Engineering Characterization of Course Aggregate Used in Cement Concrete from Local Quarries in Dir (Lower), KP, Pakistan

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Abstract – In District Dir Lower, coarse aggregates from local sources are used in cement concert in construction works, such as buildings, bridges, culverts, roads pavements etc. both in private and public sectors. There are only two established quarries of natural rocks, one at Chakadara and the other at Katkala, where coarse aggregates and stone metals of the required sizes for concrete and for roads bases are obtained from cutting and crushing of natural rocks. Being mountainous area, huge quantity of stone boulders are available from Pajkora River bed and beds of its feeding stream/khwars such as Konai khwar, Ouch Gulabad Khwar, Talash Shamshi Khan Khwar, Roud from Munda Sammar Bagh, Sucha Khawar etc; where small crushing plants have been installed by locals and coarse aggregates of various sizes are produced, which are the main sources of coarse aggregates for construction activities in the District. No proper study to investigate the engineering properties of the coarse aggregates from these sources have been carried out, so the aim of this research study is to characterize the coarse aggregates according to the standard testing procedure and compare the results with specified standard parameters.

The two quarries of natural rocks at Chakadara and Katkala were selected and two numbers sources of coarse aggregates from Panjkora river bed at Rani and stream/ naullah bed at Gulabad were randomly selected.

Coarse aggregates from all these four selected quarries/sources were tested for its physical and mechanical properties such as, specific gravity, bulk density, water absorption, crushing value, impact value, Loss Angles abrasion etc.

The physical and mechanical tests shows that the coarse aggregates from all these selected sources qualify the specified standard parameter for normal strength cement concrete making. The shape test of the coarse aggregates shows the foliated nature of Katkala rock where in both the flakiness and elongation indices shows relatively higher values as compare to the coarse aggregates from other three sources. Concrete cylinders were prepared using coarse aggregates from each source and were tested for 7 days strength for comparing the strength of concrete made of coarse aggregates from each source.

Index Terms – Coarse Aggregate, Concrete Cylinders, Physical and Mechanical Properties, Shape test.

1. INTRODUCTION

CEMENT concrete is a heterogeneous material which is made by the combination of different type of constituents of different properties such as cement, water and aggregates. Hydraulic cement and water combine chemically and provide a bonding mixture or cement paste [1] having cementing properties. The particles of aggregates are dispersed in the mixture and surrounded by this mixture. On drying the concrete behave like a pseudo rock

The aggregates in concrete occupies 60 to 80 percent of the volume [2], therefore its quality is of considerable importance. Aggregates give strength, durability and volumetric stability to concrete and increase its robustness. The properties of fresh and hard concrete such as workability, durability and strength are greatly related to the properties of the aggregates used in the concrete. Aggregate characteristics that are significant for making concrete include porosity, grading or size distribution, moisture absorption, shape and surface texture, crushing strength, elastic modulus, and the type of deleterious substances present in the aggregates.

District Dir was a princely state, governed by the Nawabs of Dir until 1960 when the state was formyl merged in Pakistan in 1968 and later on declared as District in 1970. There were no education or health facilities available to the people. Establishment of primary, middle and high schools started after 1960.

Nowadays in District Dir Lower, billions of rupees of projects in public sector such as, Communication and works department, Irrigation department, Public Heath Engineering Department and Local Government Department are under execution. In the financial year 2017-18, there are approved schemes of Rs 11.619 billion under execution in the C&W, Irrigation and PHE departments [3]. Under the financial aid of the European Union, 800 small infrastructures schemes, each valuing at the average of Rs: 1.00 million have been completed in the last 3 years [4]. Beside this, commercial plazas, shopping malls, shops, markets and houses are under construction in private sectors and huge quantity of locally available coarse aggregate are used in cement concrete.

There was no concept of using crushed stone aggregates in District Dir, up to the late nineteen eighties. Being hilly and mountainous area, locally and cheaply available streams bed natural gravels were used in concrete.

