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Comparison of Indian Standard Specification for Aggregates and Manufactured Sand With International Standards: A Review

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Abstract. Many infrastructure projects are in progress, including highways, metro rail systems, state highway expansions, and airport developments. As these projects advance, new residential areas are being established in metropolitan cities, tier-two cities, and near railway metro junctions and airports. The demand for aggregates and sand has increased significantly. Many regions in the country are facing a shortage of natural sand. Manufactured sand is created using waste materials and crushed rocks to counter the issue of lack of natural sand for construction. The IS 383-2016 outlines guidelines regarding the grading and mechanical properties of manufactured sand. This sand experiences hydrothermal and chemical reactions as well as undergoes physical changes when utilized in concrete. Alkali-silica reaction in concrete occurs due to the presence of moisture from surrounding structures, alkalis in cement and silica in aggregates. This reaction can become visible within weeks or even after 10-20 years. Current infrastructure developments including bridges, flyovers and underground metro tunnels must be built to last between 50 to 100 years with minimal maintenance. Using excellent construction materials ensures the durability and longevity of infrastructure. Natural aggregates available near construction sites vary in terms of chemical and physio-mechanical properties. Therefore, revisions are needed in Indian Standards for manufactured sand and aggregates especially for assessment of organic impurities, levels of chloride, alkali-silica reaction and clay content. They should also address the specific requirements of various construction uses. This paper overviews Indian Standards for manufactured sand and aggregates in detail. It also compares several other related standards such as Japanese, Chinese and American AASHTO as well as ASTM standards.

1 Introduction

Aggregates including sand and gravel are fundamental raw materials in construction worldwide making up nearly three-fourths of the total volume in concrete. With the rapid growth

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of infrastructure projects, the demand for these materials has surged, tripling over the past two decades to reach approximately 40 billion tonnes annually [1]. However, the increasing reliance on natural river sand has caused serious environmental challenges particularly in countries like India and China where uncontrolled sand extraction has resulted in ground-water depletion, reduced water clarity, riverbank erosion, loss of vegetation and disruption of aquatic ecosystems. The scarcity of natural sand also poses challenges for agriculture and sustainable development highlighting the urgent need for alternative materials such as manufactured sand to ensure long-term environmental and economic stability [2]. Mineral composition, durability, plasticity, permeability, particle size and strength are the crucial properties to consider during aggregates selection for engineering works. Additionally, parameters such as potential of corrosion, sand particle's angularity and conductivity of thermal and electricity for certain specific applications. Projects like highways, metro rail systems and airfields involve deep foundations, drainage systems, erosion control structures and retaining walls. Infrastructure expansion in India including new roads, airports, and railways, demands a vast quantity of aggregates. Different types of retaining walls and foundations are built depending on project requirements. Structures built during the Mughal and British periods remain in good condition in several regions of the country. Current infrastructure projects, including bridges, flyovers and underground metro tunnels must be designed to last at least half century with minimal maintenance. Therefore, sand and aggregates utilized in engineering works should be of good quality to ensure long-term durability and stability. The objective of this paper is to compare Indian Standard for man-ufactured sand and aggregates with several other countries such as Japan, America and China.

Methodology of present work. The methodology involves a comparative analysis of Indian Standard IS 383-2016 [3] for aggregates and manufactured sand against international standards including Japanese (JIS A 5005-2009 [4]), Chinese (SJG 30-2016 [5]) and American ASTM and AASHTO standards. This study systematically examines the chemical and physio-mechanical properties specified in the standards focusing on critical parameters such as gradation, content of chloride, strength, organic impurities, durability and alkali-silica reactivity. Data collection was conducted through an extensive review of standard specifications and the evaluation included a detailed comparison of testing methodologies prescribed in each standard. The analysis further identifies gaps in Indian standards partic-ularly in chemical reactivity assessments by referencing advanced testing techniques such as petrographic examinations (ASTM 295 [6]) and bar mortar test for alkali-silica reaction detection. This comparison highlights the limitations in Indian standards and underscores the need for revisions to align with global best practices for ensuring long-lasting and sustainable infrastructure.

