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NEW GENERATION FINE AGGREGATE FOR USING IN HIGH PERFORMANCE CONCRETE.

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ABSTRACT

The paper presents an experimental procedure for using of washed crushed stone sand in the mix design of high-performance concrete for precast tunnel segments and underground tremie concrete for diaphragm wall structures. The mix designs for artificial washed crushed sand and river sand were developed for achieving desired workability of concrete for smooth casting of the structure. the proportions of coarse aggregate and fine aggregate of both the concrete mix designs were optimized to achieve the rheology of concrete. The more variation observed in the results of fresh and hardened properties of both the mixes. It has been observed that concrete mix design made by artificial crushed stone sand gives better results of fresh concrete, hardened concrete and achieved better results of durability parameters as compared to concrete mix designs with river sand. The comparison of material properties,

workability, cube compressive strengths, RCPT, permeability and NT Build tests values are presented in this article.

Keywords: Concrete Mix Design, washed crushed stone sand, River sand, Fresh concrete Properties, Hardened Concrete Properties, Concrete durability tests

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1. Introduction and Literature review

India is one of the world's fastest-growing countries; in mega-infra projects like Highways, Airports, and Metro rails. The development of construction projects in India is dependent on easily available materials from natural sources but as per the current scenario we have already consumed naturally available materials in huge quantities, especially naturally available river sand. Fine aggregate plays an important role for optimizing cementitious content, water content, minimizing the voids in concrete and making workable, compact, and durable.

High-performance concrete. The consistent physical properties of river sand are quite difficult for maintaining at construction sites because of natural source of extraction from various riverbeds and frequent natural changes in geology of river. Disturbing the riverbeds by extracting natural sand for using it in construction projects, it is creating divers' impact on environment. However, the observed impacts generally lead to reduced geographic and biodiversity. Chemical and anthropogenic environmental impacts reveal that river sand mining can also seriously affect the livelihoods of people living along rivers, causing great social and economic damage (). At present river sand is not available in metropolitan cities of India like Mumbai region of Maharashtra and Gujarat are also facing a shortage of consistent quality of river sand for using in construction projects. Department for mining and geology of Gujrat government is also preferring hard stone crushed sand as a M-sand, considered as the innovative and alternative of river sand. It is also countered the unavailability and scarcity of river sand for construction projects [2]. New generation Artificial washed crushed stone sand also called engineered sand and locally it is popular as manufactured sand in Gujarat. The type of fine aggregate classified as Natural, manufactured or combination of their of As per ASTM standard

[3] but Indian standard specification is one step ahead and classification of fine aggregates described as Natural sand, Mixed sand, Crushed sand- (Sub classification -Crushed stone sand and Crushed gravel sand) and Manufactured sand, M-sand defined as a fine aggregate manufactured from other than the natural sources by processing materials using thermal or other process such as separation , washing ,crushing and scrubbing [4]. The process of making engineered sand is like manufactured sand process but it is from natural hard stone by processing cycle such as Crushing, separation and washing instead of non-natural sources like byproducts or recycled concrete debris. Hence washed stone crushed sand is also called as a M-sand due to similar process of manufacturing cycle. The definition of Artificial washed crushed stone sand or engineered sand still not covered in Indian standard codes. It is an advance and controlled quality version of crushed stone sand, it can be customized and produced according to the specific standard requirement with uniform distribution of particle sizes in consistent manner using advanced sand plant, which helps the development of superior concrete mix design. High performance concrete mix designs were developed for M50 grade precast tunnel segments and underground structure Diaphragm Wall using river sand and artificial crushed stone washed sand. The comparative properties of fine aggregate, their impact on fresh, hardened concrete and durability parameters are discussed in this paper.

2. Materials

All the concrete ingredients have been selected from locally available sources of materials for giving the preference to local manufacturers and suppliers for their financial growth and for supporting to the development of Gujrat State as per the contractual requirement of project.

2.1 Cement

OPC 53 Grade cement of M/s Ultratech from Magdala plant, Surat, Gujrat is used. Physical & Chemical properties of Cement checked and found confirming to the IS: 269:2016 [5]..

