International Journal of Scientific Research in Engineering and Management (IJSREM)
Volume: 08 Issue: 06 | June - 2024 SJIF Rating: 8.448 ISSN: 2582-3930

REVIEW OF THE EFFECTS OF GEOLOGICAL AGGREGATE PROPERTIES ON THE WORKABILITY OF HIGH-STRENGTH CONCRETE

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Abstract - *Aggregate makes roughly 60–80% of the volume of concrete and is an essential component. They make concrete more substantial, lessen its shrinkage, and also have an economic impact. Plus, it has always been thought of as an inert filler material and is very cheap compared to other components. Consequently, the necessary emphasis on understanding the potential impact of aggregates on concrete characteristics was lacking. As a result, learning more about aggregate is crucial for making concrete with the right properties. The proportions of the concrete mix, the qualities of freshly mixed concrete, and the strength, dimensional stability, and longevity of the concrete are all greatly affected by the aggregates' characteristics. As a result, this research aims to investigate how aggregate geology affects concrete's performance. In this research, five different kinds of coarse aggregates were examined for their geological properties and how they impact the performance of concrete. These aggregates are Grey Granite (GG), Anorthosite (AS), Charnockite (CK), Limestone (LS), and Gneiss (GS). Researchers looked examined the aggregates' mineralogical composition, mineral proportions, texture, structural features, and other geological traits. M30, M50, and M80 grades of concrete were subsequently developed by combining different kinds of aggregates in concrete mixtures. It took 28 days for the concrete examples to cure after casting. We measured the compressive, split tensile, flexural, modulus of elasticity, impact, fracture, and rupture energies of the curing specimens, as well as the structural behaviour of the concrete and the coarse aggregate RPCA. Concrete mixes containing GG, AS, CK, or GS aggregates with a rough surface had worse workability compared to mixes using LS aggregates with a smooth surface, according to the findings. Aggregate texture determines surface roughness. The compressive strength of high strength concrete (HSC) concrete mixes (M80 grade) formed of various aggregates varied greatly (72 to 89 MPa), suggesting that the aggregates' geological properties significantly affected the compressive strength of HSC, but had no effect on normal strength concrete (NSC). After the AS, CK, LS, and GS mixes, the GG mix showed the greatest compressive strength. As concrete's compressive strength has increased, it has been easier to mix concrete of varying grades using the same particles. The compressive strength of concrete mixes of the same grade but with various aggregates showed large differences, suggesting that the aggregates' geological properties were the most important factor. Tensile and flexural strengths, modulus of elasticity, impact and fracture energies, RPCA, and structural performance of concrete all followed a similar pattern. Because of their roughness, GG, AS, CK, and GS aggregates showed a relatively rough surface, which improved mechanical contact with the matrix and increased concrete strength. But the flat surface of limestone aggregate makes it unable to provide concrete a greater mechanical connection. The increased compressive strength of AS, GG, and CK aggregates was caused by the minerals present, the percentage of minerals, the texture, and the structure. In order to increase the concrete's strength, these particles provide a greater physical connection with the matrix. Concrete was not as strong because to the lower compressive strength of the limestone and gneiss. The changes in the texture, mineralogy, mineral proportion, Significant differences in concrete characteristics were caused by the hardness of minerals and the structure of particles. Because their properties meet the requirements outlined in BIS -383, the aforementioned coarse aggregates may be used to make NSC. The findings clearly show that in order to make M80 grade concrete, the only acceptable coarse aggregates are grey granite, anorthosite, and charnockite; limestone and gneiss are not acceptable. Therefore, while choosing aggregates to make High Strength Concrete, it is crucial to think about the aggregates' geological properties.*

Key Words*: *Aggregates, Structural Behaviour, Compressive Test, Split Tensile Test, Flexural Test, Modulus of Elasticity Test, Impact Test, Fracture Test, Rupture Energies.

1.INTRODUCTION

Aggregate is one of the important constituents in concrete and it occupies 60 to 80% of the volume, they provide body to concrete, reduce shrinkage and also affect economy. Further, it is relatively in expensive than other constituents and usually it has been considered all along as inert filler material. Therefore, efforts have been made by several researchers to study the effect of different types of aggregates on performance of concrete.

