American Journal of Applied Scientific Research
2017; 3(3): 28-36
http://www.sciencepublishinggroup.com/j/ajasr
doi: 10.11648/j.ajasr.20170303.12
ISSN: 2471-9722 (Print); ISSN: 2471-9730 (Online)

Properties of Concrete as Influenced by Shape and Texture of Fine Aggregate

Kiran Kumar Poloju[*], **Vineetha Anil, Ram Kishore Manchiryal**

Department of Civil Engineering, Middle East College, Muscat, Oman

Email address:

kpoloju@mec.edu.om (K. K. Poloju), vineetha@mec.edu.om (V. Anil), ramkishore@mec.edu.om (R. K. Manchiryal)

[*]Corresponding author

To cite this article:

Kiran Kumar Poloju, Vineetha Anil, Ram Kishore Manchiryal. Properties of Concrete as Influenced by Shape and Texture of Fine Aggregate. *American Journal of Applied Scientific Research*. Vol. 3, No. 3, 2017, pp. 28-36. doi: 10.11648/j.ajasr.20170303.12

Received: March 16, 2017; **Accepted**: April 7, 2017; **Published**: November 8, 2017

Abstract: Shape and texture of aggregate is one of the major parameter that influence the properties of fresh and hardened state of concrete. The present methods on mix proportioning of normal concrete have incorporated shape characteristics of aggregate. Since the classification of aggregates is very broad. It often leads to inconsistent results and the property of concrete varies. Thus quantification of these properties is essential to further rationalize the process of concrete mix proportioning. Various codes have envisaged certain tests that indicate the shape characteristics of aggregate. Flakiness index, Elongation index and angularity number, Index of aggregates particle shape and texture (IAPST). An elaborate study covering fine aggregates with different size, grading, shape and texture characteristics is essential. However, this paper deals with the study of the influence of shape and texture of fine aggregate (natural sand, stone dust) on concrete mix proportioning. Experimental investigation was done on fine aggregate with different shape and texture characteristics, water cement ratio, water content, and coarse aggregate content for the study. Aggregate of 10 mm and 20 mm from single source as coarse aggregate and 53 grade (28 days strength of 53 Mpa) ordinary Portland cement are considered as the constant parameters.

