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Partial Substitution of Cement and Fine Aggregate With Waste Paper Sludge Powder and Quarry Dust in Enhancing the Strength Parameters of Concrete

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Abstract

The main compositions of concrete are sand and cement. A swift construction operation leads to a shortage of these materials. The concrete industry consumes natural materials in large quantities like river sand keeping our environment in check we need to make our concrete industry more lasting by using alternative binders to make it sustainable. Squander materials, for example, Quarry dust which is the result of squashed stone and waste paper sludge coming from the paper producing businesses leads to different issues like dumping. The chance of utilizing Waste Paper Sludge Powder as a halfway trade for concrete and Quarry dust as an incomplete swap for fine aggregates is explored in this research. The substitution levels of cement with WPSP are 0.8%, 1.3%, 2.3% and 3.3%.Though the substitution levels of fine aggregates with Quarry Dust are 16%, 26%, 36, and 46%. For WPSP specimens it was seen that at a 1.3% substitution level compressive strength is expanded by 12% at 28 days when contrasted with the control blend which has a 0% substitution level.

Flexural and split tensile are likewise expanded by 15% and 14%. While at 1.3%WPSP and 36% Quarry Dust in combination shows a 24% improvement in compressive strength when contrasted with the control blend. Flexural and split tensile strength increments by 24% & 29%, respectively. M25 concrete grade is designed as per IS 456:2000.

Keywords: Waste Paper sludge Powder, Quarry Dust, Compressive strength, Flexural strength, tensile strength.

1. Introduction

Natural sand is extensively used in construction, and formed by natural processes such as river and mountain sand. Apart from water, sand is a highly utilized natural resource. The concrete industry should not depend on natural sand as the natural resources are about to end. Cement is also a key component of concrete, and its production emits a variety of toxic gases and consumes a significant amount of fossil fuels [1]. To cut down on environmental issues and costs. An alternative is required in the concrete industry to make it sustainable. Using waste products like quarry dust and waste paper sludge ash instead of fine aggregates and cement as a partial substitution in concrete is the best technique [2][3][4]. The main reason for this study is to attain the potential of QD and WPSP for improving the strength of concrete both individually and also in combination of both.

Quarry dust is a waste outcome that is produced by industries due to the crushing of stones [5]. After various investigations, alternative materials like using Quarry dust instead of sand will definitely increase the strength, used in constructing infrastructures and is a feasible solution for environmental problems and pollution [6][7]. This new technique of using Quarry dust would conserve the construction materials and also natural resources will be used correctly [8]. Quarry dust is used in many infrastructures it is also used in roads for surface finishing. Various studies show that Quarry dust is an abundantly available material produced near about 200 million tons per annum. It is utilized as construction materials, path improvement materials, totals, blocks, and tiles [9][10]. Quarry dust diminishes the expense of development as well as builds strength in concrete than ordinary sand. The previous study has confirmed that the concrete made with quarry dust had an improvement in compressive strength up to 8% to 20% [11][12][13]. Kumar A, et.al performed their experiment and observed that compressive strength was expanded by 16.5 percent, tensile strength by 14%, and around 21% of flexural strength observed [14]. Mundra S, et.al prepared concrete mixes to measure compressive strength in the presence of Quarry dust which has different proportions, and found that 30% replacement has higher strength [15]. Arpitha D, et.al performed the experiment on a different percentage of quarry dust and found that at 15% replacement compressive strength increased by 2%
[16].

The paper industry generates waste paper sludge in huge quantities various experiments performed to use waste paper sludge ash instead of cement. Using such waste materials is beneficial in many aspects because it will save the least emission of hazardous gases in the atmosphere which in turn will make our environment pollution-free [17][18][19]. The various cementitious materials are also generated from industries such as fly ash. These wastes can also be incurred as cementitious material as they have a pozzolanic property and hydraulic activities the same as that of cement [20]. The qualities of waste paper sludge make it ideal for various construction activities like highways, and embankments [21]. Various researchers show that a huge quantity of waste paper sludge is generated all over the world [22][23]. In concrete, the additions of paper waste sludge ash increase the strength due to viscosity & have a sticky nature [24][25][26][27]. Vasudevan S, et.al performed their experiment using waste paper sludge in concrete and it was found that at 6% replacement there is an increment in compressive strength up to 20 percent[28]. Kubba HZ, et.al Performed their experiment on burned waste paper and non-burned waste and concludes that 2.5% of burned waste paper and 1% of non-burned waste paper is optimum [29]. Ahmad S, et.al also showed a 15% 15% increment in compressive strength within the sight of WPSA [30]. The objective of this study is to obtain the maximum value of compressive, tensile and flexural strength by substitution of fine aggregates and cement with QD and WPSP.

