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ORIGINAL CONTRIBUTION

Synergic Influence of River Gravels and Crushed Aggregates on the Mechanical Properties of Concrete

Arif Usman [1*], Muhammad Haris Javed [2], Farhan Abbas[3], Faraz Ali Channa [4], Sami Ullah [5]

[1]CECOS University of IT and Emerging Sciences, Peshawar, Pakistan

[2] Missouri University of Science and Technology, Rolla, USA

[3] Bahauddin Zakariya University, Multan, Pakistan

[4]Swedish College of Engineering & Technology, Rahim Yar Khan, Pakistan

[5] Mirpur University of Science and Technology, Mirpur, Pakistan

***Abstract*— The study aims to replace crushed aggregate with river gravel and analyze the results of both the concrete, and compare them with each other. From the comparison, it was found that the workability of concrete was high about 19% when river gravel was used in concrete and was low when crushed aggregate was used in concrete. On the other side, the combination of both Quarry and river gravel was found to be 36% less workable than river gravel. This was because of the crushed used with river gravel crush aggregate has a greater surface and diamond cut. Comparing the Compressive strength of Quarry, gravel, and the combination of both it was observed that on average Quarry and Gravel combination concrete was 20 % stronger than concrete with quarry crushed used as aggregate and 10 % stronger than river gravel. The river gravel can be used as aggregate in concrete in a lighter structure or foundation to provide a hard and level surface.**

***Index Terms*— Concrete, Aggregate, Compressive strength, River gravel**

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I. INTRODUCTION

The use of concrete greatly increased in the last few decades, after which the demand for constituents that are used in concrete has also increased. To fulfill this demand for material which is needed more sourcing is required [1]. One of the key components is a coarse aggregate for which if demand is high quarrying speed must be increased. Which has many adverse effects such as the impact on the environment, as it blasting of rocks causes air pollution and noise pollution, it also causes harm to wildlife and its main problem is that we are using natural resources that have an end but it must be saved for the future generations so, they can utilize them in their development [2, 3]. Other than that an alternative to Quarry crush must be searched if in some areas there is no such source of Quarry crush one can use an alternative in concrete [4]. Concrete is a mix of cement, fine aggregate, coarse aggregate, water, and other admixtures it can also be said that concrete is the composition of binding material, filler material, and aggregates embedded in them [5]. The positive side of concrete is that it is good in compression, durable, economical, good in fire resistance and its maintenance is easy to compare to other construction materials [6]. As concrete is made up of a combination of constituents, its properties also largely depend upon the properties of constituents used in it, if coarse aggregate is used in concrete is less tough so the hardness of concrete would be lesser as coarse aggregate gives strength to concrete [7, 8]. So, the alternative that is going to be used against coarse aggregate, its properties must be matchable to that of coarse aggregate [9]. Natural aggregate from the quarries which is also called crushed aggregates, as they are natural resources and they have a limit and it is also causing environmental problems such as air pollution, noise pollution, etc. [10]. So, there must be an alternative to crushed aggregates in the future using our studies alternate to the crushed aggregates used in concrete [11]. On this account river gravel after sieved according to ASTM standards is the best alternative as they are available in abundance and can be sourced cheaply.

The effect of river gravel on the flexural strength of concrete materials was taken into account in this study. According to the findings, the regression model expectation for the concrete made of washed gravel has a correlation coefficient of 0.92687 and a sum of squares error of 0.51954100. In contrast, the expectation of the neural network model has a sum of squares error of 0.00629630 and a correlation value of 0.98364. All the models predicted the data rather well, however the neural network model performed better than the regression model. In comparison to the experimental technique for concrete strength assurance, the research's findings have successfully demonstrated a low-cost, straightforward, quick, and accurate substitute. Compared to analytical procedures that rely on regression analysis, the process is simpler and quicker. The results obtained point to a financially advantageous option for civil engineers and other construction industry specialists, who would assist in determining the strength