Keywords: IAPST, Shape and Texture, Stone Dust, Aggregate

1. Introduction

Advances in the development of concrete for intended use are going at a faster rate. The list of different types of concrete, each suitable for a specific, is lengthy. Some of the types worth mentioning are, structural lightweight concrete, heavy weight concrete in its entirely as a construction material is gaining popularity. This concept is symbolized with the increasing use of ready mixed concrete (RMC). The focus of the research has now shifted from mere strength as criteria in the yester years to performance of concrete. Modern concrete need to comply performance attributes such as high strength, high modulus of elasticity, high density, low permeability, improved resistance to cracking, better ductility, improvement in bond with steel, etc. High Performance Concrete (HPC) and Self Compacted Concrete (SCC) are the major developments in this regard. High strength and low permeability are the essential features of HPC. Unlike normal strength concrete the three phases, namely, aggregate, hydrated cement paste and interfacial zone are pushed to their limiting strength in case of HPC. As the strength of hydrated cement paste is, in general, more than that of aggregate hence the strength of aggregate limits the strength of concrete. It is observed that no standard procedure is available for the selection of proportions of materials for HPC. However, methods proposed by different researchers can be used as guideline for arriving at trial mix of HPC P. K. Mehta et. al, and B. H. Bharatkumar et. al and F. de Larrard et. al. The use of different types of cements, mineral and chemical admixtures has also been suggested. The limit of maximum cement content to 450 kg/m^3 will boost the utilization of mineral admixtures such as fly ash, silica fume, rice husk ash, metakaolin, ground granulated blast furnace slag etc. and prevent the concrete from the hazards of higher cement content. Concrete is a composite consisting of binder and filler materials. The binding medium in the case of hydraulic cement concrete is the paste of cement. Aggregates act as filler material. The mixture gets hardened with age giving strength and volume stability to the concrete. The properties of concrete are influenced by the properties of its ingredients and their relative proportions. Major contributors to the properties of concrete. Shape is another property, which has a major influence on properties of concrete. It is broadly described as angular, rounded, flaky and elongated. Angularity indicates sharpness of edges and corners M. F. Kaplan studied the effect of various properties of coarse aggregates on workability of concrete. The properties included were flakiness index, elongation index, angularity number, surface texture, moisture content and crushed aggregates and also by crushing the aggregates with low to high reduction ratios. Thirteen coarse aggregates were considered in the investigation. For each coarse aggregate, flakiness index and elongation index, angularity number as suggested by Shergold surface texture as suggested by Wright water absorption and moisture content as per the drying method was determined. River sand from single source and ordinary Portland cement from single batch was used in the investigation. Three mixes with each coarse aggregate were cast with different w/c ratio, aggregate cement ratio and type grading as per Road Note No.4. Compacting factor and veebe tests were conducted to assess workability of concrete. Three tests on different days were carried out and the average of test results reported. It was expressed that the reproducibility of results of compacting factor test was more than veebe test. It was shown that the angularity number of aggregate has greater effect on workability of concrete than other indices. Highly angular particles require more water for their wetting but may provide better interlocking. Rounded aggregate contain fewer voids, which result into higher workability than angular aggregates for the same water content. Flaky and elongated particles have detrimental effect on durability of concrete. M. Shabbir Hossain, Frazier Parker and Prithvi Kandhal presented data of different tests conducted on various type and sizes of coarse aggregate. The tests included fractured particles as per ASTM D 5821, flat and/or elongated particles as per ASTM D 4791, IAPST as per ASTM D3398 and uncompacted void content as per modified ASTM C1252 as proposed by Ahlrich. All the tests were performed on single sized particles, namely, 19-12.5mm, 12.5-9.5mm, and 9.5-4.75mm. In case of fractured particles tests, percentages for "one or more" fractured faces and " Two or more" fractured faces is defined as that face which has a projected area at least one quarter of the maximum projected area (maximum cross sectional area) of the particle with sharp and well-defined edges. Authors observed that the measurement of fractured face count is not precise. In case of flat and/or elongated particles test, percent of particles with width to thickness and length to width ratio 3: 1 and 5: 1 respectively, were measured on both mass and particle count basis. IAPST test as per ASTM D3398 was conducted. Uncompacted void content of coarse aggregate particles was determined as per method B of ASTM C1252 but with modified device suitable for coarse aggregate size fraction. Based on the results it was concluded that, ASTM D3398 and uncompacted void content provide a measure of coarse aggregate particle shape, angularity and surface texture. These methods were reported as more objective and precise than other methods. However, it was expressed that for the use of these methods as a specification, the criteria for flat and/or elongated particles should also be included. B. P. Hudson discussed about the production of manufactured sand and the influence of type of crushing equipment, reduction ration, etc. on the shape characteristics of aggregate particles. The author reported that impact crushers are superior to compression type crushers (Jaw crusher). Autogeneous vertical shaft impactors produce particles of good shape as the particle undergo impact and abrasion during their crushing to smaller size which is similar to the process by which natural aggregates are formed. Cubical particles are most abundant in the size range near to crusher setting. Jaw crushers are not able to produce a good particle shape in the size range of 2.36mm to 300 micron, as it is not possible to set the side setting of crusher to 2mm. in case of cone crushers choke feeding should be employed. It was expressed that low reduction ratios are favorable while crushing. Shergold suggested a method for determining angularity of aggregate based on the principle of voids. The method consisted of separating the aggregate sample in to closer size fractions. Aggregate from each size fraction is compacted in three layers. Each layer is compacted by applying 100 blows of standard tamping rod at the rate of 2 blows per second and distributed uniformly over the surface of aggregate. Each blow is applied from a height of 50 mm above the surface of aggregate. After finishing compaction of all the layers the mould is filled to overflowing and then excess material is striked off. The mass of the aggregate in cylinder is measured. The test is repeated three times using the same sample and the average value of weight of aggregate is considered for the determination voids in the aggregate sample. Author found that the percentage voids in well-rounded gravel, when compacted in the similar manner as 33, which was taken as reference. Following equation was proposed for determining angularity number of the aggregate size fraction.

Angular Number=Percentage Voids-33 Weighted average of angularity number of different size fractions in a given sample is considered as the angularity number of aggregate.

