

A Comparative Study of Geological and Engineering Properties of River Borne Aggregates and Quarry Aggregates

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ABSTRACT: Aggregates play an important role in civil engineering construction. Collection of aggregates is basically done by rock blasting which creates huge amount of pollution and excessive destruction of forest areas which disturbs the whole ecology of the surrounding. Thus, it has become necessary to locate alternative sources of locally available natural coarse aggregates. The North-eastern part of India is a hub to several rivers and their tributaries, which carry considerable amount of coarse aggregates. The properties of river borne aggregates need to be studied in details for better evaluation of their utility as construction material. The present study involves a detailed comparative analysis between river borne coarse aggregates in their natural and crushed state from river Kulsi flowing through the southern part of Guwahati (Assam, India) and quarry aggregates. The suitability of river borne coarse aggregates as a road construction material is interpreted from this study.

KEYWORDS: Pollution, River borne Aggregates, Quarry Aggregates, Road Construction

I. INTRODUCTION

Aggregates are the important constituents of concrete. In road construction, aggregates generally constitute the greater part of the body of a road which has to bear the stresses given by all types of traffic. Hence, it is very essential that one should know about the aggregates, its properties and its suitability as a construction material. Aggregates are basically collected by blasting of rocks from quarries which not only pollutes the environment by releasing harmful gases carbon dioxide, carbon monoxide, oxides of nitrogen, ammonia etc. but also creates excessive destruction of both hilly structures and forest materials [17]. Thus, locating alternative sources of natural aggregates has become necessary. In the lower part of Assam, the coarse aggregates used for construction of roads are mainly transported from other parts of the state which is very expensive. With this view in mind, a detailed study of the river borne aggregates of the river Kulsi of Assam is carried out for better evaluation of their utility as road construction material.

II. STUDY AREA

The river Kulsi flows through the southern part of Guwahati. It originates from the river “Khri” in Meghalaya. Khri meets Umsiri at Umkiam, and after flowing through East-Khasi districts of Meghalaya, it completely enters into Kamrup district of Assam. From this boundary, Kulsi flows 4.5 km and meets a stream flowing from the Chandubi Beel, near Firbhiri and then bifurcates, with one part flowing west as “Sindhu-Marang” and the other part flows 3km north and reaches the place called Kulsi near Chaygaon. The entire Kulsi River covers an area of about 3770 sq.km, before merging into the Brahmaputra. The river has been a chronic source of trouble as it deposits very high amount of silt and gravel leading to flooding lower Assam every year. Nearly 1.5 lakh people have been affected by floods in nearly 93 villages in South Kamrup district due to flood caused by Kulsi rivers [26]. Collection of river borne aggregates from the banks of the river Kulsi results in lowering of the river bed and thus, helps in reducing the flood havoc in the neighboring areas.

For the present study, quarry aggregates of various sizes are collected from *Gauripur* quarry near IIT Guwahati and river borne aggregates have been collected from three different sites viz., Dagaon Katahi, Makeli and Tarigaon from

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upstream to downstream of the river. Dagaon Katahi is at a distance of around 1.32 km from Makeli and Tarigaon is at a distance of about 1.00 km from Makeli.