*Corresponding author:Arif Usman
†Email: engrarifbannu@gmail.com

and cost-effective selection of an appropriate mixture of building materials [12]. Verifying the suitability of gravel aggregates acquired locally is the study's main objective. This study assesses the strength characteristics of concrete made using two locally obtained rock aggregates, with maximum sizes of 10 mm and 20 mm, from the rivers. Three gravel specimens were taken, and they were used for the testing after being separated into washed and unwashed gravel. The study's goal was a concrete mix design of 25 N/mm2 at 28 days. The specimens underwent tests for particle size distribution, specific gravity, water absorption, aggregate crushing value, flakiness and elongation, slump, and compressive strength. For every rock size, 150 mm concrete cubes were cast, and three samples were examined for compressive strength at 3, 7, 14, 21, and 28 days. They found that the intended mean strength of 26.2 N/mm2 and 29.7 N/mm2 was reached, respectively, by the washed gravel with the greatest sizes of 10 mm and 20 mm. Similarly, after 28 days, the unwashed rock with a typical size of 20 mm produced a compressive strength of 24.5 N/mm2 [13]. This research is meant to find the ideal choice of aggregate type and transport situation in concrete production, utilizing a multi-criteria enhancement strategy to consider economic, environmental, and technical constraints. A few concrete kinds with various aggregate types and distinctive vehicle transportation circumstances were studied. As per the Life Cycle Assessment strategy, the environmental system assessment measures were chosen. They performed for various dynamic situations that stressed different guidelines. The best approach, according to the results, is to introduce concrete that has 50% of its coarse aggregate replaced with recycled concrete aggregate (RCA). This type of concrete demonstrates just 6% less strength than regular concrete. Since river aggregate-made natural aggregate concrete was shown to have the lowest cost, more research was done to determine what financial steps should be taken to achieve cost parity between reused and natural aggregate concrete [14]. The goal of the study was to identify the models of Ultra-High-Performance Concrete's 7, 14, and 28-day compressive strength, 28-day split tensile strength, modulus of rupture, and flexural toughness. It also aimed to explore the connections and relationships between five different factors: silica fume (S.F.), cement, steel bars, super plasticizer, and w/c ratio. Based on sand weight, the models are applicable to mixtures including 1.0 part sand, 0.15-0.30 part silica fume, 0.70-1.30 part cement, 0.10-0.20 part steel fibre, 0.04-0.08 part super plasticiser, and 0.18-0.32 water cementitious material proportion. The effects of quartz sand (Qs), quartz powder (Qp), and various water curing temperatures on UHPC execution were investigated in stage two. It was discovered that these elements and mechanical qualities were related. The provided models make sense for the following parameters: water curing temperature of 25 to 95 ºC; quartz sand replacement range of 0 to 50%; and quartz powder replacement range of 0 to 20% of cement replacement. The research was planned using face-centered central composition with α=1 [15].

In order to demonstrate the viability of using river gravel in place of crushed aggregates to produce high strength Steel Fiber-River Gravel-Self Compacting Concrete (SFRGSCC), a comprehensive experimental programme was conducted. The findings of this programme are reported in this study. Compared to crushed aggregates, river gravels have distinct inherent properties, such as a greater density and elastic modulus, rounder forms with a smoother surface, and weaker behaviour. Thus, they can substantially affect the mechanical and rheological characteristics of fiber-reinforced concrete (SFRGSCC) and self-compacting concrete matrices (RGSCC) when they are in a cement-based matrix. The results demonstrate how surface roughness and the form of the river gravel aggregate impact how the concrete appears. They focus on the rheology of concrete, increasing its workability and decreasing the associated yield stress and trapped air [16]. In this study, the impact of locally obtained natural stone from the river on the properties of concrete was examined, and the results were compared with those of crushed stone. They were both purchased locally. In the Materials Testing Laboratory Tugu Dam Construction Project, Kab, Trenggalek, tests were conducted on concrete mixes using coarse aggregates from Kalitelu Crusher, Gondang, Tulungagung, and natural stone (river gravel) from the Brantas River, Ngujang, Tulungagung, in order to gather data on this based on the findings of a concrete strength test using coarse material purchased at 19.47 Mpa. During the test, the mixture of crushed stone and concrete had a compressive strength of 21.12 Mpa. [17].

