Rupture Probability of Type of coarse aggregate on fracture surface of concrete

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Abstract - The various types of aggregates such as granite, dolerite, Quartzite, dolomitic limestone, limestone and river gravel were used to produce the concrete with 28-day target compressive strength of 30, 50 and 70 Mpa. The compressive strength of concrete as well as aggregates was measured to study the effect of rupture probability of aggregate on fracture surface of concrete. Also, the petrographic studies were carried out to study the texture, type of minerals present and their relative proportions in various types of aggregates. The concrete of various grades produced with a same aggregate have shown rise in RPCA with strength. However, the above relationship has ceased to exist in the concretes of same grade, made of different types of aggregates. The carbonate aggregates namely Limestone and Dolomitic limestone have produced concrete with higher RPCA irrespective of strength of concrete. The mode of origin, texture and mineralogical composition of aggregates have significant impact on their pulse velocity and thereby the pulse velocity of concrete

1. INTRODUCTION

Normally concrete when subjected higher loads fails in three different zones: Cement matrix, Aggregate cement interface (called as transition zone) and Aggregate rupture. In high strength concrete coarse aggregate rupture is relatively more than normal strength concrete. Hence, the study of aggregate on fracture of concrete gains more importance in mechanical behaviour of concrete. A parameter [1] representing the failure mode of the coarse aggregate, rupture probability of coarse aggregate (RPCA) is determined and the relationships [2] between RPCA, the water-binder ratio (W/ B) of concrete, and the size and type of coarse aggregate are analyzed.

The RPCA of concrete is closely related to its physical and mechanical properties of coarse aggregates. The aggregate may exert profound influence on the strength and deformation characteristics of concrete (6,7). It has already been recognized that the aggregate mineral properties, texture ,and shape influence the strength and durability of concrete. The characteristics of aggregate- matrix interfacial zone which influences the properties of concrete. It depends on the type of aggregate used in concrete.(8,9,10,11,12,13). The effect of aggregate is more significant on the characteristics of high strength concrete.(14,15) This paper focuses the effect of aggregate on RPCA of various grades of concrete made of granite, dolerite, quartzite, limestone, dolomitic limestone and river gravel.

Experimental Work

Materials

Grade 53 Portland cement conforming to I.S.8112-1989, with a 28-day compressive strength of 53 Mpa was used for the program. The silica fume with 93.6% silicon dioxide and a sulphonated naphthalene formaldehyde superplasticizer was used for high strength concrete. The fine aggregate was river sand having fineness modulus of 2.35. The coarse aggregates used for the present work includes granite, dolerite, Quartzite, limestone and dolomitic limestone from Kadapa district of Andhra Pradesh,India. The locally available siliceous river gravel was also used as coarse aggregate.

Mix Proportion

In order to study the effect of aggregate on the pulse velocity of concrete, three mixes were designed to have 28-day target compressive strength of 30, 50 and 70 Mpa. The concrete mixes were made with W/B ratio of 0.5, 0.35 and 0.3 with cement / binder content of 360, 480 and 550 respectively. The type of cement and fine aggregate were same for all mixes. Mixes were coded with letter D, G, Q, DL, LS and R.G. designates dolerite, granite, quartzite, dolomitic limestone, limestone and river gravel respectively. The number following the letter indicates the target strength of concrete at 28-day. The details of mix proportions are shown in table 1.

The maximum size of the aggregates for all mixes was 20 mm. The silica fume was used only in concrete with a target strength of 70 MPa. The superplasticizer was used for the mixes with water binder ratio of 0.3 and 0.35.

Testing methods

Three concrete cubes of 150x150x150 mm were cast for each concrete mix using each type of aggregate. After twenty-four hours of casting, the specimen were demoulded and cured in water for 28 days with ambient climatic conditions of 27±2° c temperature and 65±5% relative humidity. The specimens were taken out from curing tank after 28 days and tested for compressive strength and split tensile strength. Series of software programs were developed in MATLAB to analyze the image of ruptured surface of concrete of various grades made of different aggregates to compute the rupture probability of coarse aggregate (RPCA).

Results and discussions

Table.1 Mix proportions of concrete of various grades.