2. Experimental work of materials

Aggregates are the granular materials that bind with cement so as to form a concrete mix. Their properties depend on the internal structure and bonding with the minerals of which they are composed. So, for quality assurance and better results, their parameters have to be studied and experimentally calculated so as to maintain the quality, strength, and shelf life of any structure. The following tests are performed on aggregates in order to ensure strength and better quality output:

- Specific gravity
- Water absorption

- Elongation and Flakiness Index.

2.1 Aggregates

The vendor in Gharuan provided Crushed coarse aggregates, while fine aggregates were obtained from Chandigarh University's dumping yard, see table 1.

Table 1. Physical Properties of Aggregates.

S.NO	Property	Results
1	Specific gravity (S.G) of CA	2.68
2	Absorption of FA	0.7%
3	Specific gravity (S.G) of fine FA	2.49
4	Absorption of FA	1.48%

2.2 Cement

Shree cement was utilized in this study, and it was obtained from a dealer in Kharar. The cement grade employed in the research was OPC 43, see table 2.

Table 2. Physical Properties of Cement.

S.NO	Property	Result
1	SG of cement	3.10
3	Initial setting	55 minutes
4	Final setting	325 minutes
5	Fineness of cement	233 (m^2/kg)

2.3 Waste paper sludge powder (WPSP)

WPSP was gathered via AP Paper Mill Derabassi, Punjab. It was then sun-dried and at last, converted into powder form with the help of a grinder. It was then tested in the laboratory, see table 3.

Table 3. Physical properties of WPSP.

S.NO	Property	Results
1	SPG	2.3
2	Water absorption	1.5%
3	Fineness material	9.5

Table 4. Chemical composition of WPSP.

COMPOSITION	PERCENTAGE
Carbon	38-50
Lime	33-43
Silica	22-28
Oxygen	13-20
Alumina	11-19

Magnesia	1.8-3.4
Sulphur	0.6- 1.2

Figure 1. WPS before grinding

Figure 2. WPS after grinding

2.4 Quarry Dust

The Quarry dust was obtained from the stone crusher and was tested in the laboratory before being used, see table 5.

Table 5. Physical properties of QD.

S.NO	PROPERTY	Result
1.	S.G of stone dust	2.52
2.	Absorption of stone dust	0.49%

3. Methodology

3.1. Mix Design

The Mix configuration was performed according to IS 10262(2009). M25 grade of concrete was used in this research. The mix ratio is prepared for 1:1.68:2.95. Water-cement ratio 0.50 was adopted as IS456:2000. Concrete mixes were arranged by supplanting cement with Waste Paper Sludge Powder individually and in combination with different %'s of QD as a substitution for fine aggregates.

3.2. Mix proportion

Table 6. Mix proportion.

Type	Cement (%)	FA (%)	CA (%)	PSP (%)	SD (%)
(control)	100	100	100	-	-
OS1	99.2	100	100	0.8	-
OS2	98.7	100	100	1.3	-
OS3	97.7	100	100	2.3	-
OS4	96.7	100	100	3.3	-
OS5	(100-OPT)	84	100	OPT	16
OS6	(100-OPT)	74	100	OPT	26
OS7	(100-OPT)	64	100	OPT	36
OS8	(100-OPT)	54	100	OPT	46

3.3. Batching and mixing

In this experimental work, manual batching and hand mixing is done. The aggregates are laid uniformly and then cement is spread over the aggregates and the dry material are mixed by rotating heap from one side to another and cutting with the shovel when it is properly mixed

Figure 3. Mixing of concrete.