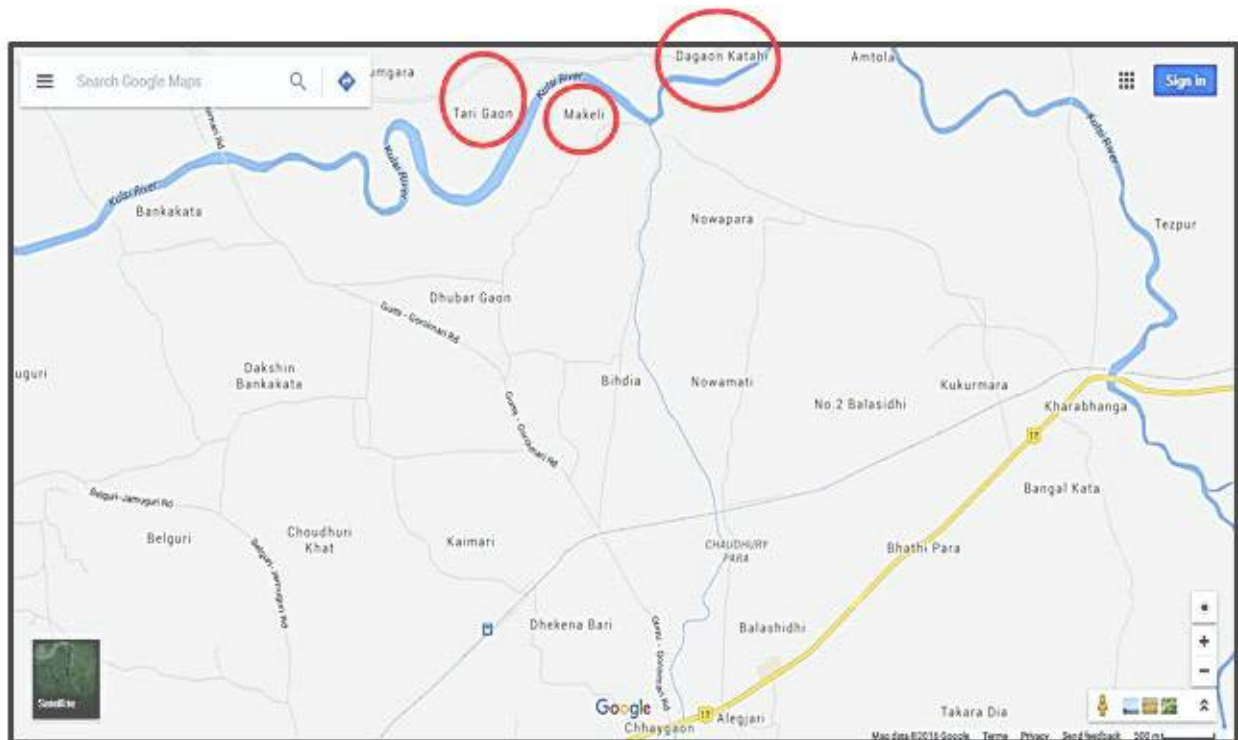


Fig. 1. Map showing Kulsu River with three sites viz. Dagaon Katahi, Makeli and Tarigaon

The main purposes of the study are as follows:

1. To carry out the geological and engineering tests on natural and crushed forms of river borne aggregates and quarry aggregates.
2. Finally, to compare the test results of quarry aggregates and river borne aggregates and to find their suitability as road construction material.

III.METHODOLOGY

The methodologies adopted during the study are field work and laboratory work. The field work involves collection of river borne aggregates by visiting the river sites where the collection is done manually by hand tools such as shovels. The collected samples were brought to the laboratory and microscopic and megascopic observation of the coarse aggregates is performed to find the distribution of rock types in the collected sample for all the three sites. Grading of the coarse aggregates is performed by the IS Sieves as per requirements for the various tests. Laboratory tests were carried out to find the various properties like Specific Gravity, Water Absorption, Aggregate Impact Value, Aggregate Crushing Value, Alkali Aggregate Reactivity, Los Angeles-Abrasion Value, Flakiness and Elongation Indices and Slake Durability.

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IV. EXPERIMENTAL RESULTS AND DISCUSSIONS

The results are categorized from geological and engineering point of view. From the geological point of view, both megascopic and microscopic observations are done for the aggregates. In the microscopic observation, constituent minerals are identified in the various types of coarse aggregates present in the site.

Figure 2 shows the microscopic view of minerals present in coarse aggregates of Dagaon Katahi site. Figure 2(a) shows the microscopic view of the Granite Gneiss rock found in the site. This rock contains the minerals Quartz, Plagioclase, Biotite (folded bend). Figure 2(b) shows Quartzite rock which contains Quartz, Plagioclase and Biotite minerals. Figure 2(c) shows Granite rock containing Microcline as essential mineral with an intrusion of quartz. Figure 2(d) shows the microscopic view of Phyllite rock which contains Quartz and Feldspar as minerals.

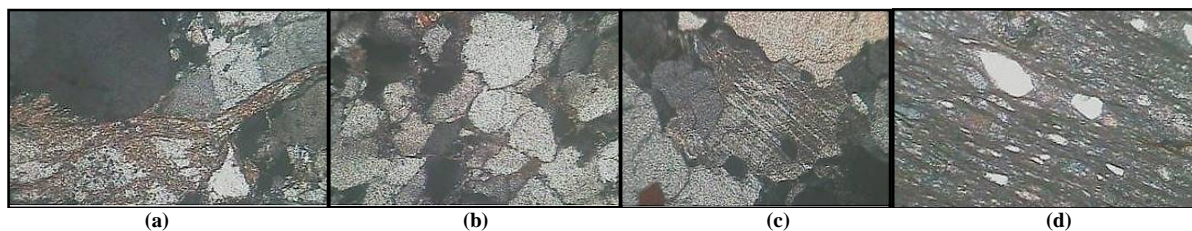


Fig. 2. Microscopic view of minerals present in coarse aggregates of DagaonKatahi site