To counter these problems, river gravel can be used to replace coarse aggregates and has the same or almost the same properties as coarse aggregate and has less or no bad impact on the environment. The following are the objectives of this research:

- To determine the effect of river gravel and crushed stone aggregate on both fresh and hardened concrete.
- To determine the suitability of natural gravel aggregates in concrete obtained from river swat.
- To determine the quality and compressive strength of river swat natural gravels.
- To replace crushed stone with river gravel because it's easily available and relatively cheap.

II. MATERIAL AND METHOD

Following are the materials used in this investigation.

A. Ordinary portland cement

Ordinary Portland cement simply called OC (ordinary cement) plays a very important role in the strength of concrete. Ordinary Portland cement (OPC) is a binding material used widely in construction industries having both cohesive and adhesive properties. OPC reacts chemically when the water and aggregate form a hard matrix that binds all materials (fine aggregate and coarse aggregate) together in a durable stone-like material [18]. In this project, we used ASTM Type-1 Ordinary Portland Cement manufactured by ASKARI Cement Limited. Following are the table shows the fineness and composition of Portland cement.

TABLE I
FINENESS OF ASKARI CEMENT

Trail No.	Total W1 (gm.)	Passing W2 (gm.)	Retained %
1	100	94.7	5.3
2	100	92.7	7.3
3	100	95.3	4.7
		Average fineness	5.58

TABLE II
COMPOSITION OF PORTLAND CEMENT

Minerals	Percentage
Minerals Percentage Silica	17 to 25%
Lime	60 to 67%
Alumina	3 to 8%
Iron Oxide	0.5 to 6 %
Magnesia	0.1 to 4%
Sulfur trioxide	1 to 3%
Soda and potash	0.5 to 1.3%

B. Course aggregates

Coarse aggregates are irregular and have diamond cut in shape; they are used in concrete to give it volume and toughness which occupy about three-fourths of the concrete volume. Coarse aggregates are retained on a 4.75mm sieve. Aggregates are inert materials that are mixed with binding material such as cement or lime for producing mortar or concrete. Aggregates give volume, and strength to the concrete with its toughness where it holds all the loads. Aggregates are used as filler material because they are less expensive than cement. It is desirable to use as many of them as possible to reduce their cost [19].

Aggregates are naturally available in different sizes. Usage of these sizes may be related to the mixed proportions which depend on the conditions of the concrete For, in high-strength concrete a 10mm size of coarse aggregate can be used, and in normal concrete 25mm size. Cobble, boulders, etc. come into this category.

C. Quarry crush

Quarry Crush is a form of aggregate, typically produced by quarrying and breaking down to the desired size using a crusher. Mostly used coarse aggregates If they pass some of the tests such as the gradation test, toughness test, etc. then they can be used in construction work otherwise they will be rejected. Its size may vary from 25mm to 10mm according to the use and strength of concrete [20].

D. Sieve analysis of quarry crush

Sieve analysis of quarry crush was performed under the provision of ASTM C136-04 to find out the particle size distribution of quarry crush that has been used in this project.

TABLE III
SIEVE ANALYSIS OF QUARRY CRUSH

Sieve	Sieve size	Weight retained (gm.)	Cumulative weight (gm.)	Cumulative percent retained (%)	Percent Passing (%)
No.	(mm)				
1 1/2"	38.1	0	0	0	100
1"	25.4	232.8	232.8	4.66	95.34
1/2"	12.7	1680.5	1913.3	38.27	61.73
No.4	4.75	2985.9	4899.2	97.98	2.02
No.8	2.37	80.6	4979.8	99.6	0.4
Pan	0	20.2	5000	100	0

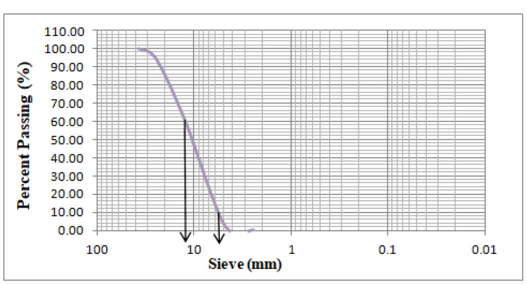

Fig. 1. Grain size distribution for quarry

The figure shows the S-curve (often referred to as a gradation curve diagram) is a logarithmic graphical representation of the cumulative percent passing of quarry aggregate grains on the y-axis, and the sieve size opening on the x-axis. Coefficient of Uniformity for quarry aggregate,

$$\mathrm{Cu} = \mathrm{D}/\mathrm{D} = 10.30/1.49 = 6.91 \quad (1)$$
60

- Cu > 6 indicates a densely graded (well-graded) material with a considerable range of particle size (used for max stability).
- Cu < 4 indicates a uniformly graded (open-graded) material having a narrow range of particle size (used for max permeability).