Research work has been carried out on coarse aggregates in various parts of Pakistan such as Qurshi et all (2015) studied the aggregate Characteristics on strength of concrete in District Khanpur Mirs Sind[5], Ghaffar et all (2010) studied the coarse aggregated of Magala Hills near Islamabad [6], Zaidi et all (2008) studied coarse aggregate of Hub river in Sind [7], Gondal et all (2009) studied coarse aggregate from Jutana formation Seakeasar lime stone and Jabbi- Warchha and Katha Sagharal area [8], Ahsan et all (2009) studied the coarse aggregate from Allai Bana area Districr Manshear[9] and

Ayub et all [2012] studied coarse aggregate of District Peshawar but no engineering study has been carried out to ascertain the properties of the aggregates from this area, District Dir (Lower) according to the specified standard parameters.

Due to high transportation charges of coarse aggregates from approved quarries of Margala, Palaay etc, hundreds of small stone crushing plants have been installed by local people and coarse aggregates are cheaply obtained from local quarries and crushed stones/boulders of the naullahs such as Chakadara , Katkala, Konai Khwar, Gul Abad Ouch Khwar, Talash Shamshi Khan Khwar, Rood from Munda Sammar Bagh and Panjkora River bed and are used in concrete.

According Pakistan building code 2007 seismic zoning map, Dir Lower lies in zone 3, where the peak ground acceleration ranges between 0.24 to 0.32 g and the risks of damages from the earth quake are high, therefore the quality and strength of the structures needs special attention that is why the need for this study was felt.

2. METHODOLOGY

The following four quarries/sources which are predominantly used for obtaining Coarse Aggregates for use in concrete were selected.

a) Natural Rocks
   i) Chakdara Quary
   ii) Katkala Quary
b) River Bed /Naullah Bed Stones/Boulders
   i) Gul Abad Khwar
   ii) Panjkor River at Rani

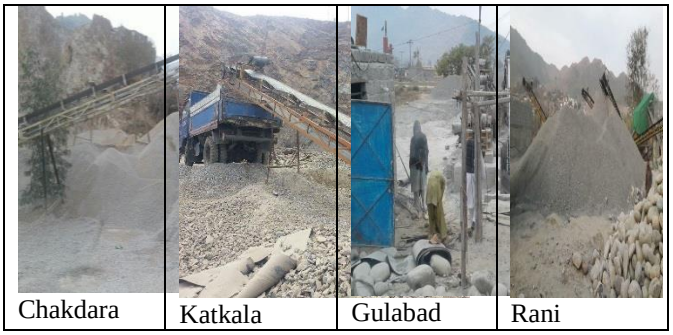

Fig. 1: Selected Quarries/Sources of Coarse Aggregates

Samples of coarse aggregates from these quarries/sources were obtained according to ASTM D 75 and ASTM C 702 methods and the following test for physical and mechanical properties were carried out.

i) Specific Gravity (ASTM C 127)
ii) Water Absorption (ASTM C 127)
iii) Bulk Density (ASTM C 29)
iv) Flakiness Index (BS 812 105.1)
v) Elongation Index (BS 812 105.2)
vi) Soundness (ASTM C 88)
vii) Crushing Value (BS 812- 110)
viii) Impact Value (BS 812-112)
ix) Las Angles Abrasion (ASTM C 131)
x) Concrete cylinders Strength (ASTM C 39)

All the above mentioned tests for physical and mechanical properties of the coarse aggregates were performed at the concrete laboratory of the National University of Science and Technology Risalpur, Khyber Pakhtunkhwa.

3. TESTS RESULTS AND DISCUSSIONS

The outcome of the above tests for determining the physical and mechanical properties of the coarse aggregates are given below;

3.1. Specific Gravity (ASTM C 127)

The result of the test specimens for specific gravity for different moisture condition such as oven dry (OD) and saturated surface dry (SSD) condition for all the four sources of aggregate is given below;

TABLE 1:

	Specific Gravity Test			
	Chakdara	Gulabad	Katkala	Rani
Specific Gravity (OD)	2.64	2.65	2.67	2.62
Specific Gravity (SSD)	2.69	2.69	2.72	2.67

