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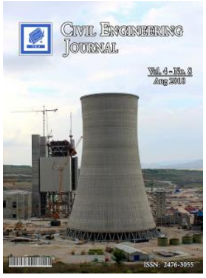

Mechanical Properties of Concrete Containing River Indus Sand and Recyclable Concrete Aggregate

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Abstract

In Pakistan construction Industry, concrete construction is cheaper than the other construction methods with respect to that construction materials demand rises. The 75% volume of total concrete fill with aggregate which contributes to decrease the natural aggregate resources day by day. The best solution for this problem is to utilize River Indus sand and recyclable concrete aggregate as fine and coarse aggregate respectively. In this research the River Indus sand and recyclable coarse aggregate were fully replaced with normal aggregates. The aim of this study was to examine the flexural and tensile performance of concrete containing the River Indus sand and recyclable concrete aggregate. The physical properties were also examined which include the sieve analysis and chemical composition of River Indus sand. The M15, M20 and M25 grade were analyzed at 7, 14, 21 and 28 days water curing. The results define that, flexural strength was reduced from 5% to 15% compared to normal aggregate whereas tensile was decreased from 1% to 1.8% at 28 days water curing.

Keywords: Flexural Strength; Tensile Strength; River Indus Sand; Recyclable Concrete Aggregate; Sieve Analysis.

1. Introduction

Concrete is one of the most utilized building material in construction industry due to its durability, accessibility and economy [1]. Basically, Cement, aggregates and water are the main ingredients of concrete but admixtures are used to get special properties [2-3]. Aggregates are considered as an important ingredient, which occupies 70% to 80% of concrete volume. Fine aggregate is utilized to fill the gaps between the coarse aggregate and made the concrete strong. The composition, shape, and size of the fine aggregate has great influence on the fresh and hardened properties of concrete [4]. Whereas coarse aggregate possessed the almost 50% volume of concrete. Coarse aggregates have great impact on the workability and strength of concrete [5-6]. In Pakistan normally hill sand is preferred as fine aggregate because it gives high packing between the ingredients of concrete, high density and improve the porosity of concrete [7-8]. The crushed stone is utilized as coarse aggregate in concrete. The utilization of hill sand and crushed stone as coarse aggregate in ample amount which reduces the natural resources day by day, in northern area of Sindh the hill sand is not available because of that its export from the natural pit aggregate areas which made the concrete un economical and In River Indus siltation problem is increasing day by day which resist the flow of water and wastages of water increases [6]. To overcome this problem, River Indus sand (RIS) and Recyclable Coarse Aggregate (RCA) were preferable to

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save the natural resources, reduces the utilization of hill sand which make the concrete uneconomical, solve the siltation problem occurred by river sand, resistance to flow of water reduces and saves energy. In this study, hill sand and normal coarse aggregate were fully replaced by RIS and RCA which moves towards the sustainability, where natural resources are save by inculpating the RIS and RCA to make the innovative sustainable concrete and to analyze the behavior of concrete in flexural and tensile strength. The experimental work which was carried out includes, sieve analysis of both sand (hill and River Indus sand), X-ray fluorescence test (XRF) of River Indus sand, flexural and tensile strength of concrete were analyzed and compare the outcomes with conventional concrete.