E. River gravel

River gravel is obtained from the river bed and it possesses rounded stones which have different colors and its diameter is no larger than 25mm. usually, it has a rounded shape because of the rubbing and flow of water over it. It's mostly used in outdoor settings, such as a park, walkways street road, etc. because it's a free and cheap source of material, easy to use, and doesn't need any maintenance in the future.

River gravel can also be used in concrete and is used in concrete but of non-standard strength as there is still no standard for river gravel for its use in concrete in civil engineering work. As river gravel is very cheap to source so, if the goal is to reduce the cost of construction it can be used in places like walkways or places where no heavy loads of structure are applied [21].

Under ASTM C136-04 the sieve analysis of coarse aggregates is determined. The coarse aggregates with a determined size of 9.5 mm are used. The coarse aggregate tests like specific gravity and the proportion of water absorption are resolute per ASTM C 128- 04.

Fig. 2. River gravel from river swat

F. Sieve analysis of river gravel

Under ASTM C136-04 the sieve analysis of coarse aggregates is determined. The coarse aggregates with a determined size of 9.5 mm are used. The coarse aggregate tests like specific gravity and the proportion of water absorption are resolute per ASTM C 128- 04.

TABLE IV
SIEVE ANALYSIS OF RIVER GRAVEL

Sieve No.	Sieve size	Weight retained (gm.)	Cumulative weight (gm.)	Cumulative percent retained (%)	Percent Passing (%)
	(mm)				
1 1/2"	38.1	0	0	0	100
1"	25.4	889.59	889.59	17.79	82.21
1/2"	12.7	817.41	1707	34.14	65.86
No.4	4.75	2649.34	4356.34	87.13	12.87
No.8	2.37	493.71	4850.05	97	3
Pan		149.95	5000	100	0

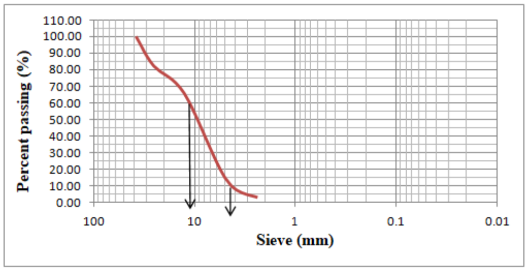

Fig. 3. Sieve analysis of river gravel

- Figure 3-10 shows S-curve (often referred to as a gradation curve diagram) is a logarithmic graphical representation of the cumulative percent passing of river gravel grains on the y-axis, and the sieve size opening on the x-axis.
- Coefficient of Uniformity for River Swat gravel

$$\mathrm{Cu} = \mathrm{D}_{60}/\mathrm{D}_{10} = 10.4/1.35 = 7.55 \tag{2}$$

- Cu > 6 indicates a densely graded (well-graded) material with a considerable range of particle size (used for max stability).
- Cu < 4 indicates a uniformly graded (open-graded) material having a narrow range of particle size (used for max permeability).

G. Fine aggregate

Fine aggregate is a small-size filler material used in construction work it consists of natural minerals which may be sediments of large boulders. Fine aggregates are the particles that pass through a 4.75mm sieve and retain on a 0.075mm sieve. Sources of fine aggregates are sand, crushed sandstone, crushed gravel sand, etc.

The function of fine aggregate is to fill voids between the coarse aggregates means it functions as a filler in concrete. This is used in mortar, concrete, and plaster, etc. [22].

Fig. 4. Sample of Fine Aggregate (Nizampur Sand)

H. Sieve analysis of fine aggregate

To determine the gradation of sand that has been used in the research under ASTM C136-04 sieve analysis was performed. Sieve analysis is a procedure commonly used to assess the particle size distribution of aggregate passing through a series of sieves of progressively smaller mesh size and weighting the amount of material that is stopped by each sieve as a fraction of the whole mass.