3.4. Casting of specimen 3.4.1 Compressive strength.

For this cube of cell dimension 150*150*150mm are used for the compressive strength test. An automatic vibrating machine was used to remove air voids. At 7, 14, and 28 days, the cubes were cured and an average of three cubes were examined on a compressive testing machine. Cubes were tested as per IS 516-1959.

3.4.2 Split Tensile strength.

It is an aberrant technique for testing elasticity of concrete. For this Cylindrical moulds of sizes 150mm in diameter and 300mm in height are used for the test. The cylindrical moulds were cured at 7, 14, and 28 days of age. Three moulds were examined as per IS 5162-1959 and the average of three were evaluated.

3.4.3. Flexural Strength.

To determine flexural modulus of a material, flexural test are by and large considered. This test is liked as

more reasonable than a pliable test and the outcome got are somewhat unique. A beam of size 500,*100,*100, mm is used for the test. After 24 hours duration of casting the beams are then drawn out and cured in water following 7, 14, and 28 day's duration. A minimum of three beams were tested as per IS 516-1959 and the average of three was assessed.

4. Results and Discussion

4.1 Concrete containing Waste Paper Sludge Powder (WPSP)

4.1.1 Compressive Strength Test.

On making a concrete, containing waste paper sludge powder the percentage results for compressive strength are clearly variable which are presented in Table 7. The outcome exhibited that supplanting 1.3% of waste paper sludge powder expands the compressive strength by 19%, 9%, and 12% following 7, 14, 28 days when contrasted with the control mix. However, higher substitution levels decrease the strength, see figure 4.

Table 7. Compressive strength of concrete containing WPSP.

Waste Paper Sludge Powder %	Compressive Strength (N/mm^2)		
	7 days	14 days	28 days
0	18.28	25.56	28
0.8%	19.31	26.87	29.7
1.3%	21.8	28.06	31.46
2.3%	17.83	23.80	26.4
3.3%	14.5	18.46	21.92

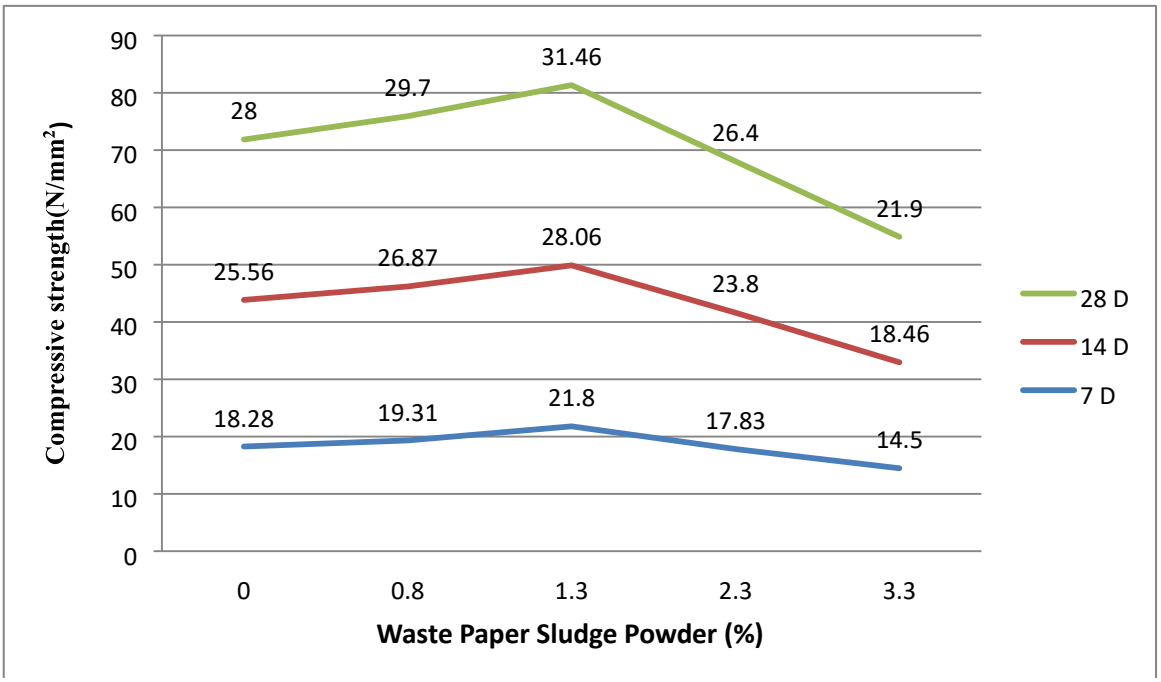

Figure 4. The disparity of Compressive strength with the inclusion of waste paper sludge powder.