Comparison of Standards. The comparison of Indian standards for aggregates and manufactured sand with international standards reveals key areas where improvements are needed. The IS 383-2016 primarily focuses on physical parameters such as flakiness, aggre-gate crushing value, abrasion value, impact value, elongation index and soundness. However, it lacks detailed specifications on organic impurities, content of chloride, alkali-silica reactivity and clay content which are critical for long-term durability. In contrast, American ASTM and AASHTO standards, as well as Chinese Shenzhen (SJG 30-2016) and Japanese JIS A 5005-2009 standards provide more comprehensive guidelines particularly in evaluating chemical properties and potential reactivity issues. For example, the European RILEM standard and ASTM 295 include petrographic examination methods to detect potentially reactive minerals while ASTM bar mortar tests are used to confirm alkali-silica reactivity susceptibility. These international standards ensure that aggregates and manufactured

sand meet stringent quality criteria contributing to longer-lasting infrastructure. Therefore, updating Indian standards to incorporate advanced testing methodologies and chemical content limitations is essential for ensuring sustainable construction practices and prolonged infrastructure durability.

Properties of Aggregates. A property qualitatively describes the specific characteristics of a material [7]. Various properties control the material behavior under varying circumstances. These properties are often measurable regardless of having numerical value or not.

i Physical parameters include void content, shape and angularity of particle, glare, nominal and maximum particle size, color, surface texture, presence of harmful substances, thermal value change and conductivity, reflection, volume change due to drying and wetting, pore structure, void content, absorption, grading, unit weight, permeability and specific gravity.

ii Chemical parameters include base exchange, resistance to chemical reactions, content of chloride, slaking, coatings, organic material reactivity, surface change, solubility, hydration and oxidation reactivity as well as reactivity with chemical compounds.

iii Mechanical parameters include resilient modulus, stiffness, particle strength, resistance to degradation, mass stability and shape of abraded fragments.

Typical Physical Properties of Common Aggregates. Common aggregates include Granite, Limestone, Quartzite, and Sandstone. Table 1 presents the physical parameters of these aggregates such as average porosity, unit weight and water absorption.

Table 1. Common physical parameters of aggregates [8-11]

Parameters	Water absorption (% by weight)	Unit weight (kg m^{-3})	Average porosity (%)
Sandstone	2.0 - 12.0	1910 - 2690	1.9 - 27.3
Limestone	0.50 - 24.0	1870 - 2800	1.1 - 31.0
Granite	0.07 - 0.30	2600 - 2760	0.4 - 3.8
Quartzite	0.10 - 2.0	2640 - 2720	1.5 - 1.9

1.1 Indian Standard Specifications

Any of the listed sand types can be used for construction, as long as they meet the chemical and mechanical parameters set by IS 383:2016. It must be noted natural sand is frequently replaced by Crushed Stone Sand (CSS).

i Processing of non-natural sources through treatment of thermal, crushing, grading, washing, and scrubbing produces Manufactured Sand.

ii Crushing natural gravels produces Crushed Gravel Sand (CGS).

iii Crushing hard stone produces Crushed Stone Sand (CSS).

iv Blending natural sand with either CGS or CSS produces Mixed Sand.

Manufactured Sand. The latest version of IS 383:2016 introduced the term 'Manufactured Sand' to address the shortage of natural sand. Due to scarcity of natural resources, the Indian Standards allow usage of recycled concrete aggregate which originates as an industrial waste materials. Yet, they impose specific maximum limits on utilization as aggregates in concrete (Table 2).

Table 3 displays the allowable limits for chemical and mechanical parameters as per IS 383:2016. Meanwhile, Table 4 outlines the frequency at which aggregate properties should be tested. Table 5 the grading specifications for aggregates, as defined in IS 383:2016.

Table 2. Maximum limits on usage of manufactured fine aggregates [3]

Concrete type	Aggregate			
	Copper slag	Steel slag	Recycled concrete	Iron Slag
Lean concrete (%) (<M15 Grade)	50	100	100	100
Reinforced concrete (%)	35	Nil	20 ($\leqslant$ *M25Grade*)	25
Plain concrete (%)	40	25	25	50

Table 3. Chemical and mechanical parameters allowable limits [3]

Criteria	Allowable limits as stated in IS 383:2016
Soundness	- 12% and 18% when tested with Na_2SO_4 and $MgSO_4$ respectively specifically for coarse aggregates. - 10% and 15% when tested with Na_2SO_4 and $MgSO_4$ respectively specifically for fine aggregates.
Impact value	< 30 for wearing and < 45 for non-wearing surfaces
Combined flakiness and elongation index	By using 380 °C temperature regime, three recommended tests including accelerated mortar bar method, mortar bar method and chemical method.
Wearing surfaces (aggregate crushing value)	≤ 30%
Non-wearing surfaces (aggregate crushing value)	50 kN is the maximum load that must be applied for '10% fine' if the crushing value is > 30%