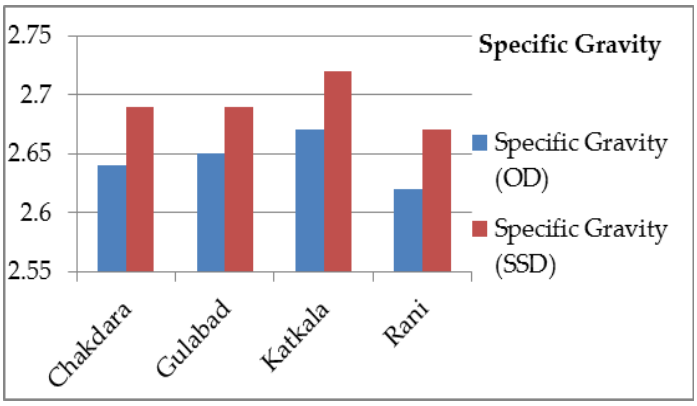

Fig. 2: Graphic representation of Specific Gravities

According to ASTM C 125 definition the specific gravity of normal weight aggregate range from 2.4 to 3.0, therefore, the aggregate of all the four tested quarries/sources are normal weight aggregates. Normally in concrete making the specific gravity at SSD condition is taking into account.

3.2. Water Absorption (ASTM C 127)

Water absorption test for the coarse aggregate give the value of 1.75%, 1.58%, 1.64% and 1.92% for Chakdara, Gulabad, Katkala and Rani respectively.

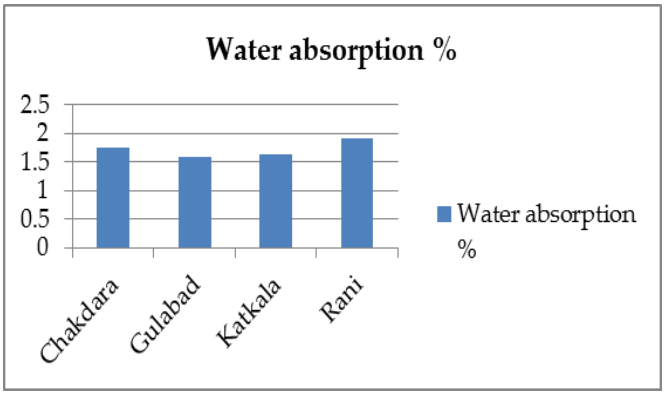

Fig. 3: Graphic representation of Water Absorption

There is no described maximum or minimum limit of water absorption of coarse aggregate for concrete making in BS standard or ASTM, however, HKSAR Construction Standards (CS3) [11] recommends water absorption of 0.8% for natural coarse aggregate, whereas, the Indian Standards [12] specify it to be not more than 2%. The water absorption of the tested aggregate is less than 2%.

3.3. Bulk Density

The results of the bulk densities as obtained from the tests of the coarse aggregate for Chakdara, Gulabad, Katkala and Rani are 100.66, 99.22, 101.58 and 99.56 lbs/cft respectively.

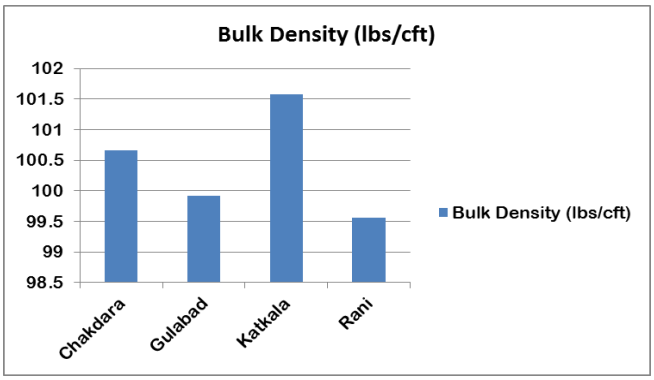

Fig. 4: Graphic representation of Bulk Densities

The results of the bulk densities shows that the aggregates falls in the range of normal weight aggregates as per ASTM C 125 definition of Normal weight aggregate i.e. 70 lbs/cft to 120 lbs/cft

3.4. Flakiness Index (BS 812 105.1)

The results for the flakiness index of the coarse aggregates for Chakdara, Gulabad, Katkala and Rani are 21.1%, 22.1%, 25.1% and 22.8% respectively.

