]. The degree of usage comes from supported research work completed with respect to expanding use of quarry fine aggregate.

II. LITERATURE REVIEW

Several studies have been carried in the past to evaluate the impact of partial supplanting of river sand with crushed rock sand. Celik and Marar [6] reasoned that incomplete substitution up to 30% prompts decline in slump value. However, a critical improvement in the compressive, flexural strength and impact resistance was watched. A noteworthy decrease in the cost of concrete without influencing the strength property was accounted for in the examination led by Ilangovan [7]. Sahu et al. [8] noticed that concrete made with crushed rock sand accomplished the comparable compressive strength, tensile strength and modulus of rupture as the control concrete. Sahul Hameed and Sekar [9] deduced that the compressive strength, split tensile strength and the durability properties of concrete made of quarry rock dust are almost 14% more than the conventional concrete.

Studies on the properties of fresh concrete have revealed that there is decrease in workability with quarry dust in concrete [10]. The decrease in workability is mostly attributed to high percentage of fines in the quarry dust and also the angular shape and rough texture of the dust particles which result in high water demand. Investigation into the durability of quarry dust concrete carried out by Ilangovana et al., [11] showed that quarry dust concrete dry shrinkage strains were larger at early ages (below 7 days) but lower at later ages compared with sand concrete. Shanmugavadivu and Malathy [12] reported lower water permeability, chloride-ion penetration, and strength and weight loss due to acid-chloride ion attack for concrete with 70% sand replacement with quarry dust. Improved impact resistance of concrete has been reported by T. Çelik, K. Marar [13].

Gulden Cagin Ulubeylia et al., [14] examined the impact of different usage areas of waste marble on the hardened concrete properties. It was discovered that the utilization of waste marble in the conventional concrete mix as an admixture material or aggregate is suitable as it can improve few properties of the hardened concrete.

Omar M. Omar et al., [15] detailed the test study attempted to explore the impact of partial replacement of sand with limestone waste, with marble powder as an additive on the concrete properties. It was discovered that limestone waste as fine aggregate enhanced the slump test of the fresh concretes. However, the good performance was observed when limestone waste as fine aggregate was utilized in presence of marble powder.

An endeavor has been made by M. Shahul Hameed and A. S. S. Sekar to ponder the durability properties on green concrete compared with the natural sand concrete. It is discovered that the compressive, split tensile strength and durability studies of concrete made of quarry rock dust are almost 14 % more than the conventional concrete. The concrete resistance to sulphate attack was enhanced greatly [16].

K. Shi-Cong, P. Chi-Sun [17], introduced the aftereffects of an investigation to contrast the properties of concretes prepared with the river sand, crushed fine stone (CFS), furnace bottom ash (FBA), and fine recycled aggregate (FRA) as fine aggregates. The outcomes suggest that both FBA and FRA can be used as fine aggregates for concrete creation.

Shehdeh Ghannama et al., [18] carried out a trial examination to investigate the plausibility of utilizing the granite powder (GP) and iron powder as a fractional substitution of sand in concrete. The test resulted showed that for 10% ratio of GP in concrete, the increase in the compressive strength was about 30% compared to normal concrete.

Literature review has revealed that many studies have been performed in the past to make use of crushed rock sand as fine aggregate in concrete. The present experimentation focuses on the effect of limited and complete substitution of river sand with crushed stone powder on compressive and split tensile strength of concrete pertaining to various grades.

III. OBJECTIVE OF STUDY

Natural river sand has turned out to be costlier presently inferable from a lack in supply. Over 90% construction activities came to granulating end crosswise over numerous parts of our nation. There is a noteworthy deficiency of sand prevailing in and around our nation. Skyrocketing demand, combined with unfettered mining to meet it, is creating the perfect recipe for sand shortages. Abundant proof unequivocally proposes that sand is getting progressively rare in numerous districts. Excessive mining on river beds to fulfill the expanding need for sand from the construction industry has led to severe ecological imbalance. The fact that rivers are running dry is being used as a reason to mine them for sand. Costly sand has raised the cost of construction and most private and public construction has slowed down like never before.

Stone dust is coarse, as opposed to fine, giving it properties that make it better than ordinary stone residue. Stone residue is a waste material obtained from crusher plants. It can possibly be utilized as incomplete substitution of normal stream sand in concrete. Utilization of stone residue in concrete not only improves the quality of concrete but also conserves the natural river sand for future generations.