However, it was expressed that the method cannot be applied for regular shaped bodies. The aggregate by Indian and British standards (IS 2386 – 1963 Part-I, BS 812-1975) Author reported that the angularity number might vary from 0 for well-rounded gravel to 12 for very angular crushed rock. The angularity number of about 100 samples of aggregate reported to have shown good agreement with visual identification. Author has also presented the results of compacting factor test conducted on concrete mixes incorporating coarse aggregate s having different angularity number. It was shown that good correlation exit is a pioneering work in the measurement of angularity of aggregate. Though the method provides a measure of aggregate angularity, it has some shaped bodies such as sphere, cube, etc. Furthermore heavy compaction involved in the process may break the aggregates, change the surface characteristics and thereby cause artificial changes in angularity M. C. Nataraja, et al Surface texture of aggregate is also an important property which influences bond between the aggregate surface and cement paste and thereby mechanical properties of concrete. L. K. Crouch and Roy C. Lotzenheiser investigated the influence of coarse aggregate angularity and surface texture on the compressive strength of high strength plain cement concrete. Rounded river gravel from single source and of the size 9.5mm to 2.36mm with constant grading confirming to ASTM C33 was used. Gravel was crushed to produce crushed aggregate. Concrete mix was produced with 10 each using rounded aggregate, crushed aggregate and equal amount of each shape. Device used in ASTM C1252 was up scaled to suit the measurement of uncompacted void content of each coarse aggregate. Compressive strength tests were conducted at 7, 28 and 56 days using 100 X 200mm cylinders for every batch. Liner regression analysis was carried out to establish the relationship between compressive strength and uncompacted void content of coarse aggregate. High correlation coefficients of 0.98, 0.95 at 7, 28, 56 days respectively indicated the influence of shape of aggregate particle on strength of concrete. It was expressed that measurement of shape of aggregate is useful for pre-evaluation of aggregate for their use in high strength concrete. The paper presented by Randy C. Ahlrich focused on the influence of aggregate particle shape and texture on permanent deformation characteristics (rutting) of hot mixed asphalt (HMA) mixtures. Uncrushed obtain aggregate with variation in shape and texture characteristics. In all there were 11 aggregate blends. Each aggregate blend was separated on the 4.75mm sieve to allow characterization of coarse and fine aggregate fractions. Each fraction was tested for IAPST as per ASTM D 3398 and uncompacted voids content as per ASTM C 1252. The device used for fine aggregate in ASTM C 1252 was modified to suit the coarse aggregate fractions (20 to 4.75mm size). Dynamic creep test was conducted on the HMA mixtures for evaluating rutting potential. It was reported that IAPST as per ASTM D3398 and modified ASTM C1252 for coarse aggregate and ASTM C1252 test for fine aggregate effectively characterized the shape and texture of aggregate blends. Generally crushed particles will have rough surface texture and hence they provide better bond than the rounded aggregate. Hence objective quantification of aggregate properties is essential for the better control over the properties of resulting concrete. Wright proposed a method for the quantification of the surface texture of aggregate particles. It consisted of embedding aggregate particle in synthetic resin and obtaining thin sections of aggregate surrounded by the resin once the resin hardened. The interface between stone and resin was magnified 125 times on a projection microscope and traced. The length of the profile was measured by means of map-measuring wheel and compared with the length of an unevenness line drawn as a series of chords. The difference between two lengths was considered as the measure of roughness. Concrete should possess adequate workability and cohesiveness in the fresh state, strength and durability in the hardened state. The properties of ingredients such as strength, chemical composition, fineness and consistency of cement, size, grading, shape and surface texture of aggregates, quality of water, and type of mineral and chemical admixtures will have a bearing on the properties of concrete. Out of the different materials used in the making of concrete, there is a least control over the properties of aggregates. However, it is one of the major contributors to the properties of concrete. It occupies bulk of the volume, imparts volume stability and because it is cheaper than cement, it reduces the cost of concrete. It is well recognized that the aggregate is not simply a filler material but its physical, chemical and thermal properties of concrete in fresh and hardened state ACI 221R-89 Size and grading of aggregate influences workability, strength, shrinkage and unit weight.

2. Preliminary Investigations

Outline of Preliminary Investigation

A broad objective of the experimental investigation is to study the role of shape and texture of aggregates in concrete mix proportioning. In this regard, the study of available methods for the quantification of these properties is a first step. It is understood from the literature that there are no precise methods for the quantification of shape and texture of aggregates. However, various codes have envisaged certain tests that indicate the shape characteristics of aggregates such as Flakiness Index, Elongation Index and Angularity Number Uncompacted Void content, Index of Aggregate Particle Shape and Texture (IAPST). Digital image processing techniques are also being attempted for the same. As ASTM C 1252 is meant for fine aggregates and digital image processing techniques are still in the development stage. IAPST test considered for preliminary investigations. Moreover, the preliminary investigation is aimed to carry out reconnaissance of aggregates available in the vicinity and study their shape and texture characteristics.

Procurement of Material

Fine aggregates from different crushing plants, river sands from different sources have been considered in the investigation. All the aggregates were washed clean and dried. The aggregates were sieved in to closer size fractions by selecting 20mm, 10mm and 4.75mm sieves in case of coarse aggregates and 4.75, 2.36mm, 1.18, 600micron, 300micron sieves for fine aggregates. Each size fraction was stored separately

Tests on Shape and Texture of Fine Aggregate

Index of Aggregate Particle Shape and Texture (IAPST)

The dimensions of the metal cylinder and tamping rod used in the test for various size fractions of the aggregate are given in Table 1. Test is conducted on each size fraction separately. A sample of aggregate size fraction to be tested was drawn using coning and quartering method of sampling. Mould and tamping rod appropriate for the size fraction of aggregate were used. The mould was placed on a level and solid base from vibrations. Mould was filled with aggregate to one-third of its height by gently poring aggregates from the scoop from a least possible height. Aggregate surface was gently leveled with the finger Layer was compacted by applying 10 drops of tamping rod uniformly distributed over the surface of aggregate. Each drop was applied by dropping the tamping rod freely from a height of 50mm above the surface of aggregate. The height of after the completion of tamping of second layer aggregate just sufficient to fill the mould and poured and compacted in a similar manner. Individual pieces of aggregate were then added and rolled till the surface of aggregate was level with top of mould. Weight of the aggregate in the mould was measured to an accuracy of 1gm. Repeat test was conducted on the same aggregate and average weight (M_{10}) was obtained. The process was repeated with 50 drops and average weight (M_{50}) was obtained. The percentage voids after 10 and 50 drops are calculated using following equations

$$V_{10} = 100\,[1 - M_{10}/\,(SxV)]$$

$$V_{50} = 100[1 - M_{50}/\,(SxV)]$$

Where,

V_{10} – Percentage voids after 10 drops

V_{50} – Percentage voids after 50 drops

S – Specific gravity of aggregate size fraction

V – Volume of Cylinder in m^3.