1.1 Coarse Aggregate

Generally, natural mineral aggregates are being extensively used for making different types of concrete. The normal weight, light-weight and heavy weight natural mineral aggregates are being used to produce normal weight concrete, light weight and heavy weight concrete respectively. Generally, properties of aggregate such as size, gradation, water absorption, specific gravity, texture, angularity index, soundness, crushing value, impact value, los angeles abrasion, ten percent fines, thermal propertiesetc are taking in to consideration to judge quality of aggregates. Water absorption of aggregate is one of the important properties which influences mix design as well as workability of concrete. Generally, aggregates with mafic minerals such as amphibole, pyroxenes, olivine, iron oxides exhibit relatively higher specific gravity than felsic minerals such quartz, feldspar etc. All mechanical properties of aggregates such as crushing value, impact value, abrasion value, soundness, stone polishing value etc depend on geological characteristics of rocks such as mineralogical composition, proportion of minerals, texture, structure, alteration of minerals etc. These aggregates undergo chemical reaction in the presence of water and release sulfuric acid in concrete, resulting in deterioration of concrete.

1.2 Scope of the Study

Several researchers have attempted to study effect of surface texture aggregate on workability of concrete. Also, efforts have been made to evaluate role of surface texture of aggregate on bond strength between aggregate and matrix in concrete. However, almost entire research work was focused only type of aggregates without taking geological characteristics such as mineralogical composition, proportion of minerals, texture, structure, alteration of minerals in aggregates in to consideration.

1.3 Objectives

1. To evaluate geological characteristics, physical and mechanical properties of aggregates such as Grey Granite (GG), Anorthosite (AS), Charnockite (CK), Limestone (LS) and Gneiss (GS) and to find out relationship between geological characteristics of aggregates and physical as well as mechanical properties of aggregates.

2. To assess role of geological characteristics of aggregates on strength characteristics of concrete such as compressive, tensile, flexural and also modulus of elasticity.

3. To determine fracture energy of normal strength concrete(NSC) and high strength concrete (HSC) made with aggregates of various types and to evaluate its relationship with geological characteristics of aggregates.

4. To assess the effect of geological characteristics of aggregate on structural behavior of RC beam made withdifferent types of coarse aggregate.

2. EXPERIMENTAL WORK

2.1 Cement

Ordinary Portland cement of 53 Grade was used for making concrete. The physical and chemical characteristics of cement were measured using procedure prescribed by BIS: 4031-1996 (Reaffirmed 2011) and BIS: 4032-1985 (Reaffirmed 2014).

Table -1: Physical characteristics of cement

S.No	Physical properties	Test Results	Requirement as per BIS: 12269-2013
1.	Specific gravity	3.14	-
2.	Standard consistency	33%	-
3.	Initial setting time	53 min	Min. 30 min
4.	Final setting time	139 min	Max. 600 min
5.	Fineness by sieving	2%	Max. 10%
6.	Soundness	0.5 mm	Max. 10 mm
7.	Compressive strength: 3 days 7 days 28 days	 28 39 56	 27 MPa 37 MPa 53 MPa

Table -2: Chemical characteristics of cement

S.No	Constituents	Test Results	Requirements as per BIS: 12269-2013
1	Calcium Oxide (CaO)	62.00%	-
2	Silicon dioxide (SiO_2)	20.10%	-
3	Aluminum oxide (Al_2O_3)	5.73%	-
4	Iron Oxide (Fe_2O_3)	5.38%	-
5	Magnesium oxide (MgO)	0.95%	Not more than 6.0%
6	Sulfur trioxide (SO_3)	2.71%	Max 3.0% when C_3A > 5.0 Max 2.5% when C_3A< 5.0
7	Ratio of alumina/Iron oxide	1.05	Min. 0.66
8	Lime saturation factor	0.94	0.80 to 1.02
9	Chloride content	0.01%	Max 0.1 %
10	Total loss on ignition	2.42	Max 4%
11	Insoluble residue	0.7	Max 5%

2.2 Silica Fume

Silica fume is a by-product of silicon and ferrosilicon metal. Its particles are spherical in shape with an average diameter of 0.1 micron.

2.3 Fine Aggregate

In the present work, locally available river sand was used as fine aggregate. The specific gravity and fineness modulus of fine aggregate are found to be 2.65 and 2.5 respectively.