Table 4. Testing frequency [3]

Criteria	Testing frequency as per IS 4926 for typical conditions
Chloride content	Half yearly
Bulk density	Half yearly
Particle density	Half yearly
Particle density	Quarterly
Water absorption	Quarterly
Silt content for fine aggregates	Once a month
Gradation	Once a month

Table 5. Grading of aggregates stated in IS 383:2016 [3]

Sieve size of IS	Passing percentage for grading region			
	I	II	III	IV
150 μm	0 - 10	0 - 10	0 - 10	0 - 15
300 μm	5 - 20	8 - 30	12 - 40	15 - 50
600 μm	15 - 34	35 - 59	60 - 79	80 - 100
1.18 mm	30 - 70	55 - 90	75 - 100	90 - 100
2.36 mm	60 - 95	75 - 100	85 - 100	95 - 100
4.75 mm	90 - 100	90 - 100	90 - 100	90 - 100
10 mm	100	100	100	100

1.2 AASTHO and ASTM Standards

ASTM. The American Society for Testing and Materials (ASTM) is an globally acknowledged nonprofit organization consisting of users, producers, and general interest groups. It creates voluntary consensus standards for services, materials, systems and products. Also, it establishes both standard specifications and testing methods to ensure compliance with these standards. The standards comprise of 65 volumes covering varies materials with many obtainable as discrete reprints.

AASHTO. Similar to ASTM, American Association of State Highway and Transportation Officials (AASHTO) also develop and publish standards but representing highway and transportation sectors. It develops testing methods and specifications, many of which are derived from ASTM standards. A compilation of ASTM and AASHTO standards related to aggregates is presented in Table 6. Meanwhile, Table 7 shows relation between standard test methods of AASTHO and ASTM. ASTM and AASHTO also conduct aggregate testing

Table 6. AASHTO and ASTM standards for aggregates [7]

Criteria	AASHTO	ASTM
Common practices	R11; R10; R 1; M 146; M 146	C3665; C 125; D 8
Soil, subbase, base	M 283; M 155; M 147M	D 2940
Portland cement	M 195; M 80; M 6	C 33
Bituminous applications	R 12; M 43; M 29; M17	D 3515; D 1139; D 693

for bituminous applications including assessment of strength of aggregate base, measurement of unit weight and specific absorption, evaluation of frictional properties of pavements and aggregates, determination of particle texture and shape indices as well as identification of density-permeability-moisture relationships of aggregate bases.

1.3 Technical Specification for Manufactured Sand Application SJG 30 – 2016, Shenzhen, China

Due to the increasing shortage of natural sand resources, the ready-mixed sand in Shenzhen City has been widely used in ready mixed mortar and ready mixed concrete. The national standard 'Construction Sand' GB / T14684-2011 was implemented on February 1, 2012. The industry standard 'Technical Regulation for Application of Artificial Sand' JGJ/ T 242-2011 came into existence on Dec 1, 2011. Several terms are defined in the said standard for Manufactured sand with brief explanation in Table 8. The Table 9 presents the crushed dust content

Table 7. Relation between AASHTO and ASTM standards for aggregates [7]

Criteria	Correlation between AASHTO and ASTM
Fine aggregate properties	-AASHTO T 176 is related to ASTM D 2419 -AASHTO T 90 and T 89 are related to ASTM D 4318 -AASHTO T 210 is related to ASTM D 3744
Deleterious materials	-AASHTO T 21 is related to ASTM C 40 -AASHTO T 71 is related to ASTM C 87 -AASHTO T 112 is related to ASTM C 142 -AASHTO T 113 is related to ASTM C 123
Sample collection and preparation	-AASHTO T 2 is related to ASTM D 75 -AASHTO T 248 is related to ASTM C 702 -AASHTO T 87 is related to ASTM D 421
Tests for general aggregate quality (unconfined or in concrete)	-AASHTO T 104 is related to ASTM C 88 -AASHTO T 161 is related to ASTM C 666 -AASHTO T 96 is related to ASTM C 131 and C 535 -AASHTO T 327 is related to ASTM D 6928
Size of particles	-AASHTO T 27 is related to ASTM C 136 -AASHTO T 11 is related to ASTM C 117 -AASHTO T 30 is related to ASTM D 5444 -AASHTO T 38 is related to ASTM D 422 -AASHTO T 37 is related to ASTM D 546
Common tests	-AASHTO M 92 is related to ASTM E 11

in M-Sand, while Table 10 provides the maximum allowable water-soluble chloride iron content in Manufactured sand mixed. There are another 21 quoted standards [12-32] related