Mix Code	Cement (Kg/m³)	Silica Fume (Kg/m³)	Coarse Aggregate (Kg/m³)	Fine aggregate (Kg/m³)	Water (Kg/m³)	Super Plasticizer (Kg/m³)	Water binder Ratio
G 30	360	------	1138	711	180	------	0.5
D 30	360	------	1261	711	180	------	0.5
Q 30	360	------	1125	711	180	------	0.5
DL 30	360	------	1221	711	180	------	0.5
LS 30	360	------	1191	711	180	------	0.5
RG 30	360	------	1099	711	180	------	0.5
G 50	480	------	881	847	168	2.4	0.35
D 50	480	------	976	847	168	2.4	0.35
Q 50	480	------	871	847	168	2.4	0.35
DL 50	480	------	922	847	168	2.4	0.35
LS 50	480	------	946	847	168	2.4	0.35
RG 50	480	------	848	847	168	2.4	0.35
G 70	500	35	868	858	160	2.5	0.3
D 70	500	35	962	858	160	2.5	0.3
Q 70	500	35	858	858	160	2.5	0.3
DL 70	500	35	908	858	160	2.5	0.3
LS 70	500	35	932	858	160	2.5	0.3
RG 70	500	35	862	858	160	2.5	0.3

When concrete is loaded, coarse aggregate is subjected to two kinds of forces: a pull-out force and intrinsic cohesion of the coarse aggregate. Hence the relative values of these two forces are responsible for the failure mode of the aggregate. Because both pull-out force and intrinsic cohesion of coarse aggregate are directly proportional to the coarse aggregate-matrix interfacial bond strength and the strength of the coarse aggregate respectively, RPCA depends on the interfacial bond strength and the strength of coarse aggregate. The mechanical properties such as compressive strength, spilt tensile strength, flexural and RPCA of concrete made with different types of aggregates are presented in table 2

Table 2 Mechanical properties of concrete and RPCA

Mix Code	Compressive Strength (Mpa)	Flexural Strength (Mpa)	Spliting Tensile Strength (Mpa)	RPCA
G 30	37.63	6.51	2.81	61.28
D 30	41.18	6.45	2.92	34.58
Q 30	38.69	6.32	2.67	32.75
DL 30	41.18	7.25	3.13	56.00
LS 30	35.06	6.91	2.98	79.54
RG 30	34.09	5.96	2.76	23.25
G 50	56.64	9.05	3.55	71.10
D 50	60.12	9.15	3.2	42.01
Q 50	54.85	8.81	3.53	52.53
DL 50	55.38	7.7	3	61.13
LS 50	55.20	9.25	3.9	80.00
RG 50	51.80	8.42	3.35	40.30
G 70	74.78	10.06	4.32	75.80
D 70	75.85	10.01	4.51	56.00
Q 70	66.34	9.4	3.7	57.13
DL 70	70.57	10.25	3.82	71.60
LS 70	71.56	10.27	4.03	82.03
RG 70	63.06	8.8	3.75	49.09

The relationship between RPCA and type of aggregate used in concrete is presented in fig 4.1. It is evident that limestone concrete has exhibited highest RPCA among all types. It is followed by Granite, Dolomitic Limestone, Quartzite, Dolerite and River gravel concrete. The variations in texture mineral constituents and their relative proportions have imparted variations in RPCA values of concrete made of above type of aggregate.