Table -3: Chemical characteristics of cement

S.No	Test	Result
1.	Specific Gravity	2.65
2.	Water Absorption	0.55%
3.	Fineness Modulus	2.5
4.	Grading Zone	II

2.4 Coarse Aggregate

Five types of aggregate such as Grey Granite (GG), Anorthosite (AS), Charnockite (CK), Limestone, (LS) and Gneiss (GS) are used as coarse aggregate in the present work (Figure 2.1).

Fig -1: Sample of Aggregates

Fig -2: Compressive Strength Testing

2.5 Mix Proportion

In the present work, concrete mixes were designed to produce M30, M50 and M80 grade of concrete. Five mixes were made using different types of coarse aggregates for each grade of concrete. The maximum size of coarse aggregate used for all mixes was 19 mm. The silica fume and super-plasticizer was used in M50 &M 80 grade mix.

Table -4: Mix Proportion of NSC AND HSC Mixes

Grade of concrete	Mix code	Cement (kg/m^3)	Silica fume (kg/m^3)	FA (kg/m^3)	CA (kg/m^3)	Water (kg/m^3)	w/b Ratio	Super-Plasticizer (kg/m^3)
M30	GG	340	-	874		140	0.42	-
	AS	340	-	874		140	0.42	-
	CK	340	-	874		140	0.42	-
	LS	340	-	874		140	0.42	-
	GS	340	-	874		140	0.42	-
M50	GG	450	74	774		150	0.33	5.6
	AS	450	74	774		150	0.33	5.6
	CK	450	74	774		150	0.33	5.6
	LS	450	74	774		150	0.33	5.6
	GS	450	74	774		150	0.33	5.6
M80	GG	550	60	714		160	0.26	6.9
	AS	550	60	714		160	0.26	6.9
	CK	550	60	714		160	0.26	6.9
	LS	550	60	714		160	0.26	6.9
	GS	550	60	714		160	0.26	6.9

2.6 Casting and Curing

The cube, cylinder, and prism specimens were cast to evaluate properties of normal strength concrete and high strength concrete made with different aggregates. Specimens were demoulded after 24 hrs and cured in water till the date of testing of specimens.

Table -5: Details of casted test specimens

S.No	Name of the Test	Type of Specimen	Specimen Dimension (mm)	No. of concrete mixes	No. of Specimens
1	Compressive Strength	Cube	150 x 150x 150	15	45
2	Split Tensile Strength & RPCA	Cylinder	150 x 300	15	45
3	Flexural strength	Prism	500 x 100x 100	15	45
4	Elastic Modulus	Cylinder	150 x 300	15	45
5	Fracture Energy	Prism	500 x 100 x 100	15	45
6	Impact Strength	Cube	100 x 100 x 100	15	45
8	Structural behavior	RCC Beam	1350 x 180 x120	5	15
Total Specimens					285

Fig -3: Split tensile Strength Testing

Fig -4: Flexural Strength Testing

3. RESULTS AND DISCUSSION

Normal and High Strength Concrete has been explored. The properties include compressive, flexural, splitting tensile strength, modulus of elasticity, impact strength, fracture energy and rupture probability of coarse aggregate (RPCA).

Table -6: Geological Characteristics of Coarse Aggregate

S.No	Name of the Aggregate	Mode of Origin	Texture	Mineralogical Composition (%)
1	Grey granite	Igneous rock	Phaneritic-hypocrystalline In-equigranular Subhedral Shape	Plagioclase Feldspar: 60-65 Microcline: 20-25 Quartz : 5-10 Clinopyroxene: 1- 2
2	Anorthosite	Igneous rock	Phaneritic-euhedral shape Equigranular grain, Panidiomorphic Holocrystalline	Plagioclase Feldspar: 55-60 Quartz: 10-15 Amphibole: 25-30
3	Charnockite	Metamorphic Rock	Coarse grained, Quartz grain showing anhedral shape	Quartz: 50-55 Plagioclase Feldspar: 40-50 Orthopyroxene: 5-10 Biotite: 1-2
4	Limestone	Sedimentary Rock	Long contact to concave convex contact	Calcite: 85-90 Albite: 10-15
5	Gneiss	Metamorphic Rock	Coarse grained rock with gneissosity	Quartz: 20-25 Biotite: 25-30 Plagioclase Feldspar: 45-50 Garnet: 1- 2 Amphibole: 3-5