Further from sieve analysis fineness modulus is find out. The fineness modulus is a numerical index that gives ideas about the main size of the particle in the entire body of the aggregate. It's obtained by adding the percentage weight of retained material on each of standard sieve and dividing it by 100. The fineness modulus (F.M) must be between (2.2 to 2.3) which is a requirement of concrete mix design. The following limits may be taken as guidance.

Fine sand: F.M:2.2 to 2.6
Medium sand: F.M: 2.6 to 2.9
Coarse sand: F.M: 2.9-3.2

If else if else this value is greater than (3.2) then the fine aggregate is not suitable for construction work. The main objective of the Fineness modulus is to grade a particular aggregate for the most economical and workable concrete mix. Table and Figure show the results of those sieve analyses.

TABLE V
GRAND SIZE DISTRIBUTION OF FINE AGGREGATE

Sieve No.	Sieve size (mm)	Retained weight (gram)	Percent retained (%)	Percent Passing (%)	Percent sum retained residual (%)
4	4.75	0	0	100	0
8	2.37	0.7	0.14	99.86	0.14
16	1.18	2.6	0.52	99.34	0.66
30	0.6	15.4	3.08	96.46	3.54
50	0.3	170.34	34.068	62.39	37.608
70	0.21	155.3	31.06	31.33	68.668
100	0.15	97.5	19.5	11.83	88.168
Pan	0	49.75	9.95	1.88	98.118
The sum of cumulative retained					296.902
F.M = Sum of cumulative retained /100					2.97

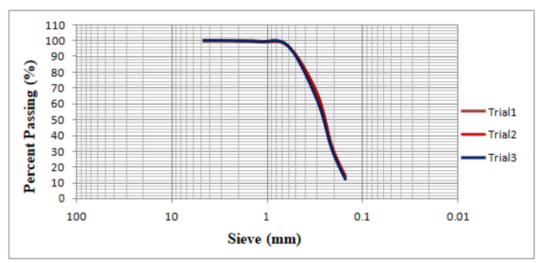

Fig. 5. Grain size distribution curve

The above table and figure show that the fineness modulus of sand is between 2.9 to 3.2. The range shows us course sand so it can be used in construction works.

I. Water

Water is essential for humans but in concrete, it plays a key role without water concrete is impossible to make. When water is mixed with cement it forms a paste that binds the aggregates together with the incorporation of sand. The excessive use of water increases the workability of concrete but decreases the strength of concrete but if we decrease the content opposite of that happens [23].

Following is the method followed for this investigation. In this project, the Ratio of mix design (1:2:4) is used with water cement ratio of 0.60. Three samples each were cast for river gravel, quarry crush, and a combination of Gravels and quarry crush. Calculations were done to obtain the quantities of cement, sand, and coarse aggregates.

Volume of one mould = 339.42 in^3

V = 0.1964 ft^3

V = 0.1964/ 35.28 = 0.00557 m^3

Total volume of 3 moulds = T.V = 0.00557 x 3 = 0.01671 m^3

Then the quantity of Cement, sand, and aggregate or river gravel was found out Mix design ratio = (1:2:4)

Water cement ratio = 0.60

The wet volume of concrete for three mold samples = 0.01671 m^3

Dry volume of concrete = 0.01671 m^3 x 1.54 = 0.02572 m^3

Sum of ratio = 1+2+4 = 7

Quantity of cement = 5.71 kg

Quantity of sand = 11.42 kg

Quantity of crushed or river gravel = 22.84 kg

Water content = 0.60 x 5.71 kg = 3.426 kg = 3.426 litter. The following process was followed in the preparation of cylinders

- Materials like cement, sand, river gravel, and quarry crush were weighed according to the above calculations as shown in Figure.
- After measuring, all materials were put in a tray and mixed well with the help of a trowel.
- Then, water was added according to the water-cement ratio of 0.60 and was mixed well to make the concrete.
- The prepared concrete mix was poured into the mold in three layers with each layer properly tamped.
- The sample was then finished by trowel to obtain a smooth surface and after 24 hours, all cylinders were de-molded.
- Cylinders were kept in a curing tank for 28 days to gain proper strength.