IAPST is determined using following equation

$$Ia = 1.25V_{10} - 0.25V_{50} - 32.$$

Table 1. *Details of Moulds and Tamping Rods as per ASTM D3398-97.*

Aggregate size in mm		Details of Mould					Details of Tamping Rod		
Passing	Retained	Type	Inside Dia. in mm	Inside Height in mm	Bottom Thick. in mm	Wall Thick in mm	Dia. in mm	Length in mm	Mass in gm
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
38.1	25.4	A	203.2	237	6.1	6.1	21.2	814	2204
25.4 19	19 12.7	B	152.4	177.8	6.1	6.1	15.9	610	930
12.7 9.5	9.5 4.75	C	101.6	116.5	5.1	5.1	10.6	406.9	276
4.75 2.36 1.18	2.36 1.18 600μm	D	76.2	88.9	4.1	4.1	7.9	306	116
600μm 150μm	300μm 75μm	E	50.8	59.3	3.8	3.8	5.3	201.7	34

Weighted average of IAPST of individual size fractions was determined as per the percentage of weight of the size fraction in grading. The values of V10, V50 and IAPST of all the aggregates are presented in Table 2.

Table 2. *Results of IAPST Test as per ASTM D 3398-97.*

Grading of aggregate	Aggregate Type	Size Fraction	% of weight Retained	IAPST as per ASTM D 3398-97		
				V10	V50	IAPST
Zone 2	Natural sand	4.75-2.36	12.5	42.65	40.42	1.4
		2.36-1.18	15	42.01	38.94	1.62
		1.18-600	25.5	40.75	38.95	2.35
		600-300	37	40.55	39.24	3.29
		300-150	10	41.48	39.91	0.99
		Weighted Average				9.65
	50 % Natural sand + 50%Stone Dust	4.75-2.36	12.5	42.85	40.72	1.42
		2.36-1.18	15	42.62	40.19	1.68
		1.18-600	25.5	41.71	40.16	2.58
		600-300	37	39.81	38.08	3.05
		300-150	10	41.93	39.72	1.05
		Weighted Average				9.78
	Stone Dust	4.75-2.36	12.5	43.3	41.26	1.48
		2.36-1.18	15	43.3	41.5	1.76
		1.18-600	25.5	42.74	41.43	2.82
		600-300	37	39.04	36.94	2.8
		300-150	10	42.26	39.54	1.09
		Weighted Average				9.95
Zone 3	Natural sand	4.75-2.36	8.5	42.65	40.42	0.95
		2.36-1.18	6	42.01	38.94	0.65
		1.18-600	20	40.75	38.95	1.84
		600-300	42.5	40.55	39.24	3.77

Grading of aggregate	Aggregate Type	Size Fraction	% of weight Retained	IAPST as per ASTM D 3398-97		
				V10	V50	IAPST
		300-150	23	41.48	39.91	2.27
		Weighted Average				9.48
	50 % Natural sand + 50%Stone Dust	4.75-2.36	8.5	42.85	40.72	0.97
		2.36-1.18	6	42.62	40.19	0.67
		1.18-600	20	41.71	40.16	2.02
		600-300	42.5	39.81	38.08	3.5
		300-150	23	41.93	39.72	2.41
		Weighted Average				9.57
	Stone Dust	4.75-2.36	8.5	43.3	41.26	1
		2.36-1.18	6	43.3	41.5	0.71
		1.18-600	20	42.74	41.43	2.21
		600-300	42.5	39.04	36.94	3.22
		300-150	23	42.26	39.54	2.52
		Weighted Average				9.66

3. Experimental Programme

Outline of the Experimental Program

Preliminary investigation has given good insight into the type of aggregates available in the vicinity and the parameters such as IAPST to characterize aggregates. The established characteristics of aggregates that influence proportioning are size, grading, shape and surface texture. They in turn influence strength and workability of concrete. Nominal maximum sizes of aggregates used in concrete are 10, 20, 40mm etc., out of which 20mm is widely used. Hence maximum size of the aggregate used in the experimental Programme is 20mm. The influence of grading of aggregate on properties of concrete is well recognized. Standard grading are prescribed by various codes for coarse and fine aggregate to be used in concrete. The influence of grading of fine aggregate is more than that of coarse aggregate. Hence in the present investigation on two fine aggregate grading (a grading each from Zone – II and III). River sand is most commonly used as fine aggregate. The reconnaissance of river sand and stone dust from various sources in the vicinity Figure 2 & 3 (FA-1, FA-2, FA-3) indicated that is considered as fine aggregate. Ordinary Portland cement having strength 54.2 M Pa of a particular make is a constant parameter in the investigation. The experimental program is designed for studying the influence of IAPST of fine aggregate on Compressive strength, Split tensile strength and Workability.