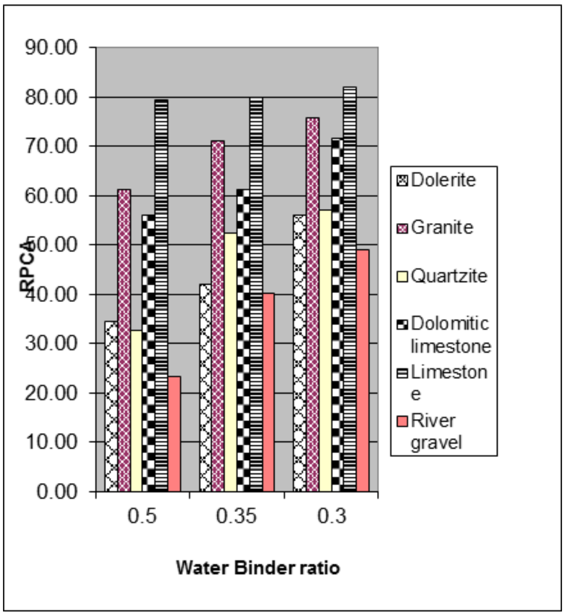

Fig. 1 Relationship between RPCA and Concrete made of different aggregates

It is surprising to note that the RPCA of granite concrete is much higher than other types of concrete other than the limestone concrete. It is due to the fact that the presence of minerals such as Sericite, Muscovite, Biotite and Chlorite with very low friction coefficient makes it more susceptible to fail under load.

RPCA of concrete – W/B ratio

The water binder ratio is the foremost and important factor which influences the bond strength between the matrix and aggregate. RPCA of concrete of various grades made of same aggregate is found to be increasing with decrease in water binder ratio. It is obvious that the interfacial zone is the weakest in the concrete with higher water binder ratio. The weaker transition zone results in debonding of coarse aggregate. However, concrete with low water binder ratio, the strength of interfacial zone is greatly improved which results in more and more rupture of coarse aggregate thereby increasing the RPCA value.

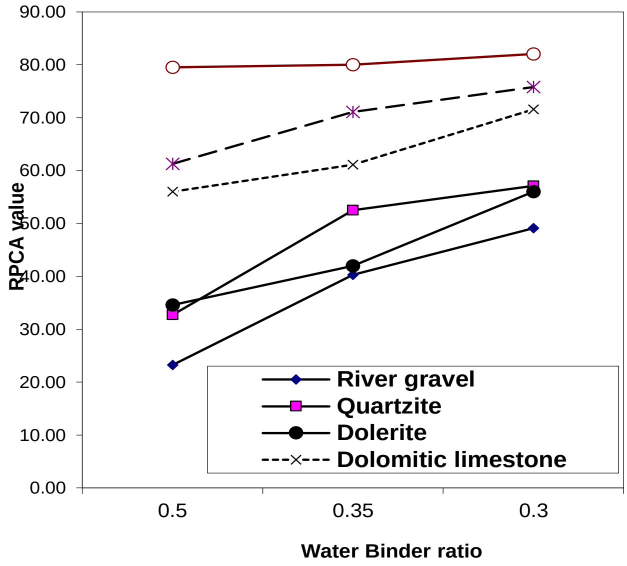

Fig. 2 Relationship between different concrete RPCA with W/B ratio.

However, concrete of same grades made of various aggregates have shown marked variation in RPCA. The variation in mineralogical composition,. their relative proportions, surface texture responsible for variations in RPCA of concrete of same grade made of different aggregate. The effect of mineralogical composition on RPCA of concrete has been explained earlier.

The texture of aggregate also affects the bond strength between matrix and aggregate. The aggregate exhibits various surface texture such as crystalline, smooth, granular, glossy, etc., all crystalline aggregates such as Granite, Dolerite, Quartzite except River gravel exhibits crystalline texture (rough surface). This type of texture enhances mechanical bonding between the matrix and the aggregate and there by influence the RPCA.

In spite of higher bond strength, RPCA of concrete made of Quartzite and Dolerite have shown lower RPCA due to the internal texture of aggregate. The sub-ophetic texture in dolerite and fine interlocking nature of grains in quartzite reduced the RPCA of concrete. The higher RPCA in granite concrete is noted due to the presence of foliated minerals in the aggregate. The concrete made of river gravel has shown least RPCA than other concrete. It is due to the weaker bond strength between the matrix and aggregate because of smooth surface texture of aggregates.

RPCA of concrete – Compressive strength of concrete

The strength characteristics such as compressive strength, split & flexural strength depends on W/B ratio and the type of aggregate and their characteristics. The figure 4.3 shows the characteristics between RPCA and compressive strength of concrete.