4.1.2 Flexural and split Tensile Strength Test.

On making a concrete, containing waste paper sludge powder the results for Flexural strength are clearly variable which are presented in table 8. The result demonstrated that replacing 1.3% of waste paper sludge powder also increases the Flexural strength by 16%, 17%, and 15 % following 7, 14, and 28 days when contrasted with the control mix. However, higher substitution levels greater than 1.3% decrease the flexural strength. See fig 5. Split Tensile strength is also increased at 1.3% by 13%, 8%, and 14% after 7, 14, and 28 days strength when contrasted with the control blend, see figure 6.

Table 8. Flexural & Split Tensile test results of concrete containing WPSP.

Waste Paper Sludge Powder %	Flexural Strength (N/mm²)			Tensile Strength (N/mm²)		
	7 days	14 days	28 days	7 days	14 days	28 days
0	2.93	3.46	4.26	2.05	2.27	2.51
0.8%	3	3.8	4.53	2.15	2.31	2.57
1.3%	3.4	4.06	4.93	2.32	2.44	2.84
2.3%	2.73	3.26	3.39	1.67	2.1	2.35
3.3%	1.66	2.1	3	1	1.25	1.64

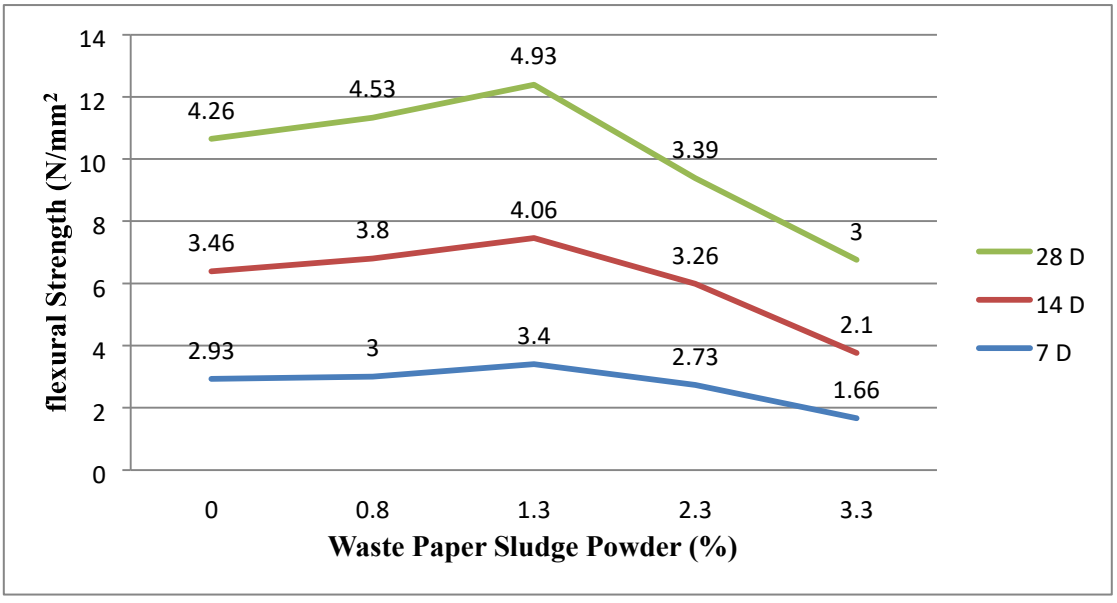