Crusher dust is a common by-product of mining and quarrying. As opposed to being disposed of as a waste material in any case, recycled crusher dust has many practical applications around the home and in construction.

IV. EXPERIMENTAL PROGRAM

4.1. Materials

The materials for the current investigation comprised cement, fine aggregate, coarse aggregate, crushed stone powder, super plasticizer and potable water. Ordinary Portland cement (OPC) 53-grade was employed in all the concrete design mixes. The fine aggregate obtained from Tungabhadra River from Kurnool region of Andhra Pradesh state. The coarse aggregate utilized for the study consisted of 20 mm and 12.5 mm sized aggregate. The potable water was employed for mixing and curing of concrete.

4.2. Concrete mix and preparation of specimens

The design mixes corresponding to grades M25, M30, M35, M40 & M60 were developed and casted. Fine aggregates, crushed rock sand and coarse aggregates were first mixed thoroughly in a dry form until the mixture becomes uniform. The binding cement was added to dry mixture and mixing continued till the mixture turns homogeneous. Eventually, the potable water was added to the rotating mixer and mixing is continued until complete homogeneity is attained. The mix for each sand replacement level of particular concrete grade was cast in standard 150 mm x 150 mm x 150 mm cube moulds and 150 mm x 300 mm cylindrical moulds and compacted with a tamping rod in three layers. The specimens were de-molded after 24 hours and cured normally by immersion in water at a room temperature for 7, 14 & 28 days. After curing the cubes & cylinders for the specified period, they were removed and wiped to remove surface moisture.

The cubes were then placed in the compression testing machine centrally.

The cubes were placed correctly on the machine plate by checking the circle marks on the machine. The load was applied to the specimen axially at the rate of 14 N/mm^2 per minute till the cube collapses. The maximum load at which the specimen breaks is taken as compressive load.

The compressive strength was computed by dividing the maximum load with the cross sectional area of the cube specimen. Three identical specimens were tested in each case and the average of the three values is taken as compressive strength of the specimen. Concrete cube undergoing compression loading test in compression testing machine is shown in fig-1.

Fig.1: Testing of cube specimen

Fig.2: Test on cylindrical specimen

Fig.3: Tested specimens

Split tensile test is a technique for deciding the tensile strength of concrete utilizing a cylinder which parts over the vertical diameter. It is a backhanded technique for testing tensile strength of concrete. It is expressed as the minimum tensile stress (force per unit area) needed to split the material apart. It is communicated as the base elastic pressure (power per unit zone) expected to part the material separated. It is the standard test, to determine the tensile strength of concrete in an indirect way. The tests were performed in accordance with IS: 5816-1970. Concrete cylinders split into two halves along the vertical plane due to indirect tensile stress generated by Poisson's effect. Tensile strength is an important property of concrete because concrete structures are highly vulnerable to tensile cracking due to various kinds of effects and applied loading itself. However, tensile strength of concrete is very low as compared to its compressive strength. The cylindrical specimen experiencing split elastic test is delineated in figure-2. The photos of the tested specimens are appeared in figure-3.

V. RESULTS AND DISCUSSION

5.1 Compression Test Results

Table 1: Compressive strength of M25 grade concrete cubes

Mix	Percentage of crushed rock powder	Compressive strength (Mpa)			Percent change in Compressive strength		
		7 days	14 days	28 days	7 days	14 days	28 days
M25	0%	16.8	20.71	26.62	0.00	0	0.00
	25%	19.8	22.83	29.84	18.26	15.06	12.09
	50%	23.9	26.72	34.37	42.44	29.01	29.11
	75%	18.45	24.72	33.24	10.15	19.36	24.87
	100%	14.37	18.81	21.38	-14.21	-9.17	-19.68

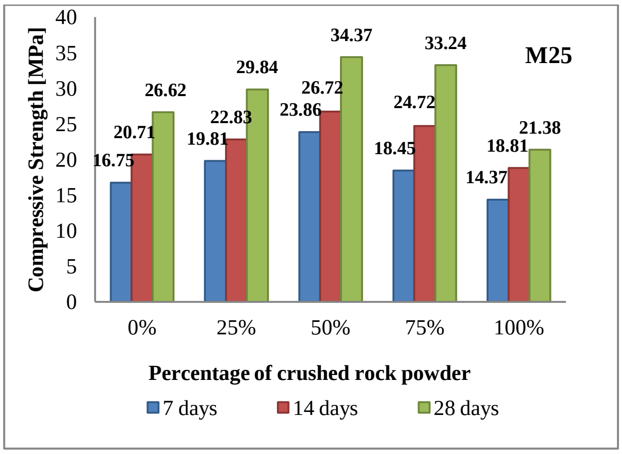

Fig-4: Variation of Compressive strength of M25 grade concrete at 7, 14 & 28 days