Table 8. Standard for Manufactured sand in China

Item	Explanation
Particle size of natural sand, Manufactured sand, rock tailings of Manufactured sand	< 4.75 mm
Particle size of crushed dust	< 75 μm
Particle size of clay lumps and friable particle content	1.18 mm > Particle size < 600 μm
Water absorption	The aggregate surface to be dry
Methylene Blue Value	Determined for particle size < 75 μm
All particle sizes of ready mixed mortar with manufactured	< 4.75 mm

to Manufactured sand including Ready mixed concrete (GB/T 14902), Design regulation for concrete structure (GB50010), Radionuclide limit of building materials (GB6566), etc.

1.4 Japanese Standard for Manufactured Sand and Crushed Stone for Concrete (JIS A 5005:2009)

The Japanese Industrial Standards Committee proposed this standard which was examined by Japan Crushed Stone Association (JCSA) and revised by Japanese Minister of Economy, Trade and Industry. Approximately 11 standards [33-43] are associated with JIS A 5005:2009

Table 9. Common physical parameters of aggregates [8-11]

Item		Index
Content of crushed dust (%)	MB < 0.5	≤ 15%
	0.5 ≤ MB < 1.4	≤ 10%
	MB ≥ 1.4	≤ 5%

Table 10. The maximum content of water-soluble chloride ions in concrete mixes using Manufactured sand

Ambient conditions	Maximum content of water–soluble chloride ions (%)		
	Reinforced concrete	Pre-stressed concrete	Plain concrete
Dry	0.30	0.06	1.00
Humid but not-chloride	0.20		
Humid and chloride	0.10		
Corrosion	0.06		

including Method of test for sieve analysis of aggregates (JIS A 1102), Method of test for determining the amount of material passing a 75 μm in aggregates (JIS A 1103), Method of test for solid content in aggregates and bulk density (JIS A 1104), etc. Table 11 show the classification by types and particle sizes for crushed stone and manufactured sand. Meanwhile, 12 depict the classification by alkali-silica reactivity for crushed stone and manufactured sand.

Table 11. Classification by types and particle sizes

Type	Classification by particle size	Range of particle size (mm)
Crushed stone	Crushed stone 4005	40 ~ 5
	Crushed stone 2505	25 ~ 5
	Crushed stone 2005	20 ~ 5
	Crushed stone 1505	15 ~ 5
	Crushed stone 1305	13 ~ 5
	Crushed stone 1005	10 ~ 5
	Crushed stone 8040	80 ~ 40
	Crushed stone 6040	60 ~ 40
	Crushed stone 4020	40 ~ 20
	Crushed stone 2515	25 ~ 15
	Crushed stone 2015	20 ~ 15
	Crushed stone 2513	25 ~ 13
	Crushed stone 2510	25 ~ 10
	Crushed stone 2010	20 ~ 10
Manufactured sand	Manufactured sand	Below 5

1.5 Quality of Aggregates

Impurities. Crushed stone and manufactured sand shall not contain mud, organic impurities trash, and other content that are harmful to concrete.

Table 12. Classification by alkali- silica reactivity

Classification	Designation
A	Those judged to be "harmless" as a result of the alkali-silica reactivity test.
B	Those judged to be "not harmless" as a result of the alkali-silica reactivity test, or those which have not been subjected to this test.

Physical Properties. Crushed stone and manufactured sand shall be tested to satisfy the physical parameters shown in Table 13.

Table 13. Physical parameters for Manufactured sand

Criteria	Crushed stone	Manufactured sand
Density (kg m^{-3})	≥ 2500	≥ 2500
Water absorption (%)	≤ 3.0	≤ 3.0
Soundness (%)	≤ 12	≤ 10
Abrasion loss (%)	≤ 40	-

1.6 Grading and Fineness Modulus

Grading. The grading of crushed stone and manufactured sand shall be tested, and the scopes are shown in Table 14.