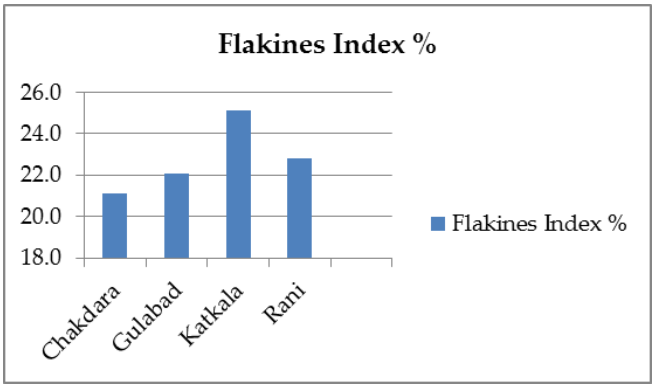

Fig. 5: Graphic representation of Flakiness Index

Method for determining Flakiness Index is given in BS 812 part 105.1 but no prescribed limits have been given but according to BS 882 : 1992, Flakiness index should not be more than 50 for natural gravel aggregate and not more than 40 for crushed or partially crushed aggregate. For wearing surface lower value of the flakiness index is required. The HKSAR Construction Standards (CS3) limit it to maximum of 30 and the Indian Standards specify it to be ≤ 25 for ordinary concrete and to be ≤ 15 for high quality concrete.

3.5. Elongation Index (BS 812 105.2)

The results for the elongation index of the coarse aggregates for Chakdara, Gulabad, Katkala and Rani are 18.4%, 18.7%, 24.2% and 14.7% respectively.

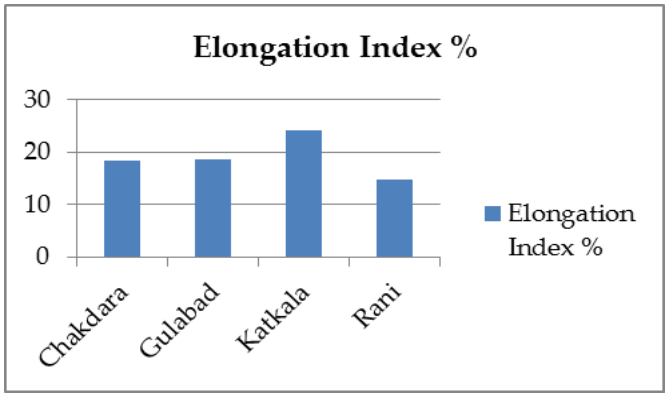

Fig. 6: Graphic representation of Elongation Index

There is no recognized limit for the elongation index of coarse aggregate but generally in excess of 10 to 15 [13] percent of the mass of coarse aggregated is considered as undesirable. The HKSAR Construction standards (CS3) limit

max elongation index to 35%. The value for the coarse aggregate at Katkala as compare to the other three aggregate is on higher side but the shape of the coarse aggregate also depends on the type of crushing machine. The quarry is of natural rock and has great potential of yielding coarse aggregate. If the crushing machine is changed may be it produce aggregate of desired shape limit.

3.6. Soundness Test (ASTM C 88)

After 18 hours of immersion of the test specimen in Saturated Solution of Sodium Sulfate (Na_2SO_4) followed by oven drying at 105 °C for each cycle the weight in loss of the coarse aggregate after 5cycle, for Chakdara, Gulabad, Katkala and Rani are 3.35%, 5.04%, 4.1% and 4.88% respectively.

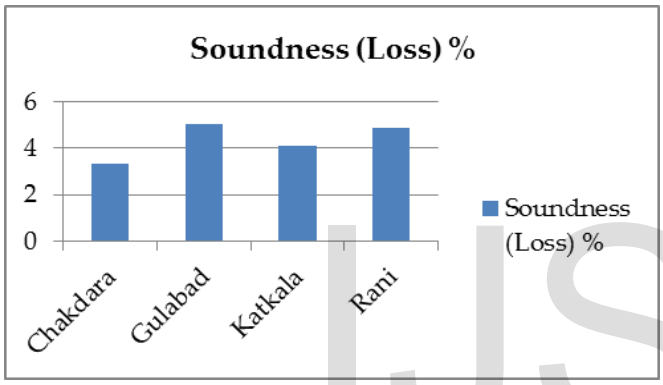

Fig. 7: Graphic representation of Soundness Test

According to ASTM C 33,"Specification for concrete aggregates" the limit for the loss in soundness, when Sodium Sulfate is used is 12% and 18% when Magnesium Sulfate is used. The Soundness results for all the four samples are within the limit. All the four samples qualify the soundness value.

3.7. Aggregate Crushing Value (BS 812 Part 110)

The test value for the four numbers of tests specimens of the coarse aggregate from the selected quarries/ sources are given as, 22.41%, 13.23%, 19.38% and 15.61% for Chakdara, Gulabad, Katkala and Rani respectively.