3.1 Physical and Mechanical Properties of Coarse Aggregate

The physical and mechanical properties of various types of aggregateswere measured and results are presented in Table 7. It is evident from results that coarse aggregates have demonstrated considerable variations in physical as well as mechanical characteristics. Among different types of coarse aggregates, grey granite aggregate has exhibited best performance in terms of physical and mechanical characteristics. In fact, presence of considerable amount of amphibole mineral (25-30%) adversely influenced mechanical characteristics of anorthosite aggregate.

Table -7: Physical and Mechanical Characteristics of Coarse Aggregate

S. No	Properties	Grey Granite (GG)	Anorthosite (AS)	Charnockite (CK)	Limestone (LS)	Gneiss (GS)
1	Specific Gravity	2.72	2.79	2.77	2.71	2.74
2	Texture	Crystalline	Crystalline	Crystalline	Smooth	Crystalline
3	Water absorption (%)	1	1.1	0.7	1	1.2
4	Flakiness index (%)	18	22	20	18	19
5	Elongation index (%)	20	32	25	15	11
6	Angularity number	7	6	6	5	3
7	Impact Value (%)	16	17	18	17	20
8	Crushing Value (%)	20	22	23	22	26
9	Abrasion Value (%)	16	17	22	20	19
10	Compressive strength of rock(Mpa)	158	162	146	91	62

Even charnockite aggregate having 50- 55% of quartz content failed to perform better than grey granite due to formation of minerals in the form of strips. Limestone aggregate, which is sedimentary in origin, hasexhibited mechanical properties on par with anothosite and charnockite aggregates. Further, aggregates exhibited wide variations in compressive strength and it is ranging from 62 to 162 MPa. The gneiss has demonstrated least compressive strength of 62MPa due to gneissose structure and presence of biotite mica to considerable proportion. These two characteristics ofaggregates influence global properties of concrete adversely.

3.2 Workability of Fresh Concrete

The workability of concrete mixes made of different aggregate was measured with the help of slump cone test and test results are furnished in Table 8. The results show that workability of normal strength concrete mixes vary in the range of 60 to 80 mm. However, high strength concrete mixes exhibiting workability in the range of 40 to 75mm.

Table -8: Workability of Fresh Concrete Mixtures

Mix Code	Type of Coarse Aggregate	Density (kg/m3)	Slump(mm)
GG30	Grey Granite	2400	60
AS30	Anorthosite	2461	70
CK30	Charnockite	2447	70
LS30	Limestone	2410	80
GS30	Gneiss	2436	75
GG50	Grey Granite	2396	52
AS50	Anorthosite	2471	65
CK50	Charnockite	2464	68
LS50	Limestone	2443	75
GS50	Gneiss	2452	70
GG80	Grey Granite	2426	40
AS80	Anorthosite	2485	45
CK80	Charnockite	2472	47
LS80	Limestone	2457	55
GS80	Gneiss	2468	50

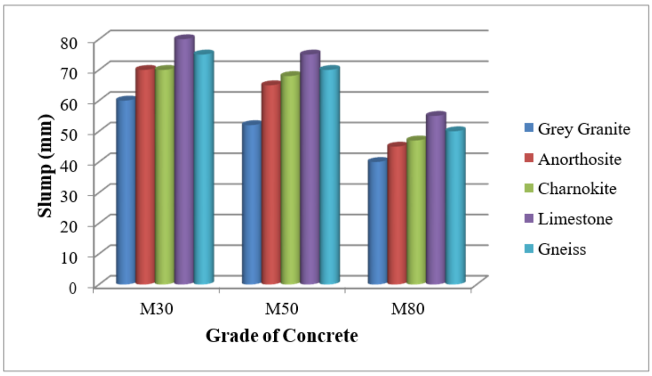

Fig -5: Relationship b/w different types of coarse aggregate and workability of concrete

4. MECHANICAL PROPERTIES OF HARDENED CONCRETE

4.1 Compressive Strength

The result shows that compressive strength of M30 grade of concrete made of different types aggregates vary in the range of 37 to 40MPa (Figure 6). However, strength of different type of concrete mixes vary in the range of only 2.5 to 7.4% indicating that type of aggregate has not shown considerable effect on compressive strength of normal strength concrete. Nevertheless, LS concrete mix also demonstrated compressive strength almost on par with other concrete mixes.