Figure 3 shows the microscopic view of minerals present in coarse aggregates of Makeli site. Figure 3(a) shows the microscopic view of the Quartzite rock found in the site. This rock contains Quartz and Feldspar as the essential mineral with a Biotite vein. Figure 3(b) shows Granite Gneiss rock which contains the minerals Quartz, Plagioclase, Microcline, Biotite and Hornblende. Figure 3(c) shows Fine grained Granite rock containing the minerals Quartz, Feldspar and Biotite.

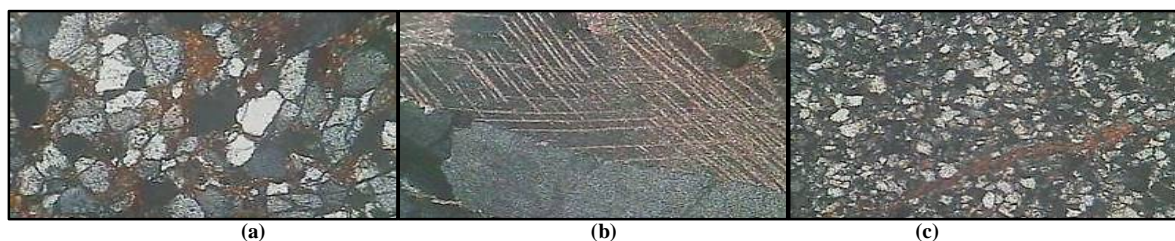


Fig. 3. Microscopic view of minerals present in coarse aggregates of Makeli site

Figure 4 shows the microscopic view of minerals present in coarse aggregates of Tarigaon site .Figure 4(a) shows the microscopic view of the Quartzite rock found in the site. This rock contains Quartz and Muscovite minerals. Figure 4(b) shows Granite Gneiss rock which contains the minerals Quartz, Biotite and Plagioclase. Figure 4(c) shows Granite rock containing Quartz as the essential mineral.

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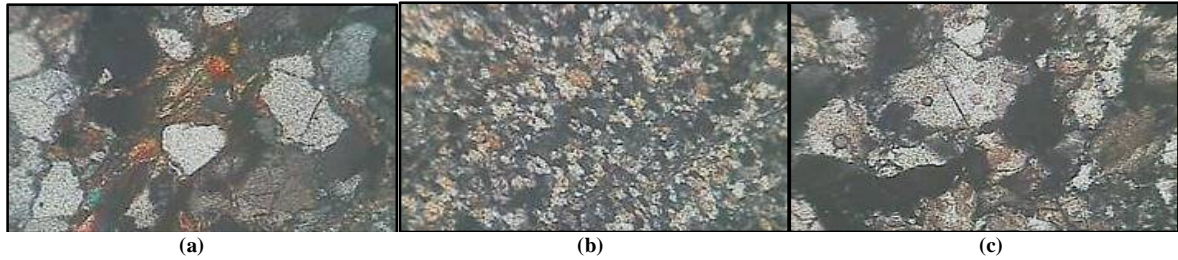


Fig. 4. Microscopic view of minerals present in coarse aggregates of Tarigaon site

Table 1: Megascopic characteristics of river borne coarse aggregates of all three sites

Type Of Rocks	Percentage Of Rocks Present (By Weight) (Approx)	Texture And Structure	Colour
Granite Gneiss	55	Medium grained, Gneissose structure	Grey Colour
Quartzite	25	Coarse to medium grained, Hard and Compact, Granular Structure	Light Brown Colour
Granite	18	Coarse grained, Porphyritic Structure	White Coloured with Black and Brown Spots
Phyllite	2	Fine grained, Foliated Structure	Grey Colour

Table 1 shows the megascopic observation of the coarse aggregates found in the site. The river borne aggregates of Kulsu River comprises mostly of rock units like Granite Gneiss, Quartzite and Granite. Phyllite is also present in small amounts. The coarse aggregates collected from the banks of the river Kulsu mostly contains Granite gneiss which is considered to be very hard and durable. Hence, we can say that, from the geological point of view, these aggregates are suitable for road construction purposes [25].