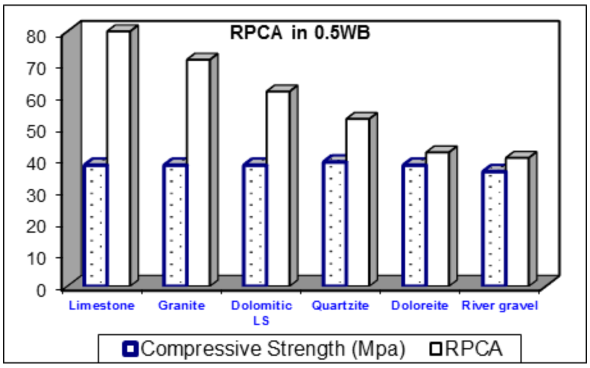

Fig 3: Relationship between Compressive strength and RPCA in 0.5WB

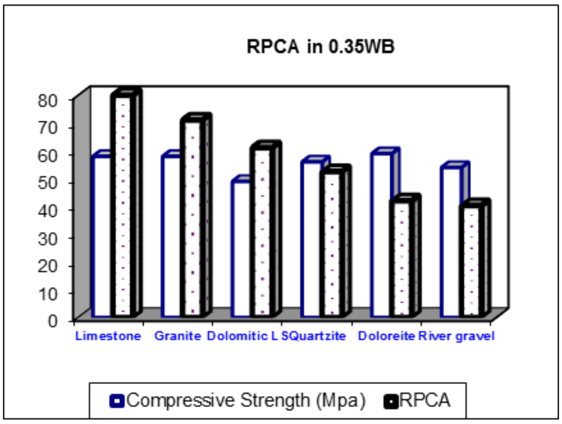

Fig 4: Relationship between Compressive strength and RPCA in 0.35WB

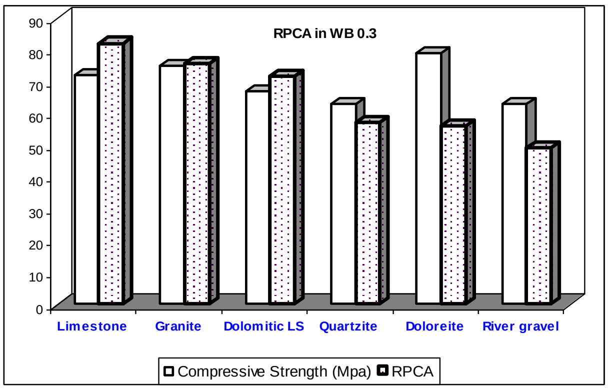

Fig 5: Relationship between Compressive strength and RPCA in 0.3WB

It is evident from the above figures that RPCA value dependent not only on the compressive strength of concrete but also the type of aggregate used. It was observed that RPCA is higher in all grades of concrete made of Limestone, Granite and Dolomitic Limestone aggregate. Even in the concrete made of these aggregate ratio of 0.5, having weaker bonding between matrix and aggregate has shown higher RPCA value. The concretes of various grades made with Quartzite, Dolerite and River gravel have recorded lower RPCA values. However with increase in strength of concrete made of same aggregates the RPCA value of concrete increased considerably.

In the case of higher grade concrete it was observed that the concrete made of River gravel and Quartzite with relatively less compressive strength have shown lesser RPCA than the Limestone and Granite concrete having higher strength. This shows that the aggregate properties plays equal important role in RPCA of concrete.

RPCA of concrete - Tensile Strength

The relationship between flexural strength and RPCA is shown in Fig.4.4 It is observed that the relationship is same as what was observed in the case of compressive strength. The river gravel concrete with very low flexural strength has shown least RPCA value. At the same time, the limestone concrete having highest flexural strength yield maximum RPCA values. Also, Dolerite concrete with relatively higher flexural strength than Quartzite has exhibited lower RPCA value. This trend shows that the type of coarse aggregate has more impact on RPCA than flexural strength of the concrete. The relationship between split tensile strength of concrete and RPCA is same as flexural strength.