2. Literature Review

Dsouza [9] examined the compressive strength of M25 grade concrete using different proportions 10%, 20%, 30%, 40% and 50% fine aggregate replaced with foundry sand. The outcomes demonstrated the 30% replacement was optimum and gave the maximum compressive strength of concrete. Amrutha [10] conducted the experimental work to examine the workability and strength (compressive, split tensile strength and flexural strength) of concrete at 10%, 20%, 30%, 40%, and 50% partially replacement of foundry sand to natural sand. The results showed that the workability of 30 % replacement of fine aggregate was adequate and the strength performance was better than all proportion. Bhimani also [11] analyzed the strength (compressive, split tensile strength and flexural strength) of concrete while utilizing the foundry sand as fine aggregate replacement. The different proportions 0, 15, 25 and 35% were adopted. The results showed that the 25% replacement of foundry sand gave the maximum strength compared to other proportions. Based on the above researches, in this research the River Indus sand utilized as fine aggregate replacement. Whereas Fan [12] analyzed the physical, chemical, compressive and flexural strength of concrete containing the recyclable coarse aggregate as partially replacement with natural coarse aggregate at various percentages 0%, 35%, 50% and 65%. The outcomes define that the recyclable coarse aggregate have less specific gravity, high water absorption compared natural aggregate. The compressive and flexural strength was reduced up to 35% compared to control sample. And Yap [13] examined the compressive, surface properties and permeability of concrete at various replacement percentages 20%, 40%, 60%, 80% and 100% with natural aggregate. The results demonstrate that compressive strength was lower compared to control sample the permeability was great when RCA used in concrete compared to normal concrete. The greenhouse gases examination also defines that the CO_2 emission of this 100% RCA mix is 24% lower than the control mix. Based on the above previous research, it was concluded that River Indus sand and recyclable concrete aggregate could be adopted as fine and coarse aggregate in concrete respectively which will be responsible to save the natural resources and protect the environment from construction waste whereas utilization of River Indus sand the siltation problems in River will be solved.

3. Research Materials and Methods

3.1. Methods

Ordinary Portland cement CEM I 42.5 N that observes with ASTM C0150-04AE01, registered name as Thatta cement was chose for this study. In this study, hill sand and River Indus sand are utilized as fine aggregate. The Fineness modulus of hill sand was 3.01 and water absorption was 1.2%. The Fineness modulus of river Indus sand was 3.16 and water absorption was 1.9%. The Fineness modulus of coarse aggregate was 3.16 and water absorption was 1.9% and fineness modulus of recyclable coarse aggregate was 3.09 and water absorption was 1.68. The sieve analysis was performed according to the ASTM C136 / C136M–14 [14]. The sieve analysis of hill sand and river Indus sand is shown in Table1and 2, Figure 1 and 2. The X-ray fluorescence test (XRF) of River Indus Sand was conducted according to ASTM E1621–13 [15], the results are shown in Table 3.

Table 1. Sieve analysis of hill sand (Sample taken = 4000 gm)

Sieve Size (mm)	Mass Retained (g)	Mass Retained (%)	Cumulative Passing (%)	Passing Limits [13]
4.75	200	5	95	95-100
2.36	550	13.75	81.25	80-100
1.18	600	15	66.25	50-85
600 µm	950	23.75	42.5	25-60
300 µm	1300	32.5	10	5-30
150 µm	250	6.25	3.75	0-10
PAN	150	3.75	0	--

Table 2. Sieve analysis of River Indus sand (Sample taken = 4000gm)

Sieve Size (mm)	Mass Retained (g)	Mass Retained (%)	Cumulative Passing (%)	Passing Limits [13]
4.75	15	0.5	99.5	95-100
2.36	30	1.0	98.5	80-100
1.18	150	5	93.5	50-85
600 µm	780	26	67.5	25-60
300 µm	1050	35	32.5	5-30
150 µm	840	28	4.5	0-10
PAN	135	4.5	0	--