From engineering point of view:

Table 2: Engineering Test Results

Name of Tests	IS Codes	Sites						Quarry Aggregates
		DagaonKatahi		Makeli		Tarigaon		
Type		Natural	Crushed	Natural	Crushed	Natural	Crushed	
Fineness Modulus	IS: 2386-Part I-1963	6.28	5.57	4.77	5.09	4.42	4.09	4.52
Combined Flakiness & Elongation Indices (%)	IS: 2386-Part 1-1963	25.67	25.87	26.15	26.21	26.35	26.39	25.56
Impact Test (%)	IS : 2386-Part IV-1963	19.15	18.29	18.14	17.39	17.45	16.85	16.23
Abrasion Test (%)	IS : 2386-Part IV-1963	Grade A	Grade A	Grade A	Grade A	Grade A	Grade A	Grade A
		29.04	28.90	27.40	26.10	26.80	24.04	25.65
		Grade G	Grade G	Grade G	Grade G	Grade G	Grade G	Grade G
		29.34	29.20	24.50	23.50	23.50	22.50	23.67

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Crushing Test (%)	IS : 2386-Part IV-1963	25.70	24.57	25.26	24.20	22.54	21.34	22.45
Specific Gravity	IS: 2386-Part III-1963	2.72	2.74	2.74	2.76	2.77	2.79	2.75
Water Absorption (%)	IS: 2386-Part III-1963	0.48	0.47	0.46	0.45	0.44	0.44	0.42
Slake Durability (%)	IS: 10050-1981	98.10	98.19	99.30	99.49	99.40	99.50	99.47
Alkali Reactivity Test (Sc/Rc) mmol/l	IS: 2386-Part-VII-1963	99.9/255 = 0.39		23.31/350 = 0.07		29.97/320 = 0.09		42.34/220 = 0.19

The experimental observations are compared to the different Indian Standard and Indian Road Congress codes for evaluation of their suitability as road construction material. Starting with, the fineness modulus is a ready index of coarseness and fineness of the material. For coarse aggregates, its range lies between 3 to 7 [22]. Thus, the river borne coarse aggregates are within suitable limit of fineness modulus. Flaky and Elongated particles should be avoided as far as possible. These particles tend to orient in one plane with water and air voids forming underneath. As a result, these particles are liable to break up and disintegrate during pavement rolling process. The specification limits for combined flakiness and elongation indices is 30% max (MORTH Specifications, 2001). From the experimental observations of flakiness and elongation indices, it is found that, the flakiness and elongation indices of river borne coarse aggregates are within the permissible limit and hence, they are suitable for road construction purposes. The aggregate impact value gives relative measure of the resistance of an aggregate to sudden shock or impact. The standard specifications laid down by Indian Road Congress are tabulated in Appendix 1.

It is found that the experimental aggregate impact values for both natural and crushed river borne aggregates lie within the limit of 35%. Hence, from the point of view of impact value, the river borne coarse aggregates are suitable for road construction. The aggregate abrasion value is defined as the resistance to wear or abrasion. Los Angeles Abrasion test is used to determine the relative hardness of aggregates. In this paper, Abrasion test is carried out for both the natural and crushed form of aggregate for all the three sites for Grade A and Grade G. The experimental results are compared with the specifications given by IRC as given Appendix 2. On comparing the experimental results with Appendix 2, it is found that the experimental results lie within the limit of 30% for both the grades A and G for both the natural and crushed form of aggregate and hence, the aggregates are suitable for road construction. The aggregate crushing value gives a relative measure of the resistance of an aggregate to crushing under a gradually applied compressive load. Aggregates having lower crushing value are preferred for high quality pavements. IS: 384-1970 specifies that when aggregate crushing value is determined in accordance with IS: 2386 (Part IV)-1963 shall not exceed 45% for aggregate used in concrete other than for wearing surfaces and 30% for concrete for wearing surfaces, such as runways, roads and pavements. Laboratory experiment shows that it is within the permissible limit and hence suitable for road construction work. Specific gravity is the measure of quality and strength of the material. The allowable limits of specific gravity of aggregates are not specified. However coarse aggregates with specific gravity ranging from 2.6 to 3.0 are preferred for road construction purpose [19]. Water Absorption of an aggregate is usually accepted as a measure of its porosity. Porosity and water absorption affect the water-cement ratio and the workability of concrete. The aggregates when mix with bituminous binders, are likely to absorb binder at a rate of about half of the water absorption rate. The usual allowable limit for water absorption is 2% maximum for dense bituminous macadam (IRC 94-1986). However, IRC: 23-1966 has specified that for two coat bituminous surface dressing, maximum value of water absorption is 1%. IS: 2386-Part III has also suggested a maximum value of 1% for water absorption for pre-coated aggregates used for bituminous surface dressing. The experimental values of water absorption are within the allowable limit and thus