2.2 Fly ash.

Fly ash is used from GNFC power plant, Bharuch Gujarat after classifying of fly ash through manufacturing cum processing unit of M/s Suyog supplier, Bharuch, Gujarat to meet the requirement of IS:3812:2013 (Part-1) [6].

2.3 Ultrafine GGBS

Ultrafine GGBS (UFGGBS) is used from local manufacturer M/s Suyog, Bharuch Gujarat, UFGGBS is a processed supplementary cementitious material for improving the properties of concrete. UFGGBS confirming the requirement of IS: 16715:2018 [7].

2.4 Superplasticizer and crystalline growth waterproofing admixtures

PCE based super plasticizer brand name SG 60 of M/s Yashka and brand name AT-CARPOL 151S of M/s ATPL have been used for the concrete mix designs. Both the brands are confirming to the requirements of Indian Standard Specifications I S: 9103:1999 [8]. Crystaline growth waterproofing admixture (CWA), product name Conplast of M/s FOSROC is used for improving the durability and reducing the permeability of concrete structures. CWA is confirming the standard requirement of ASTM C-1556-4 and ACI-212-3 R-10 [9] [10]

2.5 Aggregates

Coarse aggregate and manufactured crushed stone sand are used from the nearest source i.e., Chikhali Navsari, Gujrat. Advanced vertical shaft impactor (VSI) crusher plant is used for producing cubical shape and equidimensional particle size and to avoid elongated and flaky shaped aggregate. Uniform distribution of shape and size of aggregates improve the packing property and helps to achieve maximum strength of concrete. New generation fine aggregate is the innovative technique for making fine aggregate by hard stone crushed sand from VSI crusher plant and removing non usable silt and clay partials by using hydro cyclic processing unit with automatic set manners [11]. Artificial processed fine aggregate - washed crushed stone sand is more suitable, consistent, controllable, and easily available in Gujarat State. High performance concrete mix designs with processed washed crushed stone sand are having more compatibility with other concrete ingredients and results of durability parameters also found more suitable as compared with river sand. Artificial washed crushed sand or M/sand and coarse aggregate are conformed to Indian Standard Specifications IS: 383-2016 [12].

Sive size analysis is done for normal crushed stone sand and processed washed crushed stone sand and found more variation according to the requirements of standard and practical size distribution requirements for making pumpable concrete, comparison is given in Table -1.

Table 1- A comparative statement for normal crushed stone sand and washed crushed stone sand

S.No.	Sieve Size	Crushed Stone Sand Results - % of passing	Washed Crushed Stone Sand Results- % of passing	Specification as per 383-2016 for Zone-II	Specification as per Contract, Morth, and IRC 112:2019 for Pumpable concrete
1.	10 mm	100	100	100	
2.	4.75	98.32	100	90-100	
3.	2.36	80.52	89.43	75-100	
4.	1.18	64.52	61.38	55-90	
5.	600 mic	43.62	42.41	35-59	
6.	300 mic	27.55	21.82	8-30	15-30
7.	150mic	7.95	8.81	0-10	5-10
8.	Finer than 75 microns (%)	13.85	2.9	<3.00% for uncrushed and <15% for crushed and no limit mentioned for Washed Crushed stone sand	<3.00% for uncrushed and <15% for crushed and no limit mentioned for Washed Crushed stone sand

Particle size distribution in washed crushed sand found better than crushed stone sand, comparison graph showing in fig.1