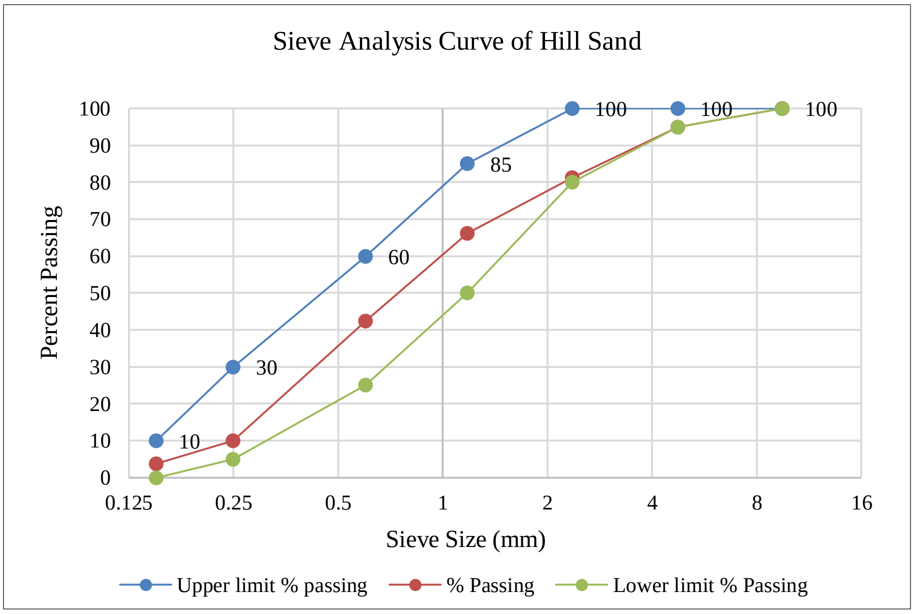

Figure 1. Sieve Analysis of Hill sand

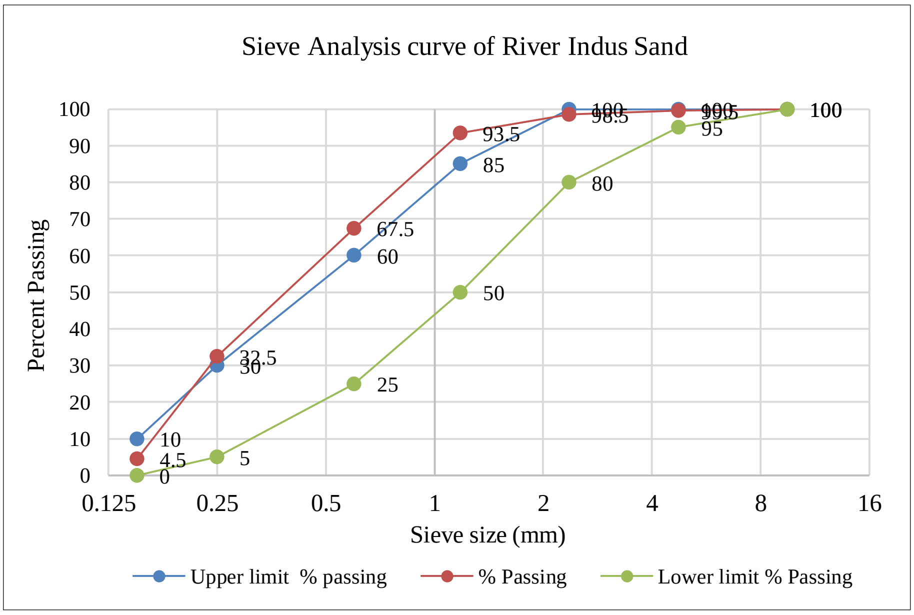

Figure 2. Sieve Analysis of River Indus sand

The sieve analysis results demonstrated that hill sand was well graded while the RIS was poorly graded because it contains the smaller size particles.

Table 3. Chemical composition of River Indus Sand [15]

Element Present	Percentage (%)
Alumina	13.86
Silica	79.98
Potassium and Sodium	1.67
Calcium	0.87
Titanium	0.15
Iron	1.89
Manganese	1.44
LOI	0.31

The chemical composition results describe that the RIS contain great amount of alumina which shows that in RIS possesses the clay particles.

3.2. Test Parameters and Mixture Proportions

The M10, M15 and M20 grade concrete mixtures were analyzed for flexural and tensile strength of concrete the outcomes were compared between conventional concrete and RIS and RCA concrete. The 150 × 150 × 1000 mm dimension beams were used and 150 mm diameter, 300 height cylinder were used for flexural and tensile strength of concrete respectively. The beams and cylinders were tested for the flexural and tensile strength of concrete at the curing regimes of 7, 14, 21, 28 days. The experimental setup for analyzing flexural and tensile strength, the failure pattern is shown in Figure 3. Rotary mixer was used for mixing. Flexural strength of the concrete was carried by three-point load method utilizing Universal Testing Machine and used the overall procedure defined in ASTM C78/c78 M -16 [16] and for tensile strength ASTM C496/c496M-17 [17].