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aggregates are suitable as road materials. Slake durability test is generally performed for assessing the influence of weathering on rock and its destruction. To describe the ranking of rock durability, an index to alteration is used known as Slake Durability Index. *Gamble (1971)* has proposed a test to determine slake durability index [3]. He recommended two cycle but *Franklin and Chandra (1972)* recommended for only one cycle of revolution [2]. IS: 10050-1981 has suggested a tentative sub division of Slake Durability scale which is shown in Appendix 3. On comparing the experimental results with Indian Standard Code values, it is found that the river borne aggregates are extremely durable and are suitable for road construction purposes. Alkali Aggregate reactivity is the reaction between the active silica constituents of the aggregates and alkalis present in the cement. Aggregates containing reactiv silica will react with alkali hydroxide in concrete to form a gel that swells as it absorb water from the surrounding cement paste or environment and induce enough expansive pressure to damage concrete by cracking. IS: 2386 (Part-VII) 1963, describe two methods namely the Mortar Bar Expansion test and the Chemical test for the determination of potential reactivity of the aggregates. In this study, Chemical test has been performed to determine the alkali aggregate reactivity. Indian Standard Code has given a graph and if the plotted value falls to the right of the boundary line, then a potentially deleterious degree of alkali reactivity is indicated. By plotting the value in the prescribed graph and comparing it with the recommended value in the graph, the aggregates are found to be innocuous; hence they can be used in concrete works in road constructions. From the comparison of the test results with the standard specifications given by Indian Standard (IS) Codes and Indian Road Congress (IRCs), it has been found that both the river borne coarse aggregates of both the forms (natural and crushed) and quarry aggregates are within the specified limits and are suitable for road construction purposes.

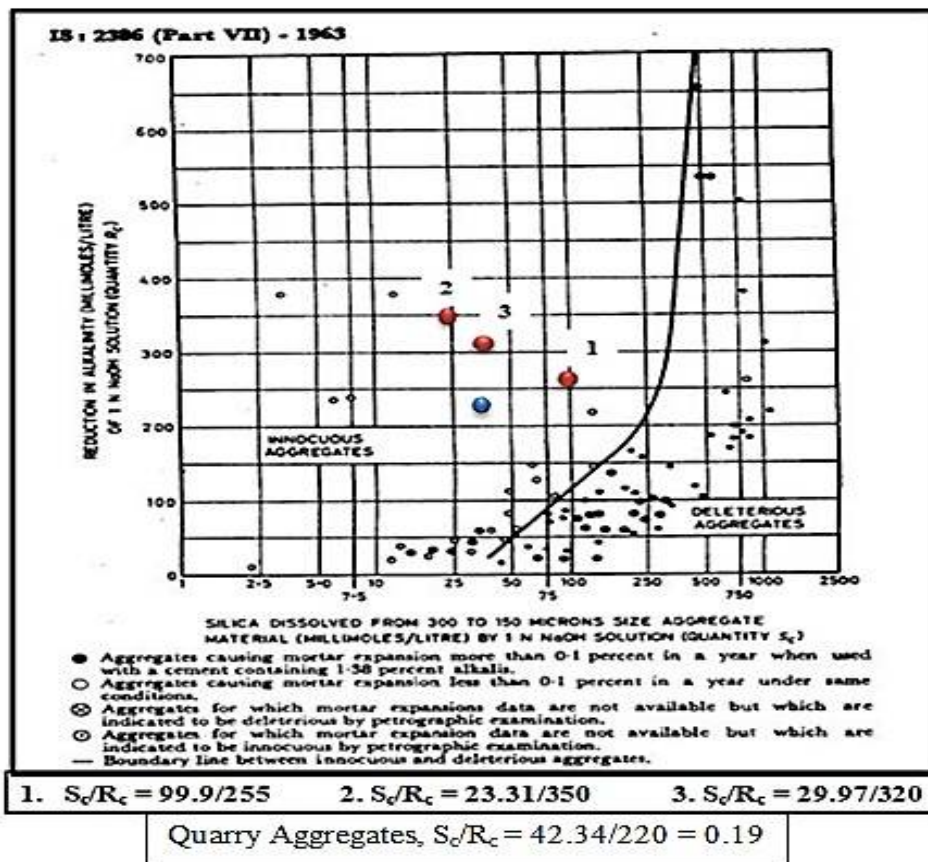


Fig. 5. Illustration of Division between Innocuous and Deleterious aggregates on the basis of reduction in Alkalinity Test