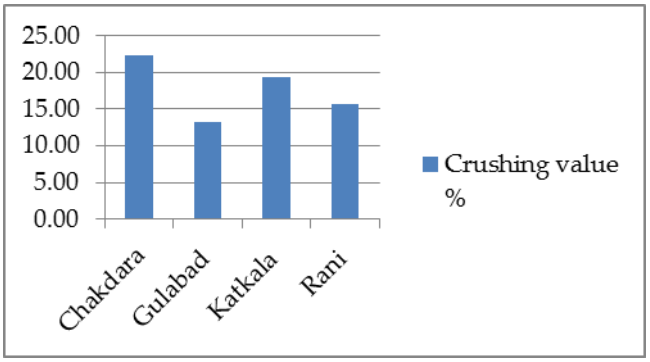

Fig. 8: Graphic representation of Crushing Values

Crushing value is a guide line to show the pulverization of the aggregate after the gradual application of 400 kN load in 10 minutes. As is evident from the results, the aggregate from Gulabad and Rani which are obtained from river and stream (khwar) beds boulders shows slightly lower crushing value due to the fact that these boulders are the result of natural rocks weathering, transportation by natural agencies such as wind and water, dragging and subjected to the action of natural forces such as impact and abrasion, which make it hard, tough and strong. There is no described limit for the crushing value in BS and ASTM specification but the Indian Specification, specify the limit of 30 for pavement and 45 for other structures. The values for all the 4 specimens are less than 25.

3.8. Aggregate Impact Value (BS 812 Part 112)

The test specimen passed from sieve no 14 mm and retained on 10mm was tested in the impact testing machine according to the prescribed procedure. The result of the test is given as 21.67%, 16.56%, 17.57% and 19.88% for the coarse aggregate from Chakdara, Gulabad, Katkala, and Rani respectively.

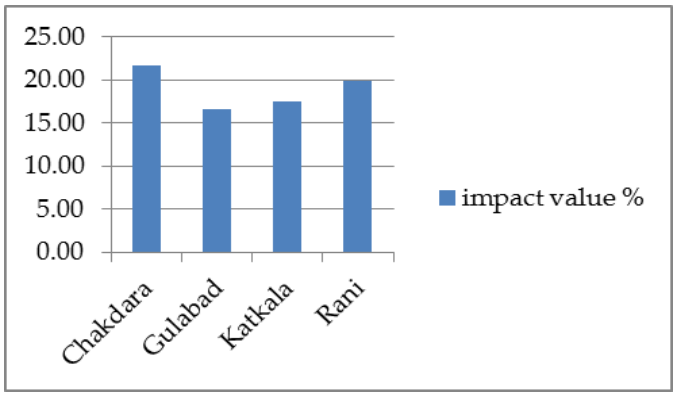

Fig. 9: Graphic representation of Impact Value

The BS 882 1992 prescribe the following limits for aggregate impact value;

i) AIV ≤ 25 when aggregates are used in concrete of heavy duty floors
ii) AIV ≤ 30 when aggregates are used in concrete for wearing surfaces
iii) AIV ≤ 45 when aggregates are used in concrete for other purposes

The tested aggregates for all the four quarries/source are within the limit.

3.9. Loss Angles Abrasion (ASTM C 131)

The Los Angles value of the coarse aggregate shows the resistance of the aggregate to degradation by abrasion, impact and grinding. The test result for the specimens of the coarse aggregates are, 26.38%, 22.08%, 28.14% and 20.12% for Chakdara, Gulabad, Katkala and Rani respectively.

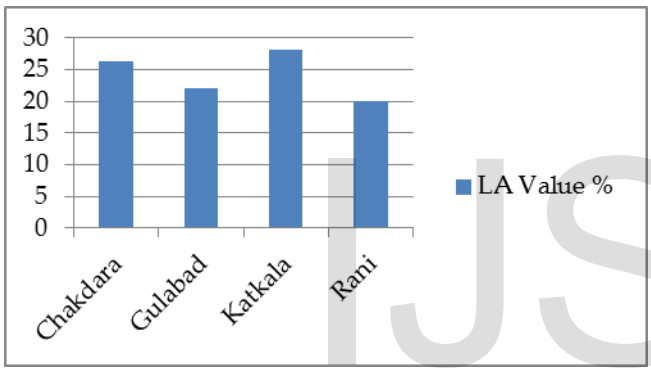

Fig. 10: Graphic representation of LA Values

According to ASTM C 33 the value of LA for all type of concrete should not be more than 50 %. As per HKSAR standard specification (CS3) it should not be more than 30%, whereas the Indian specifications limit it from 30 to 50%. The LA value of all the four tested specimens of the coarse aggregates qualify the specifications.