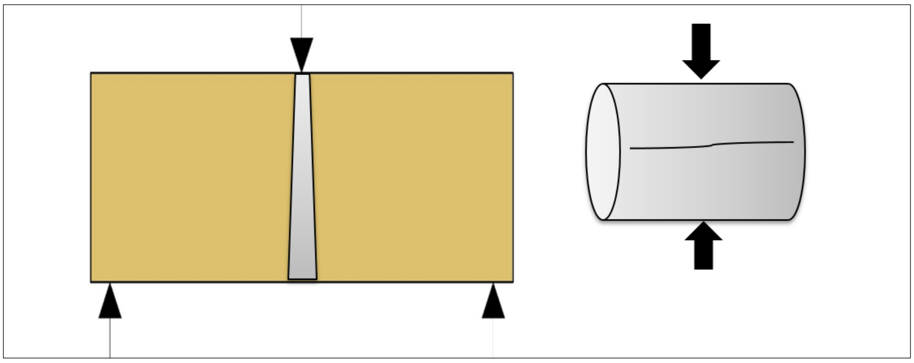

Figure 3. Experimental setup and failure profile for Flexural and tensile strength test of beams and cylinders

4. Results and Discussions

4.1. Flexural Strength

The flexural Strength outcomes of both concrete is shown in Table 4, Figure 3, 4 and 5. The outcomes demonstrated that there was reduction in the flexural strength of RIS and RCA concrete because of improper binding between the materials, due clay particles present in the River Indus sand and RCA have less crushing strength compared to the normal aggregate. From Table 4 it is seen that the RIS and RCA M25 grade concrete shows the better performance of concrete compared to the other mix proportions.

Table 4. Flexural strength of M15, M20 and M25 grade concrete

Mixture	Flexural Strength (MPa)			
	7Days	14 Days	21 Days	28 Days
Control Sample (M15)	1.80	2.52	2.85	2.90
RIS & RCA Concrete (M15)	1.17	1.85	2.22	2.47
Control Sample (M20)	2.32	3.03	3.42	3.51
RIS & RCA Concrete (M20)	1.80	2.28	2.74	3.10
Control Sample (M25)	2.62	3.43	3.72	4.10
RIS & RCA Concrete (M25)	2.24	2.96	3.28	3.85