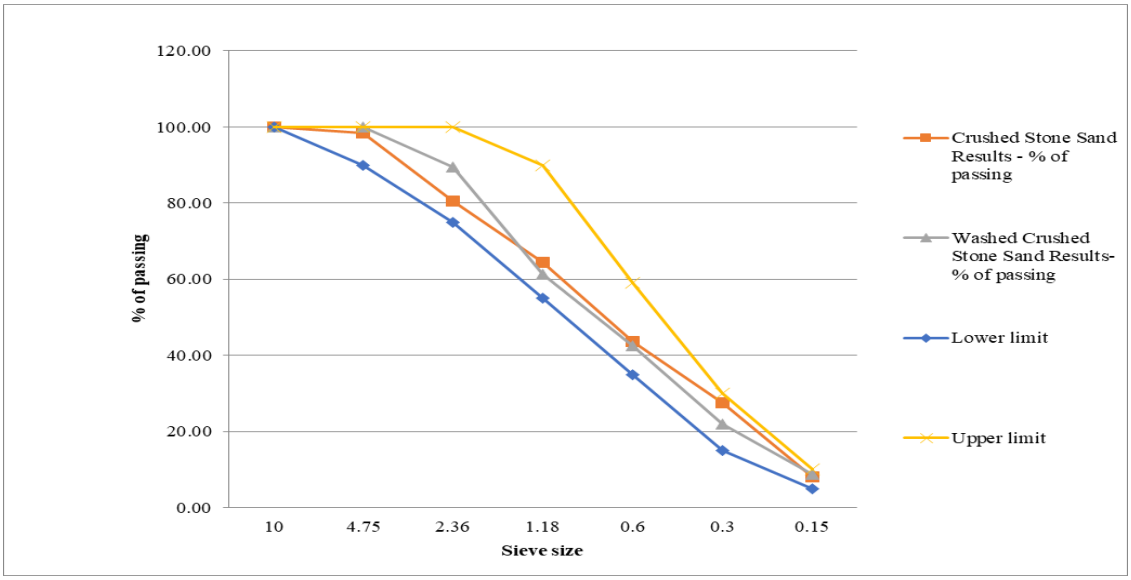

Figure 1. Comparative gradation graph for Crushed stone sand and washed crushed sand

Sive size analysis is done for crushed stone sand and processed washed crushed stone sand and found more variation according to the requirements of standard and practical size distribution requirements for making pumpable concrete, comparison is given in Table -1.

Table 2- A comparative statement for natural stone sand and washed crushed stone sand.

S.No.	Sieve Size	Natural Sand Results - % of passing (Blended with two sources)	Washed Crushed Stone Sand Results- % of passing	Specification as per 383-2016	Specification as per Contract, Morth, and IRC 112:2019 for Pumpable concrete
1.	10 mm	97	100	100	
2.	4.75	93	100	90-100	
3.	2.36	86.9	89.43	75-100	
4.	1.18	70.7	61.38	55-90	
5.	600 mic	46.3	42.41	35-59	
6.	300 mic	4.6	21.82	15-30	15-30
7.	150mic	1	8.81	5-10	5-10
8.	Finer than 75 microns (%)	2.9	2.6	<3.00% for uncrushed and <15% for crushed and no limit mentioned for Washed Crushed stone sand	<3.00% for uncrushed and <15% for crushed and no limit mentioned for Washed Crushed stone sand

Generally, for making high strength and pumpable concrete fine aggregate preferred in Zone II grade. In Gujrat region river sand is available in coarser size zone I and finer size of Zone III as per IS:383 therefore two sources of river sand i.e., Nareshwar bank of Narmada River for zone III and Badoli bank of Orsang river for Zone I are blended with required proportion for getting in zone II grade of sand. As per above sieve size analysis of river sand, fine contents in 300 micron and 150 microns are not confirming requirements of specification of MoHrth and IRC:112:2019 for pumpable concrete. Physical properties of blended river sand are found vary frequently due to changes in weather atmosphere and in river geology of two different sources. Hence consistent results could not be controlled at site by using river sand. Particle size distribution in washed crushed sand found better than natural sand, comparison graph showing in fig.2