The results of compression tests for M25 grade of concrete is presented in table 1. Variation of compressive strength of cement concrete specimens of M25 grade at different ages made with partial and complete replacement of river sand with crushed rock powder is presented in figure 4. It is observed that the compressive strength continued to increase with age. From the tabulated results, it can be clearly identified that the compressive strength increases with 25% & 50% replacement level. At 75% substitution level also, a hike in compressive strength is noticed but at 100% replacement level there is a decline in the strength. The above variations in the compression clearly indicate that the crushed rock sand can replace the river sand up to 50 to 75% substitution levels.

Table 2: Compressive strength of M30 grade concrete cubes

Mix	Percentage of crushed rock powder	Compressive strength (Mpa)			Percent change in Compressive strength		
		7 days	14 days	28 days	7 days	14 days	28 days
M30	0%	20.17	24.05	31.86	0.00	0.00	0.00
	25 %	20.93	24.33	32.44	3.77	1.16	1.82
	50 %	23.39	26.27	35.38	15.96	9.23	11.05
	75 %	22.75	27.89	35.1	12.79	15.97	10.17
	100%	17.45	21.11	27.88	-13.49	-12.22	-12.49

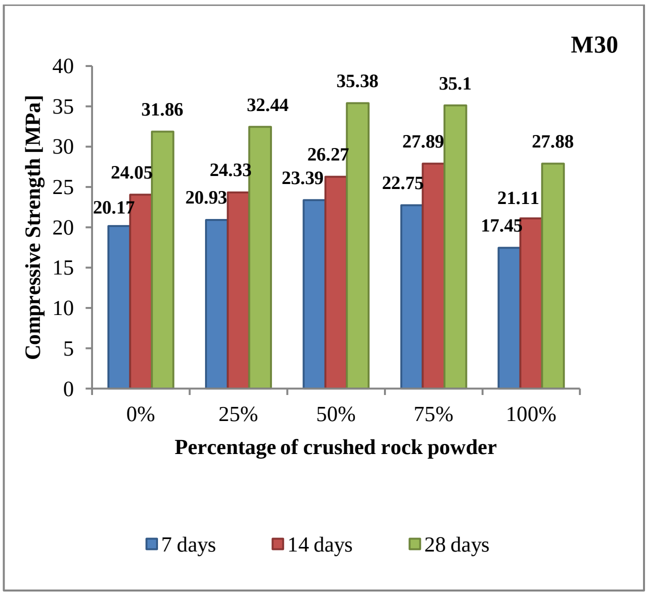

Fig-5: Variation of Compressive strength of M30 grade concrete at 7, 14 & 28 days

From the above tabulated results of M30 mix, a similar trend of increase in compressive strength was noticed as that observed for M25 mix. Table 2 shows the results of compression obtained for M30 mix and figure 5 presents the variation of compressive strength at 7, 14 & 28 days normal curing. It is noticed that there is a gradual increase in compression quality from 25 to 50% substitution levels. However at 100% supplanting levels, reduction in compression was found.

Table 3: Compressive strength of M35 grade concrete cubes

Mix	Percentage of crushed rock powder	Compressive strength (Mpa)			Percent change in Compressive strength		
		7 days	14 days	28 days	7 days	14 days	28 days
M35	0%	22.21	27.03	38.56	0.00	0.00	0.00
	25%	23.23	29.67	41.26	4.59	9.77	7.00
	50%	25.96	31.84	40.43	16.88	17.80	4.85
	75%	19.08	23.93	29.34	-14.09	-11.47	-23.91
	100%	17.6	22.12	27.08	-20.76	-18.17	-29.77