3.10. Crushing Strength of Concrete Cylinders (ASTM C 39)

Concrete cylinders from the testing specimens of the coarse aggregates from each source/quarry were prepared and tested for comparing the compression / crushing strength of the concrete, of the selected sources/quarries. Though the physical and mechanical properties of the coarse aggregates such as, shape, texture, bulk density, porosity, soundness, strength etc greatly affects the properties of the concrete, keeping all other conditions the same, but for simplicity we assumed these properties to be the same and uniform for all the aggregates of the selected sources/quarries. We further kept the quality and quantity of the other constituents of concrete such as, cement, fraction size of the coarse aggregates, quality and quantity of fine aggregate and water cement ratio the same so as to make it as a representative sample of the field as for ordinary works, the concrete used in construction of various proportions such as RCC/PCC 1:2:4, RCC/PCC 1:3:6 etc; are made by proportioning the constituents of the concrete in the same manner. Askari Portland cement type 1, clean washed sand of the same source of FM of 2.6, two fraction size of coarse aggregates of range 3/4 to 1/2 in and 1/2 to 3/8 in equal mass and water cement ratio of 0.5 were used to prepare concrete of ratio 1:2:4 by weight having approximate design cylinder strength of 3000 psi.

The values of the 7days compression test result for Chakdara, Gulabad, Katkala and Rani are 2297, 2376, 2258 and 2337 psi respectively.

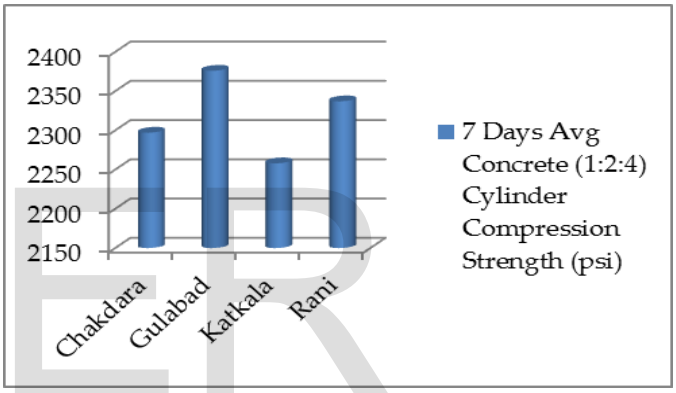

Fig. 11: Seven Days Concrete (1:2:4) Cyliners Tests

The relatively high concrete cylinder strength for Gulabad are verified by the comparative low crushing value, low impact value and low Loss Angles abrasion value of the coarse aggregate from the source. The relatively low compression strength of the concrete cylinder strength for Katkala is verified by the relatively high value of flakiness and elongation indices, Loss Angles abrasion value, aggregate crushing value of the coarse aggregate from the quarry.

4. Conclusion

The Specific gravities and bulk densities of all the four specimens of aggregates are within the range of normal weight aggregates. Water absorption of all the samples is less than 2%. The flakiness and elongation indices of the specimens are within the prescribed range. The percentage weight in loss in all the four samples of the aggregates by using Magnesium sulfate solution in the soundness test is well below 18%. The aggregate crushing values and aggregate impact values are also within the prescribed limits. The values

of the Loss Angles abrasion test for all the four samples aggregates are within the limits. From the results of the tests for physical and mechanical properties of the coarse aggregates of the samples from the selected quarries/sources, it is verified that the coarse aggregates of all the four sources qualify for making of normal strength concrete, however on comparison on the bases of crushing strength value, LA value, flakiness and elongation indices, the coarse aggregates from Gulabad is of superior quality and the coarse aggregates from Katkala are of low quality. The tests results further shows that the coarse aggregates obtained from crushing of stone boulder of the river bed or stream/naullah beds are more strong, tough and hard as compare to the coarse aggregates obtained from crushing of the natural rocks fragments. The compression test of casted concrete cylinder shows that strength of coarse aggregates influence the strength of the concrete.

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