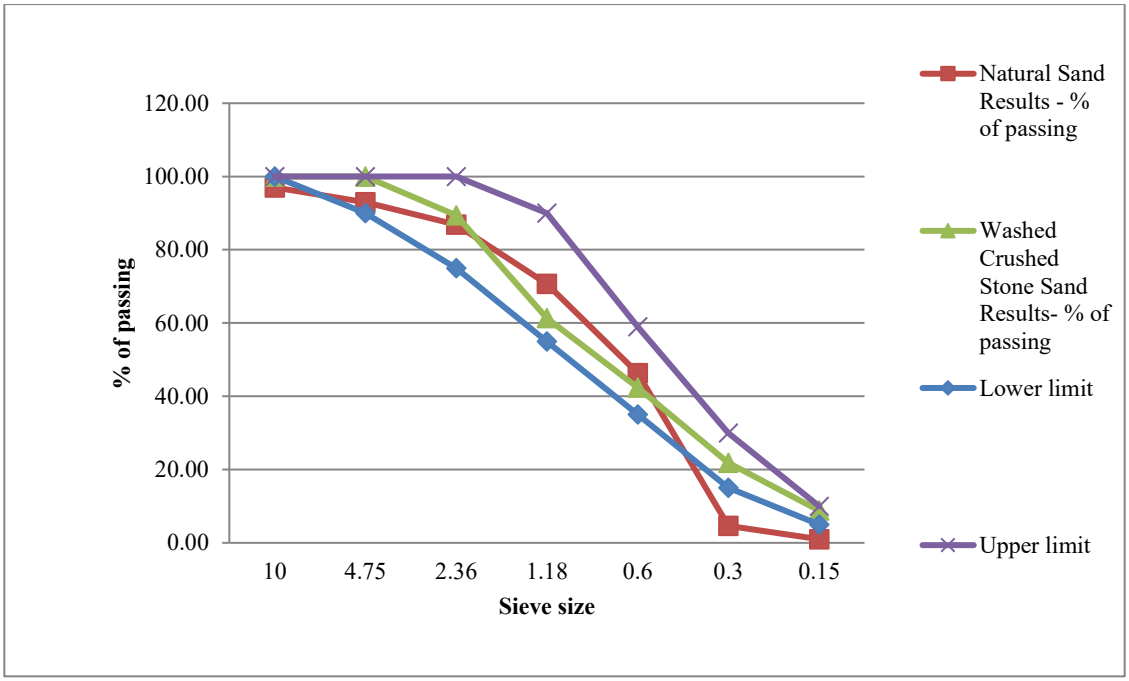

Figure 2-Comprative gradation graph for River sand and washed crushed sand

Physical and chemical tests are conducted for crushed, washed and river sand and their results represent in table 3.

Table 3- Physical & Chemical Test Result Comparison:

S.No.	Test Parameters	River Sand (Blended of two sources)	Crushed Stone Sand Results	Washed Crushed Stone Sand Results	Specification as per 383-2016
1.	Specific Gravity	2.64	2.76	2.66	--
2.	Water absorption (%)	1.06	2.97	2.84	--
3.	Bulk Loose Density (kg/lt)	1.65	1.45	1.40	--
4.	Grading Zone	Zone-II	Zone-II	Zone-II	--
5.	Fineness Modulus	3.00	2.5	2.76	2.6 to 2.8
6.	Finer than 75 microns (%)	2.58	12.42	2.1	<3.00% for uncrushed and <15% for crushed
7.	Combined FI & EI	-	-	-	-
8.	Soundness Index (Five cycles) (by Na2SO4) %	3.62	3.14	1.65	<10% for Na2SO4
9.	Soundness Index (Five cycles) (by MgSO4) %	4.64	3.32	3.41	<15% for MgSO4
10.	Chloride Content (%)	0.03	0.0011	0.009	Max. 0.04

11.	Sulphate Content (%)	0.26	0.0021	0.045	Max. 0.5
12.	Alkali Aggregate Reactivity				
12.1	Reduction in alkalinity (Rc) millimoles/L	575	463.33	320	--
12.2	Dissolved silica (Sc) millimoles/L	18.65	13.320	6.32	--
12.3	Nature of Aggregate	Innocuous Aggregate	Innocuous Aggregate	Innocuous Aggregate	--

According to above test results all the type of fine aggregates are confirming the standards requirement of Is: 383:2018 but if compare among them chloride content and sulphate content of river sand found higher side than Crushed stone sand and washed crushed stone sand. It may be observed due to sources of river sand are near to coastal areas or selection of containment riverbank for extracting the river sand.