Table 14. Grading

Classification by particle size	Mass fraction passing through each sieve (%)														
	Nominal size of the sieve (mm) (a*)														
	100	80	60	50	40	25	20	15	13	10	5	2.5	1.2	0.6	0.3	0.15
4005				100	95-100		35-70			10-30	0-5					
2505					100	95-100		30-70			0-10	0-5				
2005						100	90-100			20-55	0-10	0-5				
1505							100	90-100		40-70	0-15	0-5				
1305								100	85-100		0-15	0-5				
1005									100	90-100	0-15	0-5				
8040	100	90-100	45-70		0-15		0-5									
6040		100	90-100	35-70	0-15		0-5									
4020				100	90-100	20-55	0-15			0-5						
2515					100	95-100		0-15		0-5						
2015						100	90-100	0-15		0-5						
2513					100	95-100			0-15	0-5						
2013						100	85-100		0-15	0-5						
2510					100	95-100				0-10	0-5					
2010						100	90-100		0-10	0-5						
-										100	90-100	80-100	50-90	25-65	10-35	2-15
Note: a* = The indicated nominal sieve sizes correspond to the following nominal aperture sizes specified in JIS Z8801-1, which are 106 mm, 75 mm, 63 mm, 53 mm, 37.5 mm, 26.5 mm, 19 mm, 16 mm, 13.2 mm, 9.5 mm, 4.75 mm, 2.36 mm, 1.18 mm, 600 μm, 300 μm and 150 μm.																

Fineness Modulus. For manufactured sand, the fineness modulus should fall within a range of ±0.15 against the fineness modulus agreed on between the producer and purchaser.

Amount Retained On The Next Consecutive Sieve. Manufactured sand should not have more than 45% of particles passing through any given sieve while being retained in the consecutive sieve, as specified in Table 14.

Particle Shape. The particle shapes of crushed stone and manufactured sand are specified as following:

i Crushed stone shall not contain harmful amounts of thin stone pieces or elongated stone pieces.

ii The solid content for shape determination of crushed stone shall be tested, and the test result shall be 56% or more.

iii The solid content for shape determination of manufactured sand shall be tested. The test results shall be 54% or more.

Fines content (passing 75 μm **sieve)**. Fines content of crushed stone and manufactured sand shall be tested. The following test results shall be achieved:

i The fines content of the products shall be determined between the supplier and purchaser upon delivery to ensure that the test results do not exceed the limits specified in (b), even if there are some variations within the tolerance specified in (c).

ii The limit of fines content shall be 3.0 % for crushed stone, and 9.0 % for manufactured sand. However, the limit of fines content for crushed stone shall be 5.0 %, when its solid volume percentage for shape determination is 58% or more.

iii The tolerance of the fines content shall be ±1.0% for crushed stone, and ±2.0% for manufactured sand as reflected in the values agreed in (a).

Alkali-silica reactivity. The test results of the crushed stone may be used in the other crushed stone and manufactured sand when they are produced from the same source rocks for the representative test results of crushed stone.

2 Discussion and Conclusions

In this study, the IS 383-2016 has been compared with Japanese, Chinese and American ASTM as well as AASHTO standards for manufactured sand and crushed stone. IS 383-2016 also outlines the permissible usage of waste materials and recycled concrete. The standard considers physical properties including soundness, flakiness, aggregate crushing value, elongation index, impact value and abrasion value. IS 383-2016 defines four gradation types that are suitable for construction purposes. There is no specific limits for organic matter or impurities and content of chloride as well chemical for manufactured sand in Indian standard. Although alkali-silica reactivity is a major problem in aggregates, it is not addressed in Indian Standard. However, Japanese and American standards include test methods to identify this parameter. Also, the ASTM 295 and European RILEM standards may identify this parameter by examination of petrographic. Meanwhile, the bar mortar test of ASTM also can identify this parameter. For different applications of manufactured sand, the Indian Standard, the Indian Standard should establish clear criteria for acceptance and rejection. Thus, there is

necessity that Indian Standard for manufactured sand and aggregates is compared with other global standards including UAE for each type of construction and suitable test procedure is specified for meeting the criteria. The findings of this study are significant as they highlight the potential risks associated with the continued use of IS 383-2016 without updates. The absence of chemical impurity limits and ASR testing in Indian standards could lead to structural deterioration, reduced infrastructure lifespan and increased maintenance costs. Countries like the America, Japan and China have already incorporated stringent chemical reactivity assessments ensuring better material quality control. In conclusion, IS 383-2016 needs to revision in several criteria to enhance the reliability of manufactured sand and aggregates in India. This includes inclusion of mandatory ASR testing protocols similar to ASTM and RILEM standards, chemical composition limits for manufactured sand to prevent durability issues, comprehensive acceptance and rejection criteria for different types of aggregates as well as integrate international testing methods such as petrographic analysis and mortar testing.

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