Figure 5. The disparity of Flexural. Strength of concrete containing WPSP

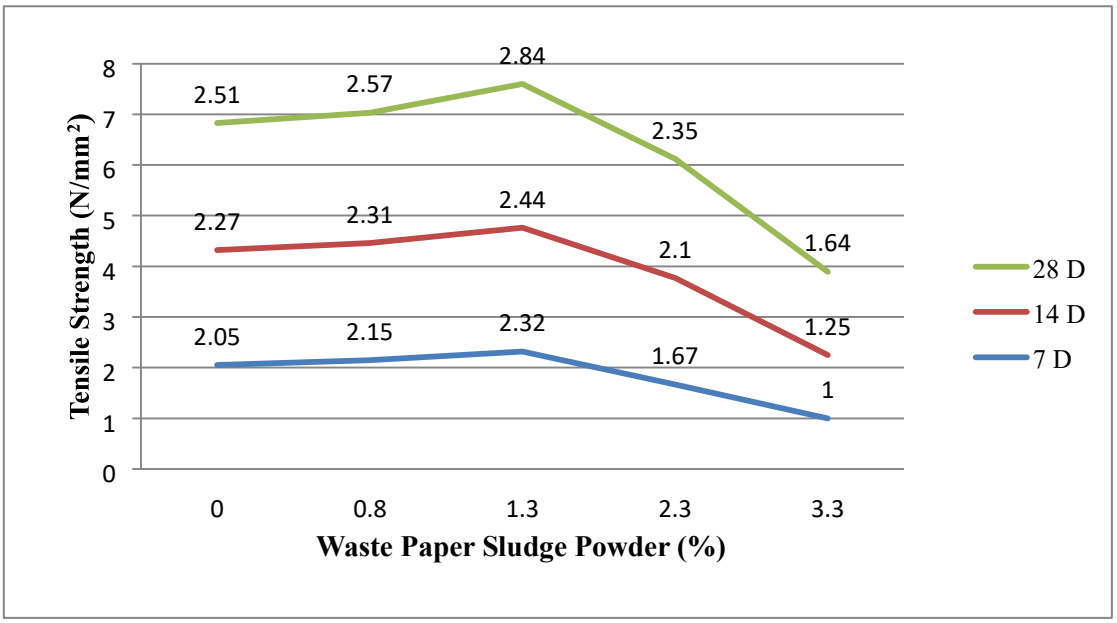

Figure 6. The disparity of Tensile. strength of concrete containing WPSP

4.2 Concrete containing Waste Paper Sludge Powder (WPSP) and Quarry Dust (QD).

4.2.1 Compressive Strength Test.

On making a concrete, containing 1.3% of waste paper sludge powder and various percentages of Quarry dust the results for compressive strength are clearly variable which are presented in Table 9.

The result demonstrated that replacing 1.3% of waste paper sludge powder and 36% of Quarry Dust increases the compressive strength by 26%, 25%, and 24% following 7, 14and 28 days when contrasted with the control mix. However, higher substitution levels decrease the strength, see figure 7.

Table 9. Compressive strength of concrete containing WPSP and Quarry Dust.

Waste Paper Sludge Powder %	Quarry Dust %	Compressive Strength (N/mm²)		
		7 days	14 days	28 days
0	0	18.28	25.56	28
1.3%	16%	21.53	28.35	31.59
1.3%	26%	21.90	30.08	33.22
1.3%	36%	23.14	32.18	34.60
1.3%	46%	17.39	24.51	27.4