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V. CONCLUSION

From the above discussion we find that both the quarry aggregates and river borne aggregates are suitable for road construction purposes. But from the ecological point of view, the quarry aggregates are not suitable for pavement construction. This is from the fact that the quarry aggregates are obtained from blasting process and according to *JuliánKondela and BlažejPandula, in 2012*, blasting of rocks not only pollutes the environment by releasing harmful gases but also creates excessive destruction of both hilly structures and forest material. Moreover, Govt. of Assam has also banned on rock quarrying by blasting in most areas which create a huge gap between demand and supply. Hence, to meet the needs of demand and supply the river borne aggregates can be used as an alternative to quarry aggregates. Also, from the comparison of the engineering properties of the various sites from upstream to downstream, it is observed that there is some variation in the properties of the aggregates along upstream to downstream of the river. This is due to the removal of unwanted or soft materials from the rock aggregates during transportation by river from upstream to downstream side. From the economical aspect, the use of river borne aggregates is more economical considering the cost of production and transportation to work site. So, collection of aggregates from river bed in these areas would also provide a means of livelihood for the local people, which will improve the socio-economic condition of the nearby areas and also considerable reduction can be made in the cost of construction. Since lesser the anti-ecological operation to prepare the required size of aggregate from river origin and no pollution and risk for accident during blasting operation, the river borne aggregate is more eco-friendly. Again collection of the river-borne aggregates in large scale from river bed of the Kushi River will help in controlling the flood havoc of the basin. From the comparison of both natural and crushed state, and also between the river sites from upstream to downstream, it can be suggested that coarse aggregates in the crushed state from downstream are more favourable for road construction purpose provided the aggregates are within the sieve size.

VI. APPENDIX

Appendix 1: Specified Limits for Aggregate Impact Value

Sl. No.	Type of Construction	IRC Specifications	IRC
1	WBM Construction		IRC 19-2005 (3 rd Revision)
	(a) Sub-base	40% Max	
	(b) Base Coarse with Bituminous Surfacing	30% Max	
	(c) Surfacing Coarse	30% Max	
2	Bituminous Penetration Macadam (full grout)	30% Max	IRC 20-1966
3	Two coat Bituminous Surface	30% Max	IRC 23-1966
4	Bituminous Macadam		IRC 27-1967
	(a) Base Coarse	35% Max	
	(b) Binder Coarse	30% Max	
5	4cm Asphaltic concrete surface course	30% Max	IRC 29-1988
6	Built up spray grout		IRC 47-1972
	(a) Base Coarse	40% Max	
	(b) Binder Coarse	30% Max	
7	Bituminous Surface Coatings using pre-coated aggregates	30% Max	IRC 48-1972
8	Dense Bituminous Macadam	35% max	IRC 94-1986

Appendix 2: Specified limits for Aggregate Abrasion Value

Sl. No.	Type of Construction	IRC Specifications	IRC
1	WBM Construction		IRC 19-2005 (3 rd Revision)
	(a) Sub-base	50% Max	
	(b) Base Coarse with Bituminous Surfacing	40% Max	
	(c) Surfacing Coarse	40% Max	
2	Bituminous Penetration Macadam (full grout)	40% Max	IRC 20-1966

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3	Two coat Bituminous Surface	35% Max	IRC 23-1966
4	Bituminous Macadam (a) Base Coarse (b) Binder Coarse	50% Max 40% Max	IRC 27-1967
5	4cm Asphaltic concrete surface course	40% Max	IRC 29-1988
6	Built up spray grout (a) Base Coarse (b) Binder Coarse	50% Max 40% Max	IRC 47-1972
7	Bituminous Surface Coatings using pre-coated aggregates	35% Max	IRC 48-1972
8	Dense Bituminous Macadam	40% max	IRC 94-1986

Appendix 3: Tentative sub division of Slake Durability scale

Slake Durability Percentage	Classification
0 – 25	Very Low
Over 25 – 50	Low
Over 50 – 75	Medium
Over 75 – 90	High
Over 90 – 95	Very High
Over 95 – 100	Extremely High

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