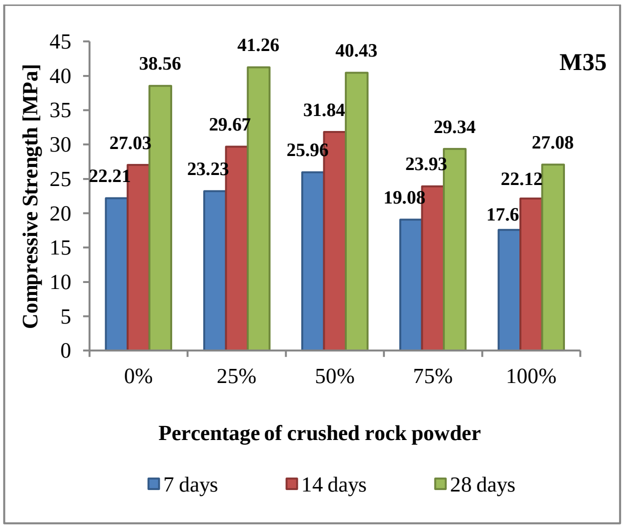

Fig-6: Variation of Compressive strength of M35 grade concrete at 7, 14 & 28 days

Table 3 depicts the results of compression test for M35 grade of concrete prepared with various substitution levels of stone dust. Figure 6 shows the variation of compression at 7, 14 & 28 days curing. The above tabulated results for M35 grade of concrete clearly prove that there is an increase in the compressive strength up to 50% substitution levels and there after a downfall in the values of strength is observed for 75 & 100% replacement levels.

Table 4: Compressive strength of M40 grade concrete cubes

Grade of concrete	Percentage of crushed rock powder	Compressive strength (Mpa)			Percent change in Compressive strength		
		7 days	14 days	28 days	7 days	14 days	28 days
M40	0%	24.58	29.78	41.11	0.00	0.00	0.00
	25%	26.57	32.15	43.73	8.10	7.96	6.37
	50%	27.78	35.29	44.51	13.02	18.50	8.27
	75%	22.97	29.96	39.12	-6.55	0.60	-4.84
	100%	23.02	26.49	37.7	-6.35	-11.05	-8.29

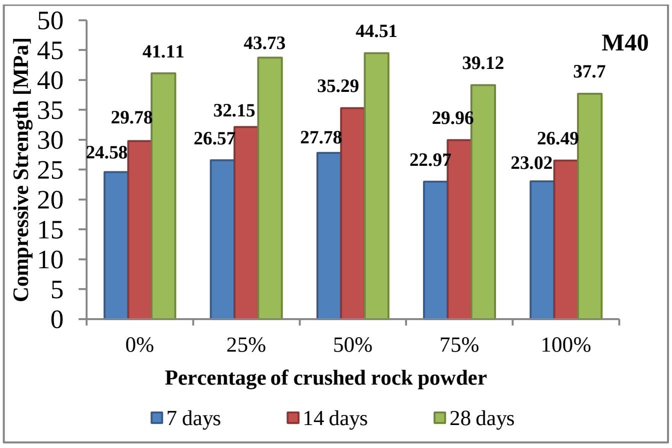

Fig-7: Variation of Compressive strength of M40 grade concrete at 7, 14 & 28 days

Table 4 shown above highlights the results of M40 grade concrete cubes tested for compression and figure 7 displays the changes in the compression for curing period of 7, 14 & 28 days respectively. For M40 grade of concrete, a decline in compressive strength was noticed from 75% replacement level. However, there was an increase in strength at 50% substitution level. The incorporation of crushed rock sand in the mix is also seen to reduce the compressive strength at 75 & 100% substitution levels.

Table 5: Compressive strength of M60 grade concrete cubes

Grade of concrete	Percentage of crushed rock powder	Compressive strength (Mpa)			Percent change in Compressive strength		
		7 days	14 days	28 days	7 days	14 days	28 days
M60	0%	36.16	45.33	59.62	0.00	0.00	0.00
	25%	41.11	46.75	61.54	13.69	3.13	3.22
	50%	41.91	47.44	62.23	15.90	4.65	4.38
	75%	31.95	36.81	46.58	-11.64	-18.80	-21.87
	100%	30.28	34.55	42.21	-16.26	-23.78	-29.20