Table -9: Strength properties of Normal and High strength concrete

Mix Code	Compressive Strength (MPa) fc			Split Tensile Strength (MPa) fst			Flexural Strength(MPa), f_t			Modulus of Elasticity (GPa), E		
	Mean	SD	COV	Mean	SD	COV	Mean	SD	COV	Mean	SD	COV
GG30	40.4	1.14	2.82	3.16	0.01	0.32	5.58	0.09	1.56	34.9	0.26	0.76
AS30	39.4	0.95	2.42	3.06	0.02	0.5	5.37	0.10	1.80	32.7	0.40	1.24
CK30	38.6	1.67	0.95	2.47	0.04	1.76	5.25	0.07	1.33	28.6	0.21	0.73
LS30	38.1	0.65	1.71	2.98	0.02	0.51	5.17	0.12	2.24	27.4	0.21	0.76
GS30	37.4	0.86	2.30	2.85	0.03	0.88	5.04	0.02	0.30	25.3	0.26	1.05
GG50	58.4	0.96	1.65	3.74	0.02	0.56	6.86	0.03	0.39	40.7	0.15	0.38
AS50	54.2	1.06	1.95	3.69	0.03	0.72	6.47	0.02	0.32	38.2	0.32	0.84
CK50	54.5	0.81	1.48	3.52	0.04	1.02	6.24	0.01	0.09	37.5	0.31	0.81
LS50	53.2	1.10	2.07	3.44	0.05	1.31	6.19	0.04	0.65	36.7	0.23	0.63
GS50	49.1	0.81	1.65	3.27	0.02	0.53	5.87	0.02	0.35	35.5	0.36	1.02
GG80	89.4	0.78	0.87	4.47	0.01	0.22	7.84	0.01	0.07	48.5	0.95	1.97
AS80	88.2	0.85	0.97	4.25	0.03	0.72	7.63	0.02	0.27	46.4	0.86	1.86
CK80	81.5	1.28	1.57	4.16	0.04	0.91	7.41	0.01	0.13	44.3	0.82	1.85
LS80	74.2	0.57	0.77	4.04	0.05	1.13	7.24	0.02	0.28	42.5	1.00	2.36
GS80	71.5	1.05	1.47	3.87	0.03	0.68	6.87	0.02	0.22	38.2	1.05	2.74

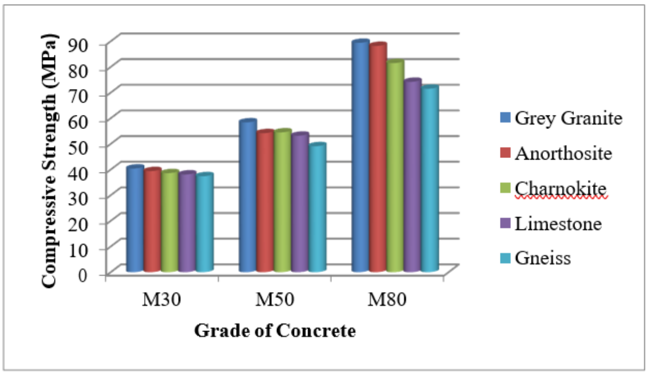

Fig -6: Compressive strength of concrete with different types of aggregates

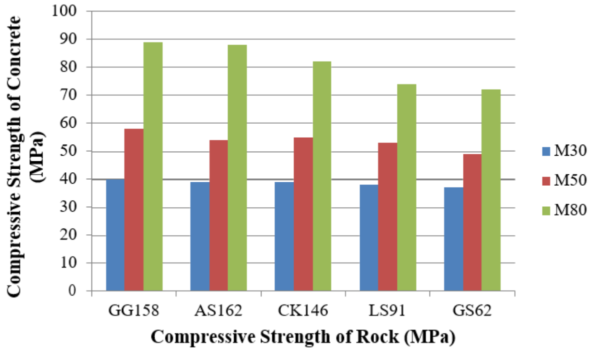

Fig -7: Compressive strength of different rock with compressive strength of concrete