III. RESULTS AND DISCUSSION

Following is the experimental program in this research.

A. Slump test

The given slump tests show that the river gravel is found to be 19% more workable than quarry crush, a combination of river gravel and crushed is 23% less workable than quarry crush and 36 % less workable than river gravel.

Less friction is produced between constituents of concrete due to the smooth and round shape of river gravel and, thus, high workability value while quarry crush has a rough and angular surface resulting in more friction between concrete ingredients causing low workability value.

Fig. 6. Slump cone test of concrete

TABLE VI
SLUMP TEST RESULT

Sample No.	Samples	Slump value (mm)
1	Quarry crush	31.5
2	Quarry crush and River gravel	24
3	River gravel	37.5

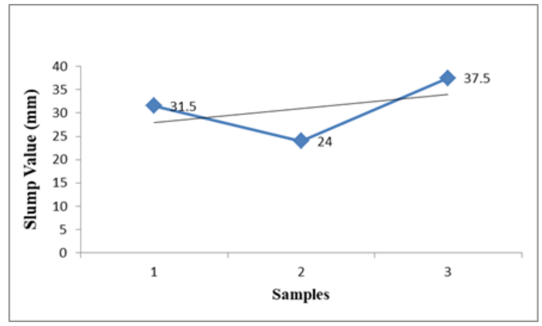

Fig. 7. Slump test for (Q.A, Q.G and R.G)

B. Compressive strength

This is a destructive strength test for concrete where a specimen of concrete with the cylindrical or cubical shape of standard dimensions, after curing for a specified 28 days is tested through a Universal Testing Machine. In this test, the cylinder is placed completely in the center of the apparatus then the axial load is applied from the upper side until the cylinder fails. The maximum load achieved is divided by the cross-sectional area of the sample and the compressive strength of the concrete is found.

Compression tests were conducted after 28 days of the casting of cylinders.

Fig. 8. Concrete sample for testing

C. Compressive strength test results of river gravel

The table and figure show the compressive strength test results for 28 days of cured river gravels.

TABLE VII
COMPRESSIVE TEST RESULT OF RIVER GRAVEL

Sample ID	28 days compressive strength (Psi)	28 days compressive strength (kg/cm^2)
R.G1	2534	178.16
R.G2	2598	182.66
R.G3	2470	173.66

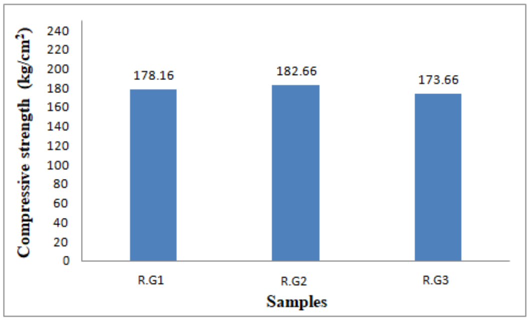

Fig. 9. Compressive strength of river gravel

D. Combine compressive strength of Quarry crush and River gravel

The table and figure show the combined 28 days of compressive strength of quarry crushed aggregates and river gravel.

TABLE VIII
COMBINE COMPRESSIVE STRENGTH OF QUARRY CRUSH AND RIVER GRAVEL

Sample ID	28 days compressive strength (Psi)	28 days compressive strength (kg/cm^2)
Q.G1	2763	194.26
Q.G2	2859	201.01
Q.G3	2667	187.51

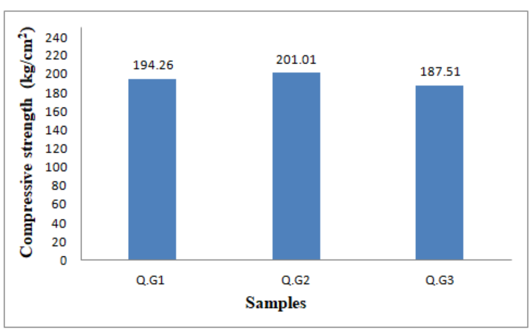

Fig. 10. Combine Compressive strength of quarry and gravel

E. Compressive strength of quarry aggregate

The table and figure show us 28 days of compressive strength of the quarry crushing.