3. Mix Design

Based on fine aggregates physical and chemical test results, crushed sand has been eliminated for trial mixes due to unsatisfactory results as compared to River sand and washed sand. Various trials were conducted along with river sand and washed crushed stone sand and selecting appropriate proportions of concrete ingredients for making cohesive and homogeneous concrete mix with desired retention time according to the guideline of concrete mix designs standard IS: 10262:2019 [13]. Finalized concrete mix design with washed crushed stone sand and River sand represented in table 4.

Table 4 Details of concrete mix design for M50 grade permanent structures.

Trial Mix No	Type of Fine Aggregate	Cement (Kg/m3)	Fly ash. (Kg/m3	UGGBS-(Kg/m3)	Cementitious (Kg/m3)	W/C Ratio	C.A (Kg/m3)	F.A (Kg/m3)	Water (Kg/m3)	Superplasticizer (Kg/m3)	C.W.A (Kg/m3)
TM-PTS-01	River Sand	420	0	25	445	0.28	1129	851	125	4.005	-
TM-PTS-02	Washed Crushed Sand	420	0	25	445	0.28	1233	763	125	4.228	-
TM-DW-01	River Sand	400	60	00	460	0.326	1061	800	161	3.22	3.45

TM-DW-02	Washed Crushed Sand	400	60	00	460	0.35	1155	715	161	3.45	3.45

Above concrete mixes are designed for permanent structures for Precast tunnel segment and Diaphragm wall. Trial mix no.TM- PTS -01 is designed for precast tunnel segment using River sand and Trial mix no. TM- PTS - 02 is designed for precast tunnel segment using washed crushed stone sand. Trial mix no.TM- DW -01 is designed for diaphragm wall using River sand and Trial mix no. TM- DW - 02 is designed for diaphragm wall using washed crushed stone sand.

Comparative test results for fresh and hardened concrete in given in Table no.5

Table 5 Fresh and Hardened Concrete Test Result Comparison for M50 grade permanent structures.

S. No.	Test Parameters	TM No.-TM-PTS-01	TM No.-TM-PTS-02	TM No.-TM-DW-01	TM No.-TM-DW-02	Limits as per contract specification
1.	Fresh Concrete					
1.1	Slump in mm after 75 minutes for Precast Tunnel Segment (PTS) and 3 hours for Diaphragm wall (DW)	105	120	150	185	More than 100 mm for PTS and more than 150 mm for DW
1.2	Cohesiveness	Cohesive	More Cohesive	Less Cohesive	More Cohesive	Mix should be Cohesive
1.2	Temperature in degree Celsius	29.8	29.9	28.6	28.3	Should not be more than 30 deg
2.	Hardened Concrete & Durability Tests					
2.1	Density Kg/Cum	2554	2570	2489	2498	Min 2400 kg/cum
2.2	Cube Compressive Strength (MPa)	61.25	67.96	61.37	62.32	50 Mpa
	RCPT in coulombs	1200	698.4	1150	700.5	Less than 1000 coulombs
5	Water Permeability in mm	12.5	5.0	12.58	4.00	Less than 10 mm
6	NT Built	3.32×10^{-12}	2.24×10^{-12}	3.44×10^{-12}	2.47×10^{-12}	-
7	Split Tensile Strength	5.22	5.30	5.25	5.4	2.8 Mpa
8	Flexural Strength	6.70	7.0	6.5	6.7	4.94 Mpa
9	Drying Shrinkage	0.018	0.016	0.017	0.015	0.5
10	Moisture Movement	0.015	0.011	0.013	0.011	0.05
11	Water Absorption	1.85	1.67	1.92	0.57	3%

12	Chloride Content	0.065	0.033	0.075	0.034	0.5
13	Sulphate Content	2.36	2.32	2.35	1.30	2.5

Concrete mix design with river sand has content less admixture quantity as compared to wash crushed sand but the results for fresh concrete with river sand achieved required limits on border line. However, mix design with washed crushed sand observed better retention time with more cohesiveness of concrete mix. Concrete mix design developed using washed crushed sand found far better results of harden concrete and durability tests results as compared with river sand concrete mix design.