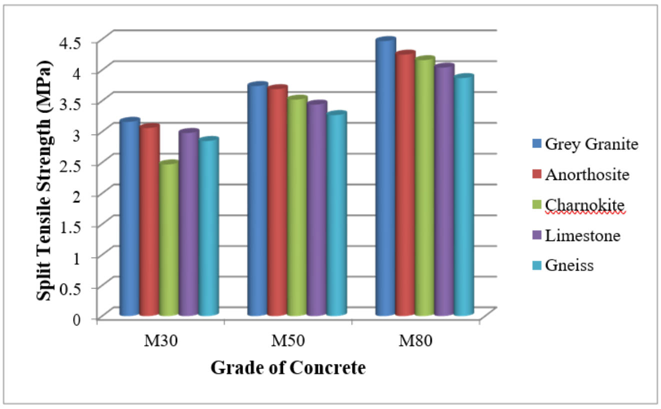

Fig -8: Splitting Tensile Strength of concrete with different types of aggregate

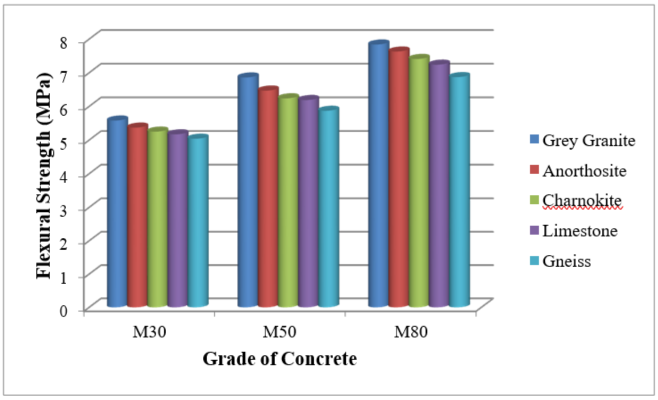

Fig -9: Flexural Strength of concrete with different types of aggregate

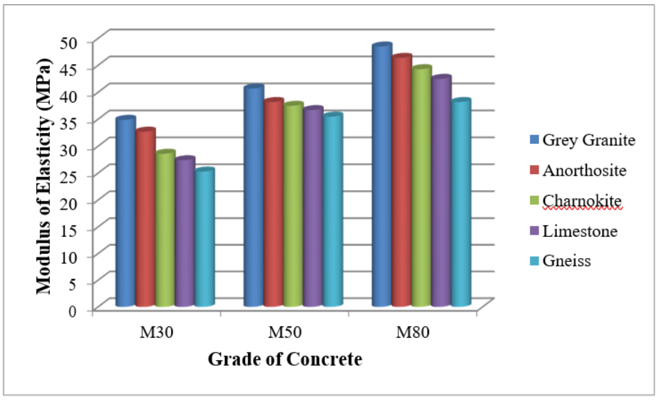

Fig -10: Modulus of elasticity of concrete with different types of aggregate

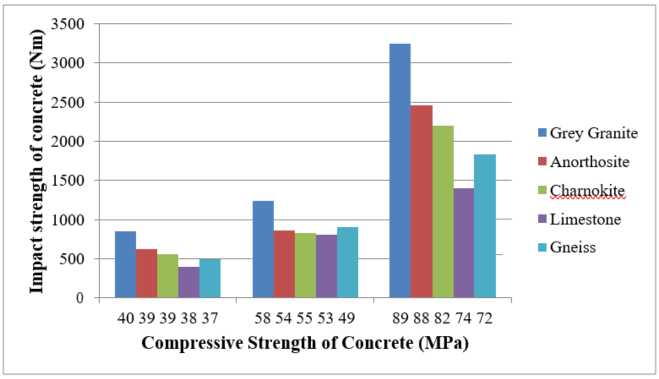

Fig -11: Relationship b/w compressive strength & impact strength

5.CONCLUSIONS

1. The aggregates selected for the present study are grey granite, anorthosite, charnockite, limestone and gneiss. Among these aggregates, grey granite has exhibited best performance in terms physical and mechanical properties and it is followed by anorthosite, charnockite, limestone and gneiss.
2. The geological characteristics such as texture, mineralogical composition, proportion of various minerals and structure significantly influenced physical and mechanical properties of aggregates. The texture made GG, AS, CK and GS aggregates to exhibit very rough surface and thereby possess better mechanical interaction with matrix to contribute higher strength to concrete. However, limestone aggregate having smooth surface fail to provide mechanical interaction with matrix in concrete.
3. The minerals present, proportion of minerals, texture and structure of AS, GG and CK aggregates made them to demonstrate higher compressive strength. Therefore, these aggregates provide better physical interaction with matrix to enhance strength of concrete. The limestone and gneiss having less compressive strength due to mineralogical composition and structure respectively may not be able to provide required physical interaction to impart higher strength to concrete.

4. The concrete mixes made of GG, AS, CK and GS aggregates demonstrated relatively low workability than concrete mix made of LS aggregate. The relatively smooth surface texture of limestone aggregate due to presence of extremely fine grain minerals, made it to impart higher workability to concrete than GG, AS, CK and GS aggregates having very high surface roughness.
5. M30 grade of concrete made of different types aggregates exhibited compressive in the range of 37 to 40 MPa, indicating that type of aggregate has not shown considerable effect on compressive strength of normal strength concrete. It is due to the fact that aggregate is not strength limiting factor as it is stronger than cement matrix and transition zone.
6. The HSC concrete mixes (M80 grade) made of different aggregate yielded compressive strength in the range of 72 to
7. 89 MPa indicating that geological characteristics of aggregates strongly influenced compressive strength of concrete. The GG and GS mixes demonstrated highest and lowest compressive strength of 89 and 72 MPa respectively. The compressive strength of GG mix was 7.2%, 6.7%, 8.9% and 15.9% higher than AS, CK, LS and GS mix respectively.