TABLE IX
COMPRESSIVE STRENGTH OF QUARRY AGGREGATE

Sample ID	28 days compressive strength (Psi)	28 days compressive strength (kg/cm^2)
Q.A1	2243	157.7
Q.A2	2330	163.82
Q.A3	2156	151.58

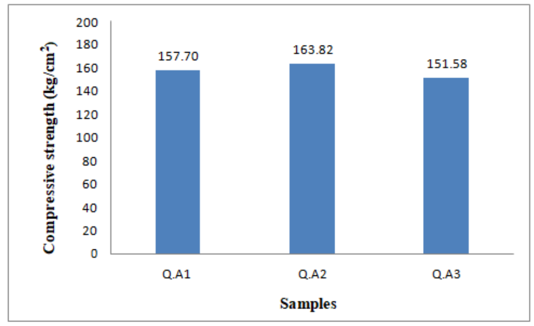

Fig. 11. Compressive strength of quarry aggregate

F. Comparison of compressive strength of river gravel concrete and quarry crush

In table and figure, show us a comparison of the compressive strength of river gravel and quarry crush concrete is made. It may be seen that the combination of river gravel and quarry aggregate has 20 % higher compressive strength than quarry aggregate and 10% than river gravel concrete. The given result shows us that the river swat gravel and (Sadero) hills quarry crush are their combined compressive strength more as compared with quarry aggregate.

As we know river gravel has less friction between constituents of concrete due to the smooth and round shape of river gravels resulting in low compressive strength values, while quarry crush has a rough and angular surface thus producing more friction between the concrete ingredients leading to high compressive strength values. From the above comparison of compressive strength, we observe that the combination of both quarry crush (Sadero) and river Swat gravel in the concrete mix has great compressive strength.

TABLE X
COMPARISON OF COMPRESSIVE STRENGTH OF QUARRY GRAVEL, QUARRY AGGREGATE, AND RIVER GRAVEL

Sample No.	28 days compressive strength of River gravel (kg/cm^2)	28 days compressive strength of quarry gravel (kg/cm^2)	28 days compressive strength of Quarry aggregate (kg/cm^2)
1	178.16	194.26	157.7
2	182.66	201.01	163.82
3	173.66	187.51	151.58
Average	178.16	194.26	157.7

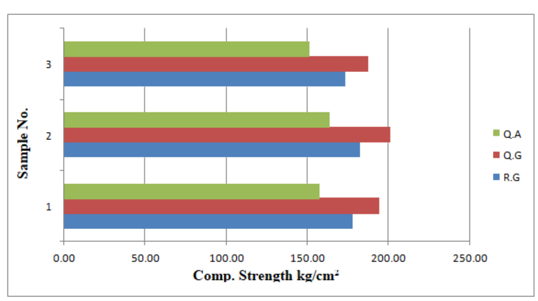

Fig. 12. Compressive strength comparison of quarry aggregate, quarry gravel, and river gravel

IV. CONCLUSION

Based on experimental work, the following conclusions are drawn. The workability of the river gravel concrete is 19 % more as compared to quarry crush aggregate concrete. This is mainly because of the smooth surface and round shape of the river gravel resulting in less friction and high workability value. The workability of Q.G (river gravel and quarry aggregate) concrete is 23% less workable than quarry crush and 36 % less workable than river gravel. If the workability had been kept constant, the water content for some of the concrete mixes could have been reduced thus benefiting the mechanical properties of concrete. The compressive strength of river gravel concrete is 20% more as compared to Quarry aggregate concrete and 10% more as compared to river gravel. Quarry crush has a rough and angular surface thus producing more friction between the concrete ingredients leading to high compressive strength values.

V. ACKNOWLEDGMENT

First of all, we would like to thank Allah Almighty who always helped us throughout our research work. We would like to pay debt of gratitude to our seniors for their profound guidance, and encouragement, to complete this project work. In the end, we would like to pay our earnest and honest gratitude to our family, friends, and teacher, especially for their unconditional support, encouragement, prayers, and patience.

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