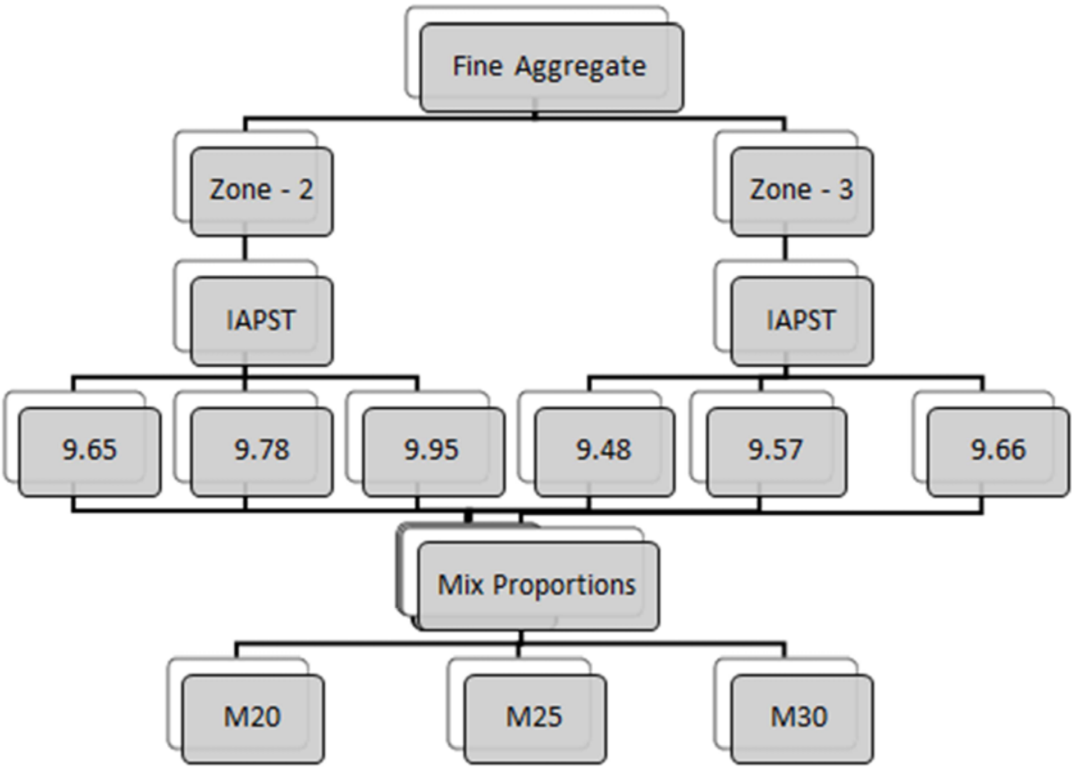

Figure 1. *Experimental Program.*

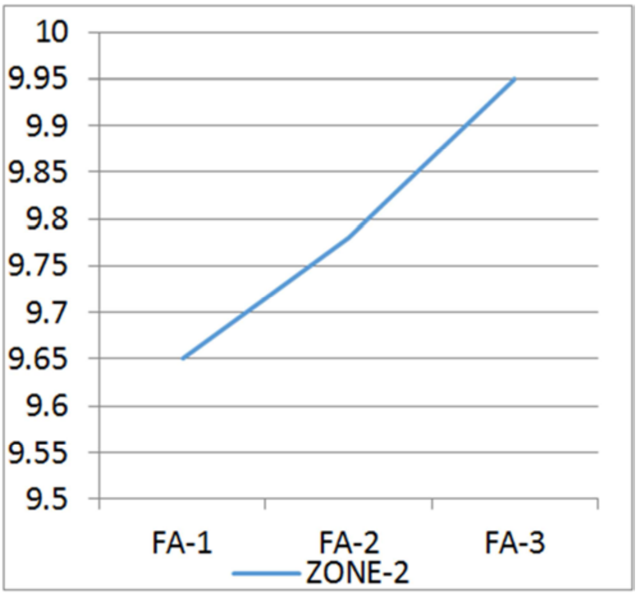

Figure 2. *Type of fine aggregate vs. IAPST (Zone 2).*

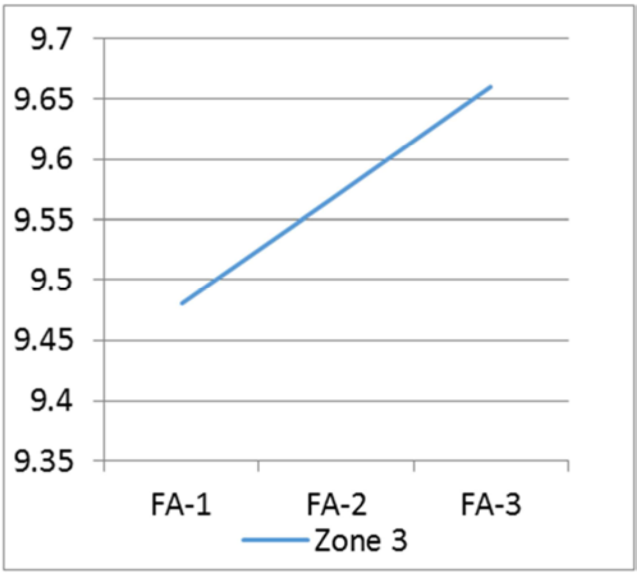

Figure 3. *Type of fine aggregate vs. IAPST (Zone 3).*

3.1. Experimental Program with Shape and Surface Texture of Fine Aggregate as Variable

Water cement ratio is a major parameter that influences the strength of concrete. It is well known that for a given material, as the water cement ratio increases there is a reduction in strength. Subsequent research indicated that shape and surface texture characteristics of aggregates also influence the strength of concrete. Cohesiveness and workability is another important property that the concrete should possess. For given material and water cement ratio there exists a unique combination of coarse and fine aggregate that gives maximum workability for particular water content. Higher the water cement ratio higher is the fine aggregate content for a cohesive mix. In this present investigation M20 (1: 1.47: 2.94, w/c=0.48), M25 (1: 1.2: 2.62, w/c=0.42) & M30 (1: 1.18: 2.69, w/c=0.37) mixes with various IAPST of fine aggregate are considered. Coarse aggregate of 20mm and 10mm size with grading were the constant parameters.