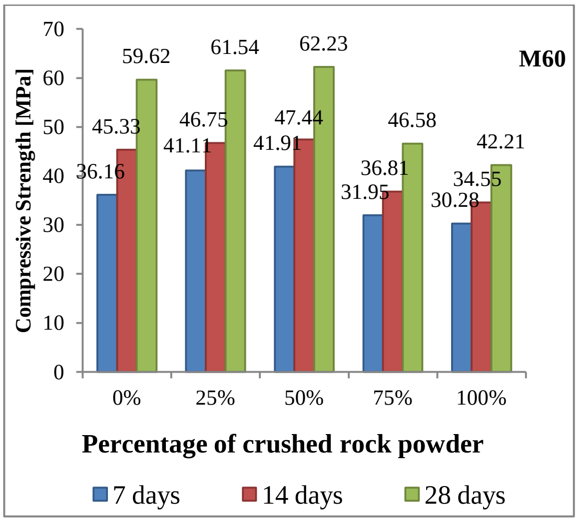

Fig-8: Variation of Compressive strength of M60 grade concrete at 7, 14 & 28 days

On observing the compressive test results of M60 grade concrete in table 5, it is observed that there is a gradual increase in the strength from 0 to 50% substitution levels. Results obtained are exhibited in graphical form in figure 8. A decline in compression was noticed for 75% and 100% substitution levels.

5.2 Split Tensile Test Results

Table 6: Split tensile strength of M25 grade concrete cylinders

Grade of concrete	Percentage of crushed rock powder	Split tensile strength (Mpa)		Percent change in Split tensile strength	
		7 days	28 days	7 days	28 days
M25	0%	1.94	2.65	0.00	0.00
	25%	2.01	2.65	3.61	0.00
	50%	2.12	2.63	9.28	-0.75
	75%	2.22	2.95	14.43	11.32
	100%	2.17	2.53	11.86	-4.53

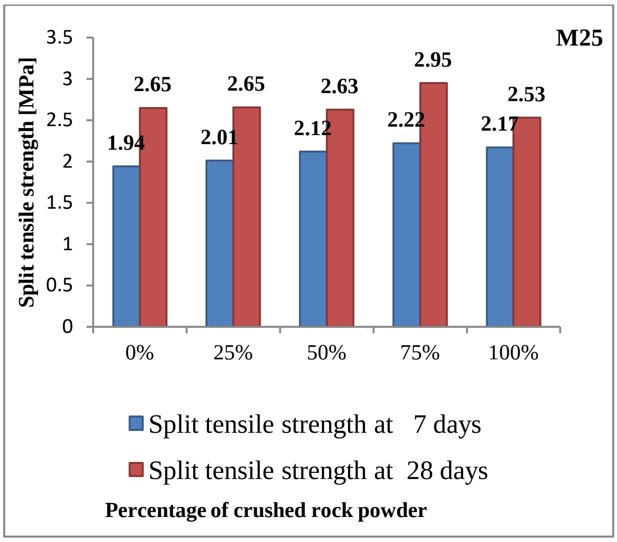

Fig-9: Variation of Split tensile strength of M25 grade concrete at 7 & 28 days

The results tabulated in table-6 for M25 mix, show that the split tensile strength is almost the same for concrete using river sand and crushed rock sand with partial and total replacement for all blending percentages. Figure 9 displays the variation of split tensile strength at various supplanting levels of stone dust. It is seen that as the substitute percentage is increased beyond 75% the splitting tensile strength tends to reduce.

Grade of concrete	Percentage of crushed rock powder	Split tensile strength (Mpa)		Percent change in Split tensile strength	
		7 days	28 days	7 days	28 days
M30	0%	2.01	3.06	0.00	0.00
	25%	2.11	3.31	8.76	24.91
	50%	2.32	3.58	19.59	35.09
	75%	2.07	3.31	6.70	24.91
	100%	1.85	2.58	-4.64	-2.64