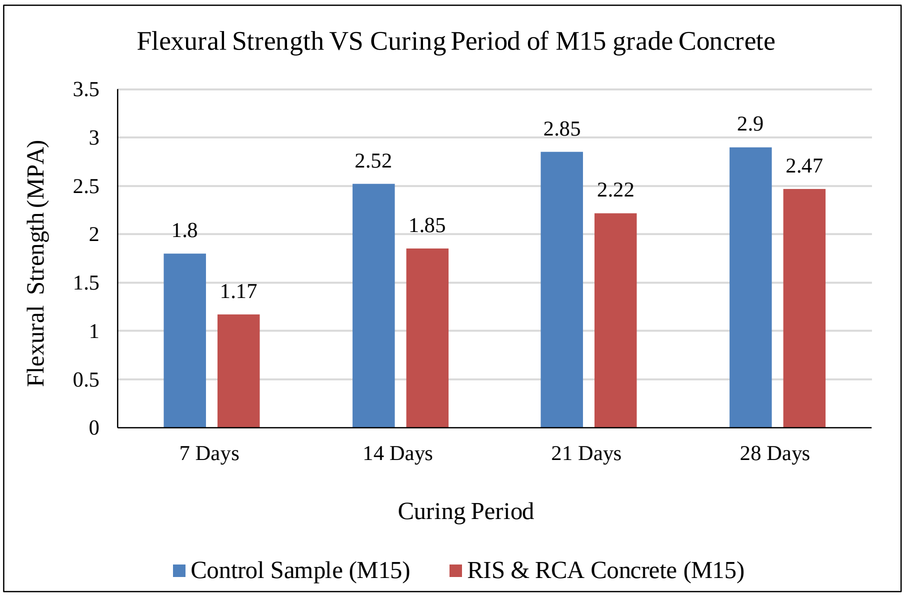

Figure 3. Flexural Strength VS curing period of M15 grade concrete

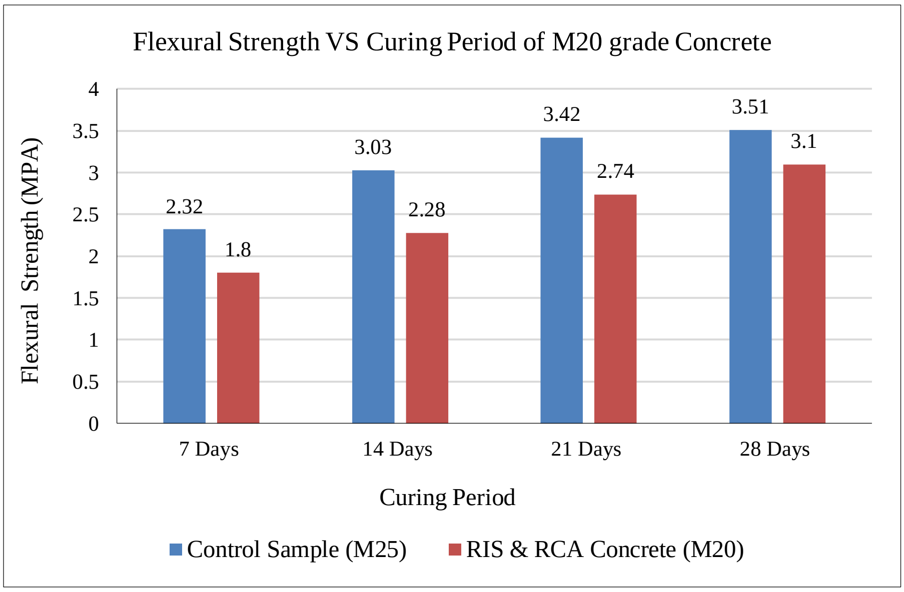

Figure 4. **Flexural Strength VS curing period of M20 grade concrete**

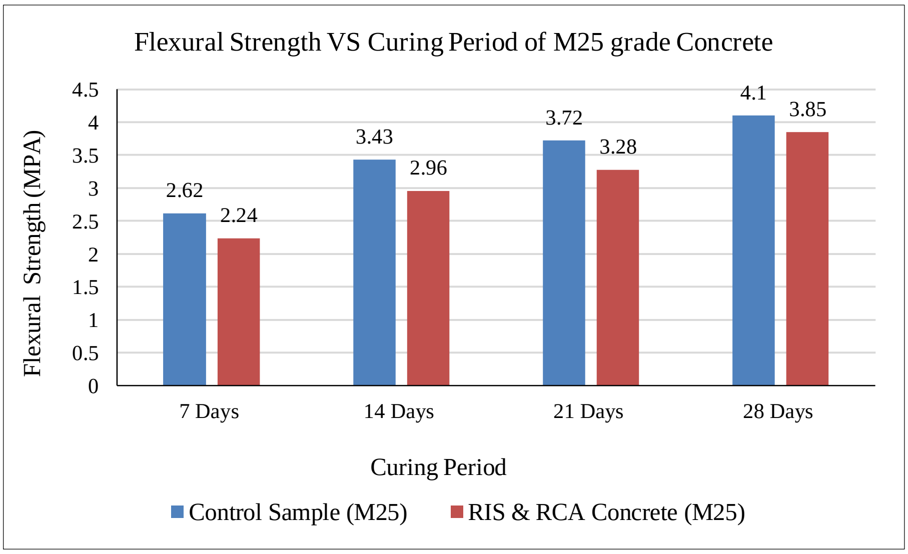

Figure 5. Flexural Strength VS curing period of M25 grade concrete

At the 7 days water curing, the M15, M20 and M25 R.I.S and R.C.A grade concrete's flexural strength was reduced by 53.80%, 28.80% and 16.90%, respectively. At the 14 days water curing, the M15, M20 and M25 R.I.S and R.C.A grade concrete's flexural strength was reduced by 40.12%, 32% and 15.87%, respectively. At the 21 days water curing, the M15, M20 and M25 R.I.S and R.C.A grade concrete's flexural strength was reduced by 28.37%, 24.53% and 13.41%, respectively. At the 28 days water curing, the M15, M20 and M25 R.I.S and R.C.A grade concrete's flexural strength was reduced by 17.40%, 13.22% and 6.49%, respectively.