8. The variations in split tensile strength, flexural strength, and modulus of elasticity of concrete made with different aggregates are same as that of compressive strength. The NSC concrete made of different aggregates demonstrated wide variations in modulus of elasticity than HSC due to higher volume fractions of coarse aggregate.
9. Further, The statistical analysis carried out on strength properties and modulus of elasticity established the reliability of test results.
10. Impact energy of concrete mixes increased with grade of concrete made of same aggregate. However, impact strength of concrete mixes of same grade varies considerably with type of coarse aggregate used in the mix. Aggregates such as GG, AS, CK and GS having rough surface and also silicate minerals having higher hardness made concrete mixes to exhibit better impact energy. However, LS aggregate with smooth surface and calcite mineral with relatively less hardness produced concrete with low impact energy.
11. The fracture energy of concrete mixes made of different aggregates is exhibiting linear relationship with compressive strength. Further, characteristic length of fracture in concrete is demonstrating inverse relationship with compressive strength of concrete. The brittle fracture behavior of HSC due to low w/b ratio and incorporation of silica fume reduced characteristic length of fracture
12. Among all concrete mixes, GG mix has exhibited highest fracture energy and it is followed by AS, CK, LS and GS mix. The texture and presence of quartz and feldspar in higher proportion in grey granite aggregate made GG concrete mix to exhibit highest fracture energy. However, presence of amphibole minerals in anorthosite aggregate to the extent of 25 to 30%, reduced fracture energy of AS concrete mix and exhibited fracture energy marginally less than GG concrete mix.
13. Both LS and CK concrete mixes exhibited almost same fracture energy but less than fracture energy of GG and AS mixes. The LS concrete mix exhibited relatively less fracture energy due to smooth surface texture and calcite mineral present in LS aggregate. Also, CK concrete mix demonstrated less fracture energy due to orientation of mineral grains in the form of strips, in spite of having quartz in higher proportion. However, GS concrete mix exhibited low fracture energy due to gneissose structure present in aggregate.
14. The RPCA of M30, M50 and M80 grade concrete vary in the range of 35 to 69%, 58 to 71% and 63 to 84% respectively. It is evident from results that RPCA is increasing with grade of concrete/compressive strength of concrete mixes made of same type of aggregate. However, concrete mixes of same grade made with different types of aggregates exhibited significant variation in RPCA, indicating that geological characteristics of aggregates do play significant role in influencing RPCA.

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