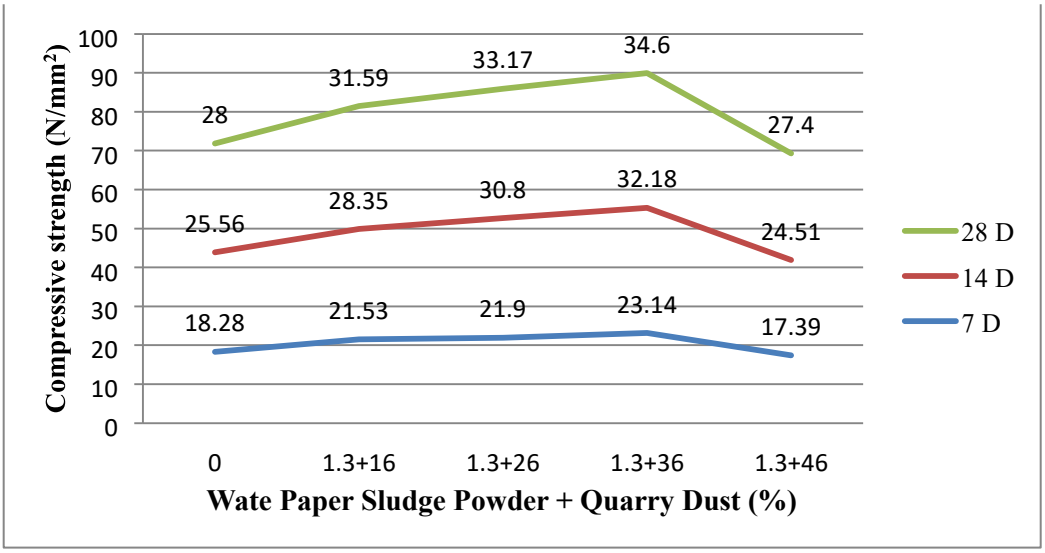

Figure 7. The disparity of Compressive. Strength of concrete containing WPSP and QD in combination.

4.2.2 Flexural and Split Tensile Strength Test.

On making a concrete, containing 1.3% waste paper sludge powder and various percentages of Quarry dust the results for Flexural strength are clearly variable which are presented in Table 10. The result demonstrated that replacing 1.3% of waste paper sludge powder and 36% of Quarry Dust increases the Flexural strength by 33%, 34%, and 24% following 7, 14, and 28 days when contrasted with the control mix. However, higher substitution levels decrease the strength. See figure 8. Split tensile strength also increased at 1.3% swapping of cement with WPSP and 36% of fine aggregates with QD by 24%, 21%, and 29% at 7, 14, and 28 days of age, see figure 9.

Table 10. Flexural and Split Tensile test results containing WPSP and Quarry Dust.

Waste Paper Sludge Powder %	Quarry Dust %	Flexural Strength F.S(N/mm²)			Tensile Strength T.S (N/mm²)		
		7 days	14 days	28 days	7 days	14 days	28 days
0	0	2.93	3.46	4.26	2.05	2.27	2.51
1.3%	16%	3.33	4	4.93	2.34	2.51	2.86
1.3%	26%	3.73	4.4	5.06	2.43	2.69	2.99
1.3%	36%	3.90	4.64	5.26	2.56	2.75	3.25
1.3%	46%	2.8	3.33	4.2	2.27	2.54	2.85

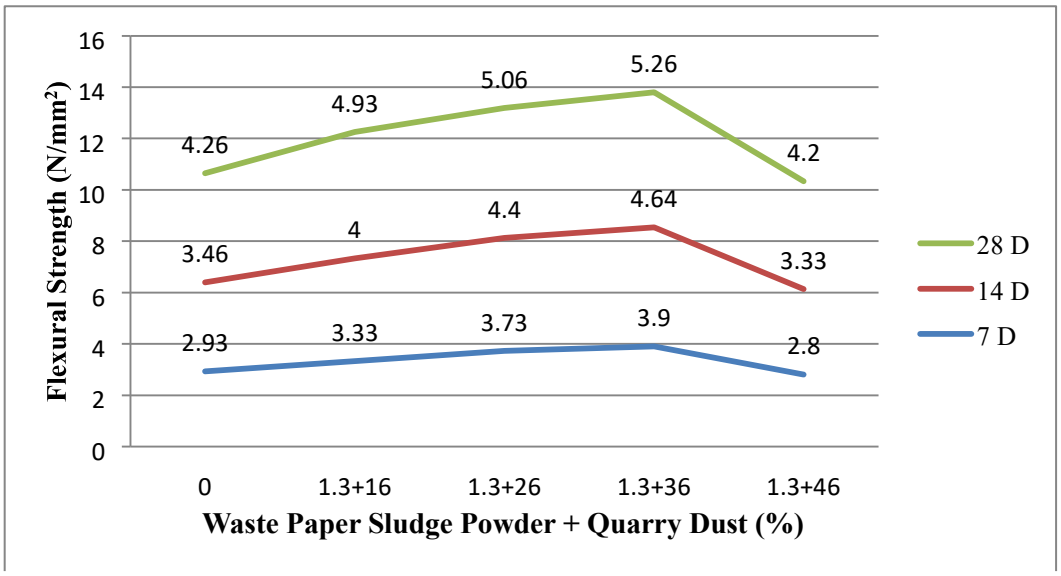

Figure 8. The disparity of Flexural. strength of concrete containing WPSP and QD in combination.