4. Conclusion

1. In Indian standard IS:383 fine aggregates are more classified as Natural sand, Mixed sand, Crushed sand- (Sub classification -Crushed stone sand and Crushed gravel sand) and Manufactured sand. The process and the specification for categorizing all four types of fine aggregate are mentioned in Indian Standard but for making required zone of fine aggregate using advanced technology like hydro cyclic processing unit with automatic set system for producing ecofriendly, washed and finely graded fine aggregate is not elaborate in Indian standard.
2. Washed crushed stone sand is manufactured and processed in a controlled manner as per the requirement of practical size distribution and silt content. Silt content can be controlled less than 3% which is meeting the similar specified limit range of river sand as per IS: 383:2018. Hence consistent results for physical properties of fine aggregate can be obtained easily by processed washed crushed stone sand.
3. High performance cohesive, homogeneous and pumpable concrete can be designed using washed crushed stone sand because of cubical shape and equidimensional particle size distribution which helps to increase voids packing and development of higher strength.
4. The consistent quality results of river sand are the challenge due to frequent changes in natural geography of river according to the weather conditions. Hence Washed crushed stone sand is more suitable for making durable concrete structures.
5. Artificial washed crushed stone sand should be preferred for making concrete structures to avoid disturbing the natural riverbanks which plays major role for flood control of rivers.

.**CRediT authorship contribution statement**

Sandip Sonule: Acquisition of data; Analysis and interpretation of data; On site execution; Drafting of manuscript.

Dr. K.C Tayade: Analysis and interpretation of data; Review and editing of manuscript.

Sachchidanand Naik: Review and editing of manuscript; Funding acquisition; Permission and approval.

Compliance with ethical standards

Conflict of interest - On behalf of all authors, the corresponding author states that there is no conflict of interest.

References

[1] E. a. C. L. Rentier, "The environmental impacts of river sand mining," Science of the Total Environment, p. 7, 8th May 2022.

[2] G. Goverment, "COMMISSIONER OF GEOLOGY AND MINING," 02 02 2023. [Online]. Available: https://cgm.gujarat.gov.in/introduction. [Accessed 2023].

[3] "ASTM C33/03," in Standard Specification for Concrete Aggregates , Annual Books of ASTM Standards, USA, 2006., 2006.

[4] I. Standard, "IS:318:2016," in Coarse and Fine Aggregates for Concrete Specification , 2016.

[5] I. Standard, “IS:269:2016 - Ordenary Portland Cement- Specification,” BIS, New Delhi, 2020.

[6] I. Standard, “IS:3812 part 1:2013 - PULVERIZED FUEL ASH — SPECIFICATION,” BIS, New Delhi, 2013.

[7] I. Standard, "IS: 16715:2018 Ultrafine Ground Granulated Blast Furnace Slag-Specification," Indian Standard, New Delhi, 2018.

[8] "I S: 9103:1999 C-ONCRETE ADMIXTURES - SPECIFICATION," BIS, New Delhi, 2004.

[9] ASTM, "ASTM C1556: Bulk Chloride Diffusion (Diffusion Coefficient)," ASTM, USA, 2004.

[10] ACI, "ACI 212.3R-10 Report on Chemical Admixtures for Concrete," ACI, 2010.

[11] C. ASIA, "CDE Asia - Combo Sand Washing Plant," CDE ASIA, [Online]. Available: https://cdeasia.com/applications/manufactured-sand.

[12] "IS: 383-2016 Coarse and Fine Aggregate for Concrete - Specification," BIS, New Delhi, 2016.

[13] I. Standard, "IS:10262:2019 Concrete Mix Proportioning —Guideline," BIS, New Delhi, 2019.

[14] IS: 16715-2018 "Ultrafine Ground Granulated Blast Furnace Slag", 2018.

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