Table 7: Split tensile strength of M30 grade concrete cylinders

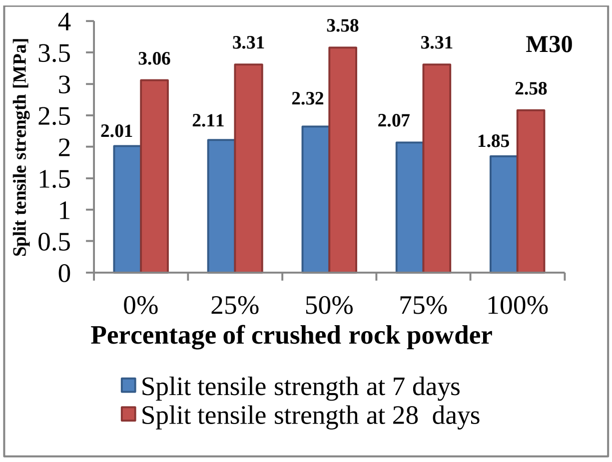

Fig-10: Variation of Split tensile strength of M30 grade concrete at 7 & 28 days

Table 7 displays the results of split tensile test at 0%, 25%, 50%, 75% & 100% replacement levels of crushed rock powder. The variation of the same is presented in figure 10. The results of M30 mix with various substitution levels show that the split tensile strength is maximal at 50% replacement and tends to reduce for 75 & 100%.

Table 8: Split tensile strength of M35 grade concrete cylinders

Grade of concrete	Percentage of crushed rock powder	Split tensile strength (Mpa)		Percent change in Split tensile strength	
		7 days	28 days	7 days	28 days
M35	0%	1.44	2.65	0.00	0.00
	25%	1.86	3.15	29.17	18.87
	50%	2.01	3.44	39.58	29.81
	75%	1.94	3.15	34.72	18.87
	100%	1.22	2.61	-15.28	-1.51

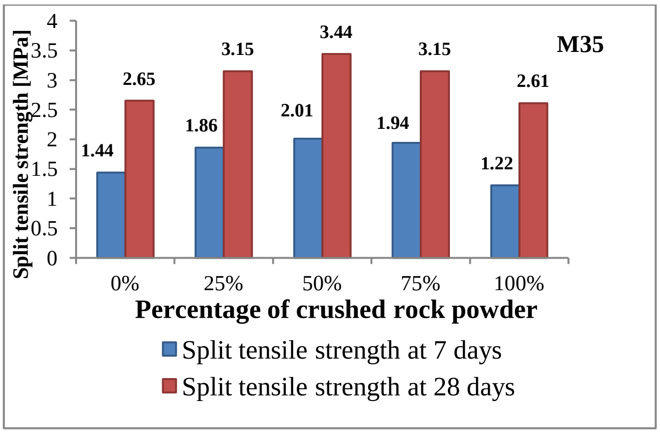

Fig-11: Variation of Split tensile strength of M35 grade concrete at 7 & 28 days

Table 8 presents the results of split tensile test for M35 grade of concrete and figure 11 shows the variation of split tensile strength at 7 and 28 days curing period. It can be observed from the above tabulation and graphs that, the splitting tensile strength markedly increased at 28 days for 50% replacement level for M35 grade of concrete. Gradual decline in strength was noticed for 75 & 100% substitutions.

Table 9: Split tensile strength of M40 grade concrete cylinders

Grade of concrete	Percentage of crushed rock powder	Split tensile strength (Mpa)		Percent change in Split tensile strength	
		7 days	28 days	7 days	28 days
M40	0%	2.04	3.27	0.00	0.00
	25%	2.11	3.61	3.43	10.40
	50%	2.36	3.89	15.69	18.96
	75%	2.14	3.11	4.90	-4.89
	100%	1.62	2.81	-20.59	-14.07

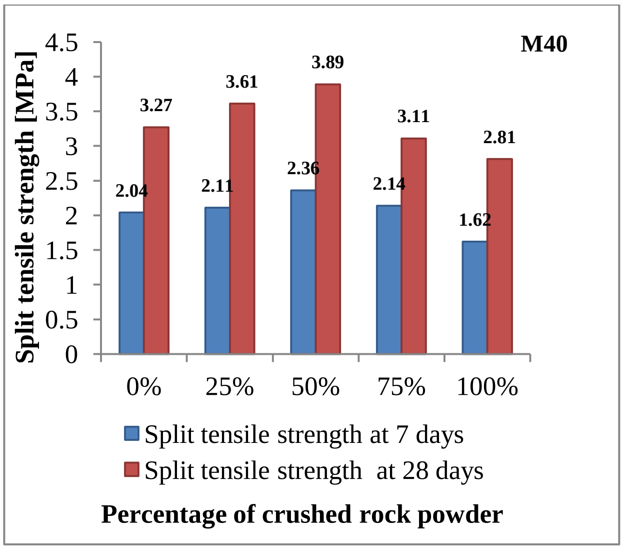

Fig-12: Variation of Split tensile strength of M40 grade concrete at 7 & 28 days

The results obtained after performing split tensile test on M40 grade concrete cylinders are tabulated in table 9. The variations of split tensile test are presented in figure 12. A similar trend as that for M35 mix was noticed for M40 grade of concrete.