3.2. Properties of Materials Used in the Investigation

Cement

OPC 53 grade of a particular brand was used throughout the work. The physical properties of cement such as standard consistency, initial and final setting time and 28 days compressive strength were tested and presented in Table-3. Cement was stored in thick plastic bags to avoid the formation of lumps.

Aggregates

Coarse aggregate, river sand and stone dust from single source are used in the experimental work. Their properties namely, specific gravity in saturated surface dry condition, water absorption and bulk density are determined and presented in Table- 4 and Table 5. While the indices of shape and texture namely, IAPST.

Water

Potable water available in the laboratory was used.

3.3. Production and Tests on Concrete

Batching

All the material was weigh batched as per the proportions of the mix. In case of aggregates, each size fraction was batched separately so as to obtain the required grading

Mixing

All the ingredients of concrete were thoroughly mixed. The mixing was carried out at a room temperature of 30 ± 2°C. The weight of the aggregate and quantity of water was adjusted as per the water absorption and status of surface moisture of aggregates.

Tests on Workability of Concrete

Compacting factor test was conducted simultaneously on each mix. In the case of compacting factor test due care taken to release the concrete from upper hopper of the apparatus two minutes after the completion of mixing.

Test on Compressive Strength of Concrete

3 cubes of size 150 X 150 X 150 mm were cast each concrete mix, cured for 28 days in the water tank and tested under compression testing machine

Test on Spilt Tensile Strength of Concrete

3 cylinders of size 150 mm diameter and 300mm height were cast each concrete mix, cured for 28 days in the water tank and tested under compression testing machine

4. Results and Discussion

4.1. Compressive Strength

In this Investigation, Compressive strength was found out for three grades of concrete. From the results, shown in Table-6 it is visible from the Figure 4 that compressive strength was increased with different shape and texture and varying IAPST values for zone -2 fine aggregate in M20 grade of concrete and decreased for M25 and M30 grade of concrete. The OPC samples showed slightly higher compressive strength when IAPST value increased. The influence of IAPST is reduced strength of M 25 and M30 grade of concrete. This was likely to decrease due to use of different shape and texture of aggregates. This was discussed earlier by L. K crouch et.al and for zone-3 fine aggregate, Compressive strength decreases with increase of IAPST values as shown in Figure 5.

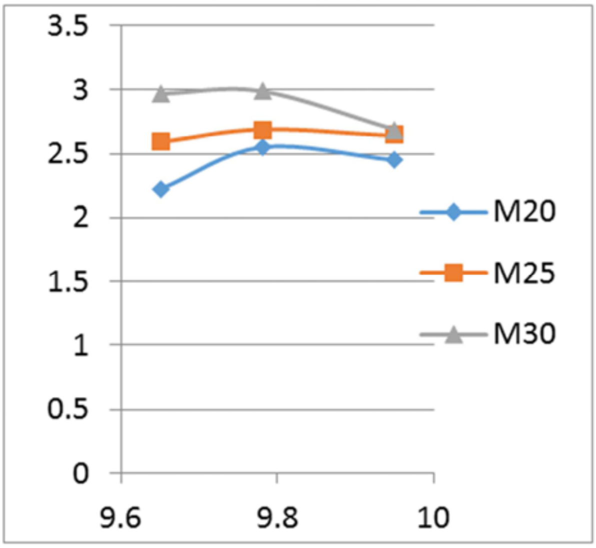

Figure 4. *IAPST vs. Compression Strength (ZONE-2).*

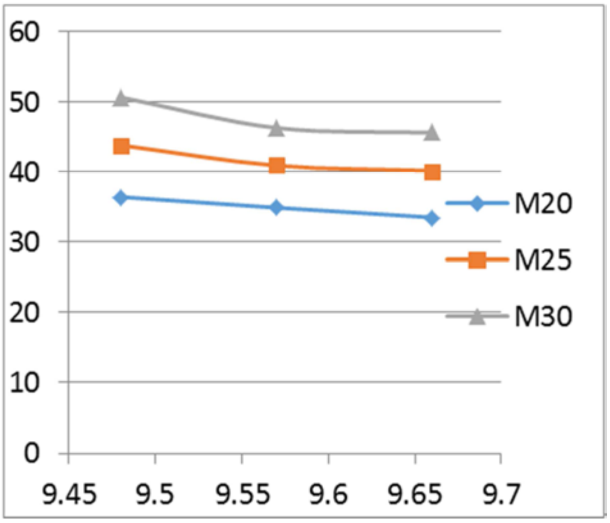

Figure 5. *IAPST vs. Compression Strength (ZONE-3).*

4.2. Split Tensile Strength

In this Investigation, Split Tensile was found out for three grades of concrete. From the results, it is visible from the Figure 6 that there was gradual increase in split tensile strength for M20 M25 and M30 grade of concrete for Zone 2 and Zone 3 and it is observed that there is further decrease in strength with increase of IAPST values as shown in Figure 7. This was likely to be due to use of different shape and texture of fine aggregate.