4.2. Tensile Strength

The tensile strength performance of both concrete is shown in Table 5, Figure 6, 7 and 8. The results describe that there was decrement in the tensile strength of RIS and RCA concrete because of more clay particles available in River Indus sand due to that the bonding between particles was improper.

Table 5. Tensile strength of M15, M20 and M25 grade concrete

Mixture	Tensile Strength (MPa)			
	7 Days	14 Days	21 Days	28 Days
Control Sample (M15)	1.84	2.10	2.18	2.23
RIS & RCA Concrete (M15)	1.58	1.98	2.12	2.14
Control Sample (M20)	2.10	2.28	2.37	2.41
RIS & RCA Concrete (M20)	1.96	2.20	2.33	2.38
Control Sample (M25)	2.35	2.59	2.67	2.80
RIS & RCA Concrete (M25)	2.22	2.53	2.63	2.77

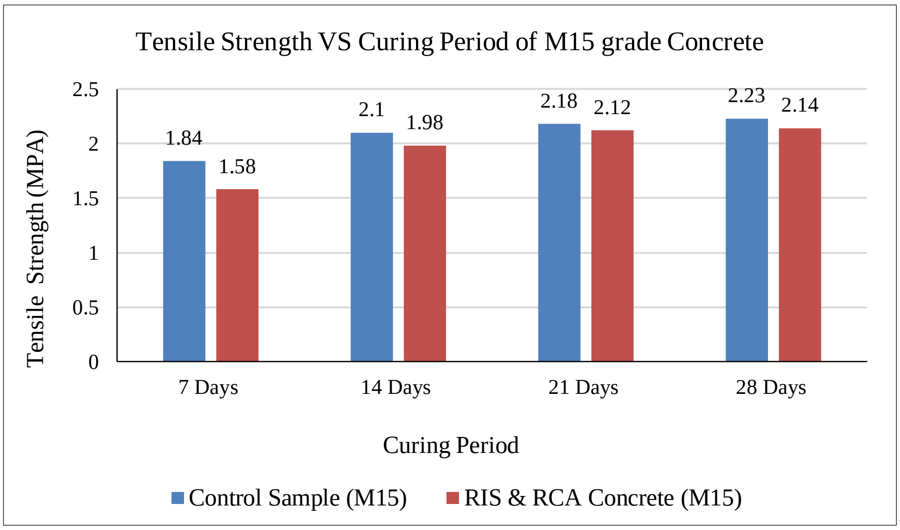

Figure 6. Tensile Strength VS curing period of M15 grade concrete

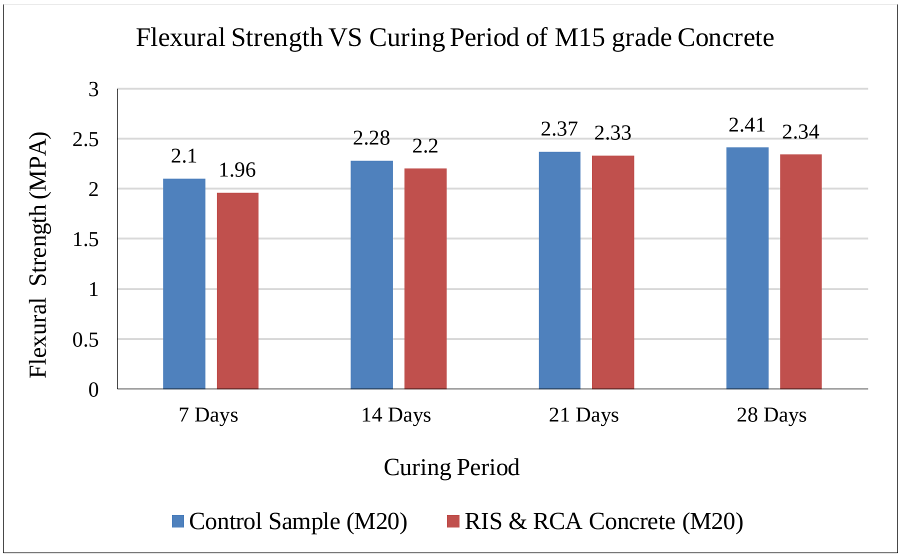

Figure 7. Tensile Strength VS curing period of M20 grade concrete

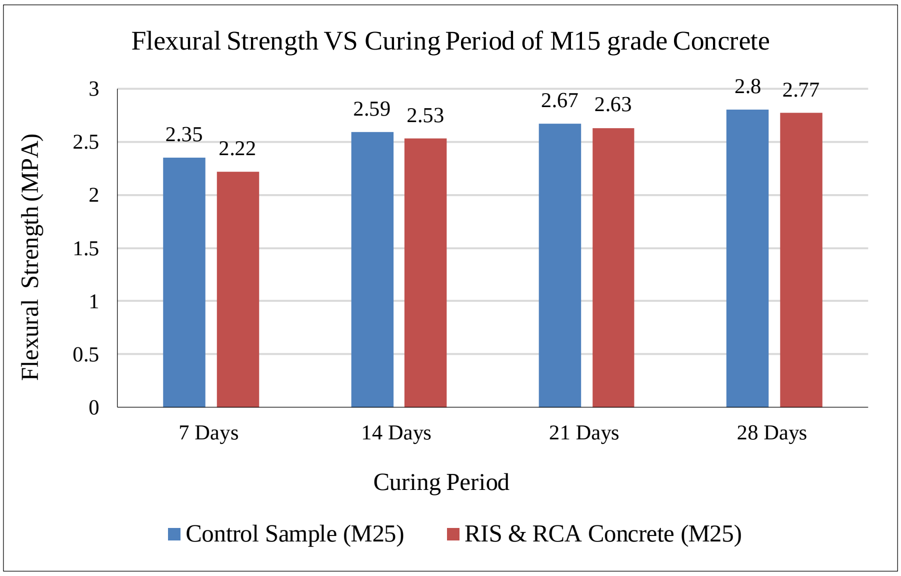

Figure 8. Tensile Strength VS curing period of M25 grade concrete

At the 7 days curing, the tensile strength of M15, M20 and M25 River Indus sand grade concrete decreased by 14%, 6.66% and 5.40%, respectively. At 14 days water curing, the tensile strength of M15, M20 and M25 River Indus sand grade concrete decreased by 5.70%, 3.50% and 2.31% respectively. At 21 days water curing, the tensile strength of M15, M20 and M25 River Indus sand grade concrete decreased by 2.75%, 1.68% and 1.20%, respectively. At 28 days water curing, the tensile strength of M15, M20 and M25 River Indus sand grade concrete decreased by 1.79%, 1.20% and 0.92%, respectively.

5. Conclusions

From the research, it is concluded that:

- The sieve analysis of RIS and hill sand was in the range of ASTM C136 standard.
- The chemical composition of RIS described that it contains more clayey particles.
- The flexural strength of RIS and RCA concrete 5% to 17% lesser as compared to flexural strength of conventional concrete because the interlocking between the particles of concrete was not good in context of conventional concrete.
- The tensile strength of RIS and RCA concrete 0.9% to 1.80% minimum then the conventional concrete.
- Hence, the results demonstrate that the flexural and tensile strength were lesser then the conventional concrete because the RIS contain the more clayey particles which reduced the bonding strength of cement between the particles but it can be utilized in low strength structures. The big reason for reduced in strength is that the addition of RCA and RIS made the concrete more brittle.

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