Table 10: Split tensile strength of M60 grade concrete cylinders

Grade of concrete	Percentage of crushed rock powder	Split tensile strength (Mpa)		Percent change in Split tensile strength	
		7 days	28 days	7 days	28 days
M60	0%	2.12	3.39	0.00	0.00
	25%	2.22	3.44	4.72	7.96
	50%	2.36	3.89	11.32	14.75
	75%	1.85	2.89	-12.74	-14.75
	100%	1.78	2.87	-16.04	-15.34

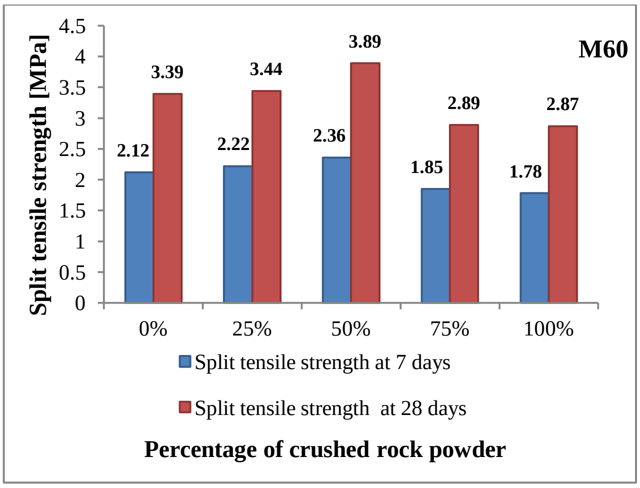

Fig-13: Variation of Split tensile strength of M60 grade concrete at 7 & 28 days

The results of split tensile strength obtained for M60 grade of concrete are presented in table 10. The variation of split tensile strength at 7 & 28 days curing are depicted in figure 13. At 50% substitute level, 11.32% increase at 7 days & 14.75% increase at 28 days in splitting tensile strength is noted for M60 mix.

VI. CONCLUSIONS

This examination intends to build up a concrete blend with most extreme stone residue that has quality properties practically identical to that of conventional concrete made with natural river sand as fine aggregate. It is expected to supplant sand with stone residue in concrete, since incorporation of higher measures of waste stone residue into concrete is environmentally friendly and financially plausible. The stone dust whenever utilized in concrete must pursue IS Code for Fine and Coarse aggregates. There is no harm in utilizing crusher dust if unadulterated by soil and other undesirable impurities. Concrete secures most extreme increment in compressive quality at half sand substitution. The silica rate in stone residue is above 80% which gives the high quality as same as sand. The specific gravity of the crusher dust samples lies in the range of 2 to 2.7 which satisfy the sand necessity.

Powdered materials fill in as better fillers and they increment the compressive quality up to specific dimensions. Anyway the grain size dispersion is hindered after a specific point which builds the pore space and thus diminishes the compressive quality of the concrete. Crushed rock sand can suitably replace the natural river sand for concreting works. The rate of the strength gain declined as the percentage of crushed rock sand replacement increased beyond 50 percent. The overall cost of concrete construction may be reduced by increasing the percentage of crushed rock dust, because cost of stone dust is negligible as compared to natural river sand. As the crushed stone dust used is very fine, it can act as filler between the particles of fine aggregate. Compressive and split tensile strength of concrete made with partial & total substitution of crushed stone dust is comparable with natural river sand results. Stone dust contains higher percentage of fines than natural sand and hence requires more water to saturate the particles. Utilization of crushed rock powder not only relieves pressure on sand but also reduces the need for its dumping as quarry dust is considered a waste product in the quarries. Use of crushed stone powder will reduce environmental degradation. It was found that blending of crushed rock sand and natural river sand produces a concrete of enhanced mechanical properties. Utilizing quarry residues as a substitute of sand in construction materials would resolve the ecological issues brought about by the large scale exhaustion of the natural sources of river and mining sands. The angular shape particles may impart improved characteristics for split tensile strength of concrete. The above conclusion gives a clear picture that quarry residue can be used in concrete blends as a decent substitute for normal waterway sand with higher quality at half substitution.

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