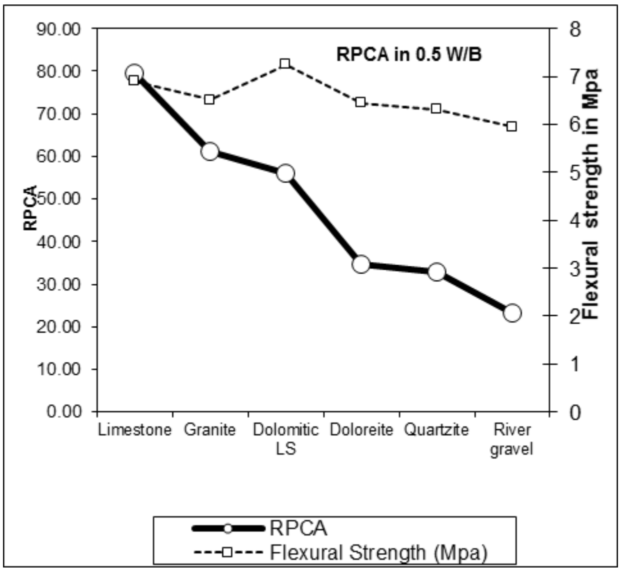

Fig.6: Relationship between Flexural strength and RPCA at 0.5WB

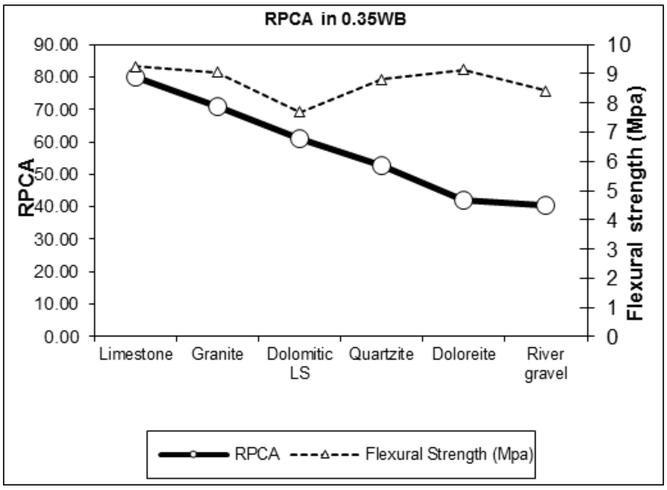

Fig.7: Relationship between Flexural strength and RPCA at 0.35WB

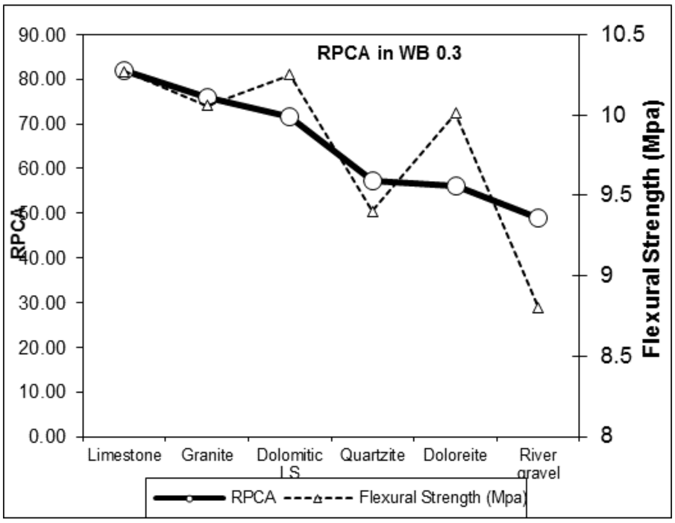

Fig.8: Relationship between Flexural strength and RPCA at 0.3WB

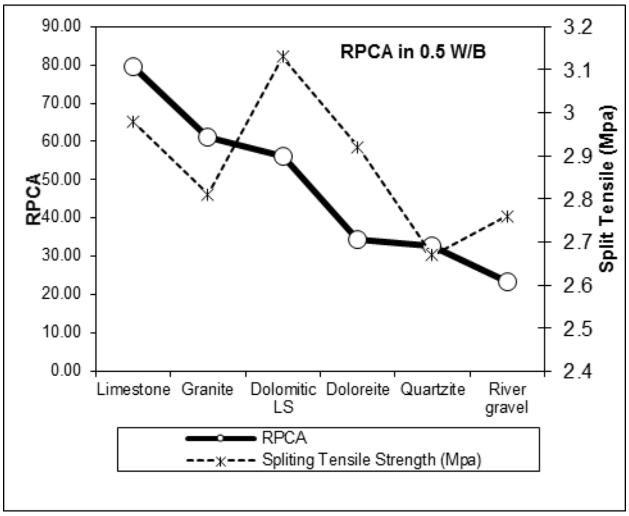

Fig.9: Relationship of Splitting tensile strength and RPCA at 0.5WB

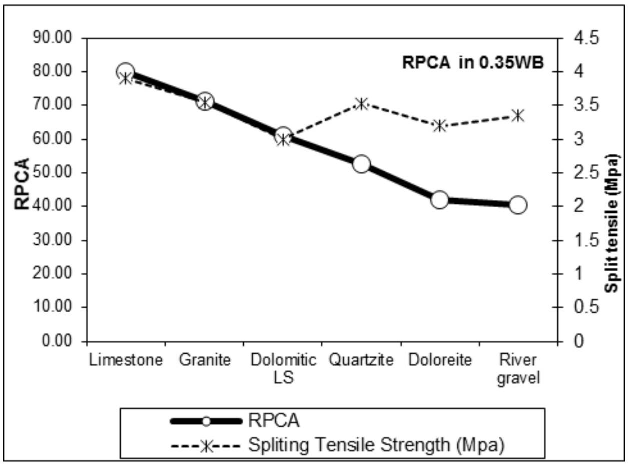

Fig.10: Relationship of Splitting tensile strength and RPCA at 0.35WB

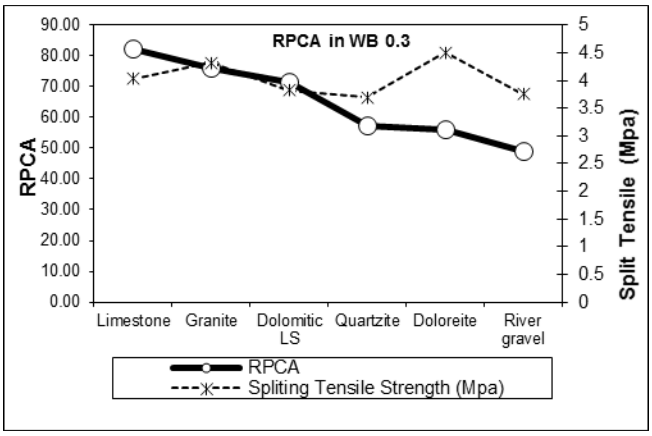

Fig.11: Relationship of Splitting tensile strength and RPCA at 0.3WB

3. CONCLUSIONS

In the present study an attempt has been made to analyze the effect of the type of Coarse aggregate on rupture probability of concrete using Digital Image Processing and following conclusions are drawn.

1. The Ruptured surfaces of concrete of various grades made of different aggregates were analyzed using the developed software programs in Matlab, to compute the Rupture Probability of Coarse Aggregate (RPCA).
2. Limestone concrete has exhibited highest RPCA among all types. It is followed by Granite, Dolomitic Limestone, Quartzite, Dolerite and River Gravel concrete.
3. The highest RPCA in concrete with Limestone and Dolomitic Limestone is due to chemically improved bond strength between matrix and aggregates because of the chemical interaction between the Calcite/Dolomite present in the aggregate and the Calcium hydroxide in hydrated cement paste.

4. The Granite concrete has exhibited highest RPCA value among the concretes made of crystalline aggregates. It is due to the presence of minerals Sericite, Muscovite and Biotite which enhances the rupture of Granite aggregate.
5. RPCA of concrete of various grades made of same aggregate is found to be increasing with decrease in water binder ratio. However, the concrete of same grade made of various aggregates has shown marked variation in RPCA. It is due to the influence of type of aggregate used.
6. The increase in strength of concrete made of same aggregate has improved the RPCA value. However, this relationship cannot be generalized in the case of concrete of a particular grade made of different aggregates, the Dolerite concrete with highest compressive strength has yielded very low RPCA value when whereas the Limestone concrete with relatively low compressive strength has yielded highest RPCA

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