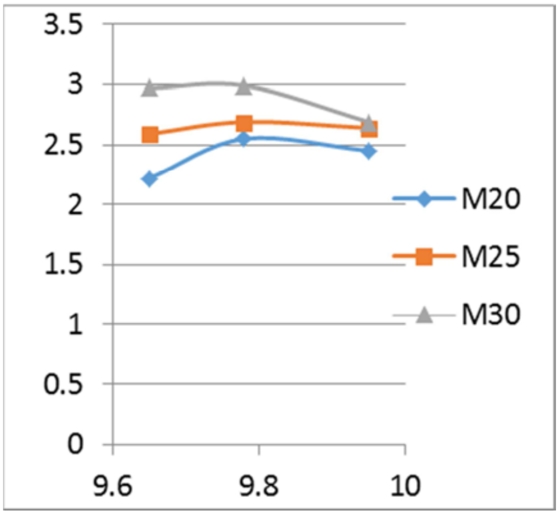

Figure 6. *IAPST vs. Spilt Tensile Strength.*

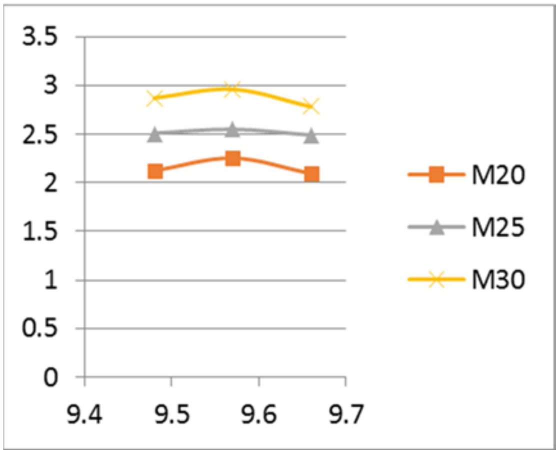

Figure 7. *IAPST vs. Spilt Tensile Strength.*

4.3. Workability

It is observed that there is further decrease in work ability with increase of IAPST values in zone 2 and zone 3 as shown in Figure 8 and Figure 9. This was likely to be due to use of different shape and texture of fine aggregate.

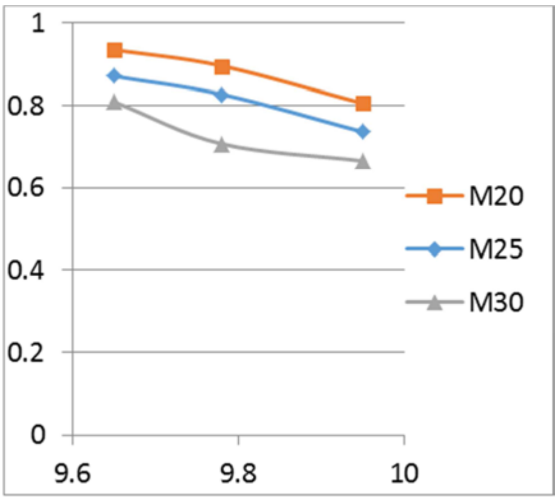

Figure 8. *IAPST vs. Compaction factor (Zone 2).*

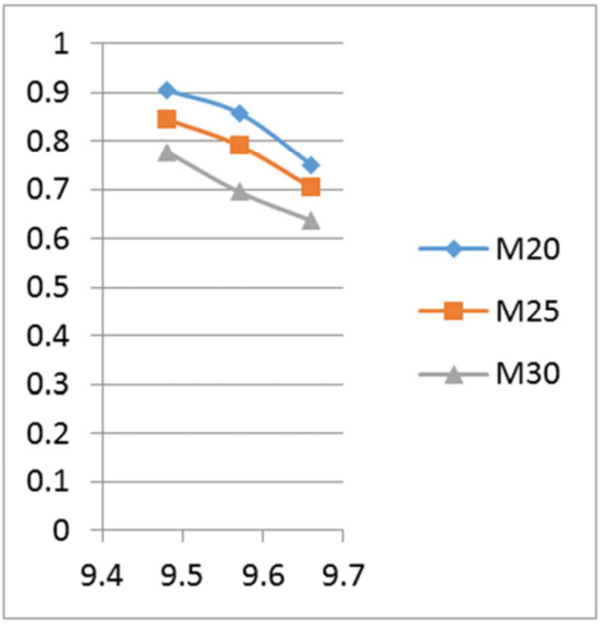

Figure 9. *IAPST vs. Compaction factor (Zone 3).*

5. Conclusions

In this study, the effect of IAPST on zone 2 and zone 3 fine aggregate on the mechanistic properties of concrete was examined. Replacement of the fine aggregate with different shape and texture led to a decrease of compressive strength and work ability compared with the conventional OPC concrete. The split tensile strength for zone 2 and zone 3 were higher than the conventional concrete.