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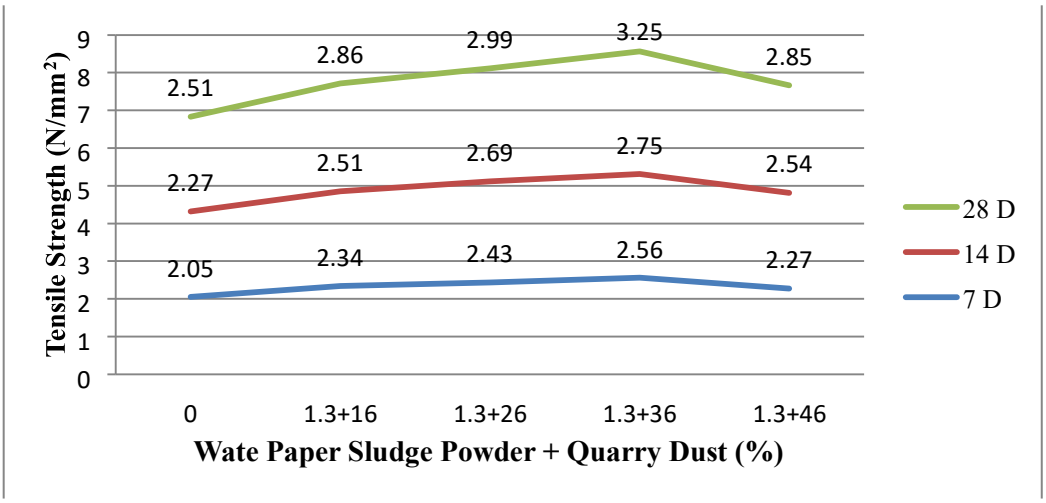

Figure 9. The disparity of Tensile. Strength of concrete containing WPSP and QD in combination.

5. Conclusion

This study scrutinizes the impact of WPSP and Quarry dust in concrete which are the wastes generated from the paper mill and crushing of stones. Waste paper powder content is varied by 0%, 0.8%, 1.3%, 2.3%, and 3.3% of weight of cement and stone dust by 0%, 16%, 26%, 36%, and 46% of weight of fine aggregates. The reason for this study is to attain the potential of using quarry dust and waste paper sludge ash for improving the strength of concrete.

1. When 1.3 percent of the cement in the concrete blend is substituted with WPSP, it was gathered that the compressive strength(CS) of the concrete rises by up to 12 percent following 28 days of age. However, the strength is decreased when the substitution level surpasses 1.3 percent.
2. The split tensile strength is 14.5 percent higher, while the flexural strength is 15% higher at a 1.3% substitution level following 28 days of age when contrasted with the control blend.
3. Concurrently utilization of Quarry dust and Wastepaper sludge powder showed an improvement in compressive strength(CS) up to 24% at 28 days of age for 1.3% waste paper sludge powder and 36%

quarry dust combination. Whereas at the 46% substitution level the compressive strength is near equal to the control blend.

4. Split & flexural strength also increased by 28 days age by 29% and 24% respectively at 1.3% substitution of cement with WPSP and 36% of fine agg with Quarry Dust when contrasted with the control blend. Whereas at the 46% substitution level the tensile strength is increased by 13% when contrasted with the control blend.
5. Based on the above outcomes, it was presumed that supplanting 1.3% cement with WPSP and 36% of fine aggregates with Quarry dust yields superior outcomes.
6. The use of Waste Paper Sludge Powder and Quarry Dust in concrete is the best alternative material and also helps to preserve natural resources.
7. By using these waste materials in concrete we can minimize environmental problems like waste disposal.
8. The reason for the increased strength of concrete can be, the decreased voids by the use of waste paper fibers which inturn increases bonding linkage and hence can become the reason for improved concrete strength

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