It can be concluded that the concrete containing different shape and texture having relatively better tension properties, but lower in compressive strength and work ability properties than conventional concrete.

Table 3. *Properties of Cement.*

Sr. No	Test	Result	Specifications as per IS 12269-1987
1	Standard Consistency	28 %	-
2	Initial Setting Time	100 min	Not less than 30 min
3	Final Setting Time	347 min	Not more than 600 min
4	28 days compressive strength	54.2 Mpa	Minimum 53 Mpa

Table 4. *Properties of Coarse and Fine Aggregate.*

Grading of aggregate	Type of Aggregate	Specific Gravity	IAPST
	Natural sand	2.552	9.65
Zone-2	50% natural sand +50% stone dust	2.457	9.78
	stone dust	2.445	9.75
	Natural sand	2.544	9.48
Zone-3	50% natural sand +50% stone dust	2.492	9.572
	stone dust	2.443	9.66

Table 5. *Grading of Coarse and Fine Aggregate.*

Coarse Aggregate		Fine Aggregate				
Sieve Size (mm)	Cumulative % Passing	Sieve Size (mm)	Cumulative % Passing Zone-I	Zone-II	Zone-III	Zone-IV
(1)	(2)	(3)	(4)	(5)	(6)	(7)
40	100	10	100	100	100	100
20	97.5	4.75	100	100	100	100
10	40	2.36	77.5	87.5	92.5	97.5
4.75	05	1.18	50	72.5	87.5	95
2.36	0	600 µm	24.5	47	69.5	90
-	-	300 µm	7.5	10	21	25
-	-	150 µm	0	0	0	0
Fineness Modulus			Fineness Modulus			
6.575			3.405	2.830	2.295	1.925

Table 6. *Mix proportions and test results.*

Grading of fine aggregates	IAPST	Mix	Compressive strength	Spilt tensile strength	Compaction factor
		M20	39.4	2.22	0.935
	9.65	M25	45.93	2.59	0.871
		M30	51.85	2.97	0.809
		M20	44	2.55	0.896
Zone-2	9.78	M25	42.97	2.69	0.827
		M30	48.33	2.99	0.707
		M20	36.6	2.45	0.805
	9.95	M25	40.89	2.64	0.736
		M30	45.63	2.69	0.665
		M20	36.43	2.12	0.905
	9.48	M25	43.83	2.51	0.845
		M30	50.68	2.87	0.778
		M20	34.9	2.25	0.858
Zone-3	9.57	M25	40.93	2.55	0.791
		M30	46.31	2.96	0.695
		M20	33.5	2.09	0.751
	9.66	M25	40.19	2.49	0.704
		M30	45.63	2.78	0.636

References

[1] P. K. Mehta and P. C. Aitcin, Principles underlying the production of high performance concrete, cement, concrete and Aggregates, 12 (2) (1990) pp. 70-78.

[2] B. H. Bharatkumar, R. Narayanan, B. K. Raghu Prasad and D. S. Ramchandramurthy, Mix proportioning of high performance concrete, Cement and concrete Composites, 23 (2001) pp. 71-80.

[3] F. de Larrard and T. sedran, Mixture proportioning of high performance concrete, Cement and Concrete Research, 32 (2002) pp. 1699-1704.

[4] M. F. Kaplan, The effects of the properties of coarse aggregates on the workability of concrete, Magazine of Concrete Research 29 (10) (1958) pp. 63-74.

[5] F. A. Shergold, The percentage voids in compacted gravel as a measure of its angularity, Magazine of Concrete Research 13 (5) (1953) pp. 3-10.

[6] P. J. F. Wright, A method for measuring the surface texture of aggregate, Magazine of Concrete Research, 5 (2) (1955) pp. 151-160.

[7] M. S. Hossain, F. Parker and P. S. Kandhal, Comparison and evaluation of tests for coarse aggregate particle shape, angularity, and surface texture, Journal of testing and Evaluation, 28 (2) (2000) pp. 77-87.

[8] R. C. Ahlrich, Influence of aggregate properties on heavy duty pavements, Transportation Research Record No.1547, Transportation Research Board, Washington DC, (1996) pp. 8-14.

[9] B. P. Hudson, Manufactured sand for concrete, The Indian Concrete Journal, (May 1997) pp. 237-240.

[10] L. K. Crouch and R. C. Loutzenheiser, Applying superpave aggregate technology to high-strength PCC, Concrete International, (May 1999) pp. 28-31.

[11] R. C. Ahlrich, Influence of aggregate properties on heavy duty pavements, Transportation Research Record No.1547, Transportation Research Board, Washington DC, (1996) pp. 8-14.

[12] P. J. F. Wright, A method for measuring the surface texture of aggregate, Magazine of Concrete Research, 5 (2) (1955) pp. 151-160.

[13] F. A. Shergold, The percentage voids in compacted gravel as a measure of its angularity, Magazine of Concrete Research 13 (5) (1953) pp. 3-10.