Potential Utilization of Alternative Construction Materials in Qatar, in lieu of Conventional Washed Sand

Subrahmanyam Pilaka Venkata
AECOM/ Public Works Authority (Ashghal), Roads Projects Department, Doha, Qatar.
svenkata@ashghal.gov.qa / pvsubbu23@gmail.com

Ahmed Ghanim Abdulsalam Abunahia
Public Works Authority (Ashghal), Roads Projects Department, Doha, Qatar
anahia@ashghal.gov.qa

Aisha Zayed M. A. AlKhayareen
Public Works Authority (Ashghal), Roads Projects Department, Doha, Qatar
aalkhayareen@ashghal.gov.qa

Noora Ibrahim Q. S. Al-Ansari
Public Works Authority (Ashghal), Roads Projects Department, Doha, Qatar
nalansari@ashghal.gov.qa

Abstract

Natural sand that has been washed is an essential material used in infrastructure development and construction projects of all sizes. Due to the depletion of natural sand sources in Qatar, there has arisen a need to develop alternate materials to replace it. Substitutes such as wadi gravel, marine sand and manufactured sand, including crushed imported limestone, recycled sand and crushed gabbro have been considered and explored. Consequently, a proposal to encourage local washed sand producers to incorporate varying proportions of these alternate materials into the various material demands was considered by the Public Works Department, depending on the application in either structural and/or precast members. This paper primarily focuses on providing an overview of some of the available alternate materials to washed sand that could be utilized without affecting the physical, mechanical, or strength properties of concrete, precast, and other construction materials that use washed sand, while at the same time providing a long-lasting, durable and economically beneficial alternative material to the national economy.

Keywords: Alternative materials; Recycled aggregates; Wadi gravel; Washed sand; Imported limestone; Marine sand; Strength aspects; Economically beneficial

1 Introduction

Sand is the world's second most consumed raw material after water and an essential ingredient in the construction industry. In the future, industrialization, population growth, and urbanization are all likely to fuel explosive growth in sand demand. The global use of sand and gravel has been discovered to be ten times that of cement. This means that the world consumes 50 billion tonnes of sand and gravel per year just for construction. (United Nations, 2022)

Qatar's waste generation output is expected to rise in the near future due to the country's growing population, and increase in construction related to the World Cup 2022 projects, and a general increase in industrial output. More than 2.5 million tonnes of municipal solid waste are produced annually in Qatar, or around 2.5 kg per person per day. Qatar's waste generation problem is not just limited to municipal solid waste; the construction sector is also a major contributor. Currently, Qatar

generates 8.0 million tonnes per year of construction waste, and this number is predicted to remain above 6.0 million tonnes per year through 2030 (Qatar Development Bank, 2017).

Domestic demand for sand in Qatar, like in many other countries, is increasing, raising the possibility that the country's reserves will be consistently reduced. As a result, there is a risk that washed sand will soon be a scarce commodity. This can be mitigated by systematically implementing certain alternative materials through sustainability policies and regulations. This paper provides an overview of identified alternative materials to washed sand that do not affect the physical, mechanical, or strength aspects of concrete, precast, and all other construction elements that use washed sand, while also being long-lasting, durable, and economically beneficial to the national economy.

This paper will cover the following alternative construction materials, with a particular emphasis on alternatives to washed sand.

1. Recycled aggregates.
2. Wadi gravel.
3. Marine sand.
4. Imported crushed limestone sand.
5. Imported crushed gabbro sand.
6. Imported processed washed sand.

2 Alternative Materials

2.1 Recycled Aggregates

The Building Projects Department of the Public Works Authority (PWA) completed a pilot project using recycled aggregates in the State of Qatar for a holding tank, part of the Quarantine Veterinary & Laboratory Project at Hamad Seaport through Envi-Beton Company & Qatar Primary Materials Company (QPMC). The results were more than satisfactory, exceeding the Qatar Construction Specifications (QCS, 2014) requirement. Durability tests were conducted at the request of Ashghal's Quality and Safety Department (QSD), and the results exceeded the requirements of all applicable specifications.

The main issues with recycled aggregates include high values of acid soluble sulfate and chloride, sand equivalent, water absorption and fractions falling grading limits. The solutions include new system of recycling processes and modification of impact crushers and the use of new technology. The conclusion is that using recycled aggregates with no extra natural aggregates or sand will undoubtedly benefit the industry. Increased usage of recycled aggregate will reduce waste accumulation in landfills while decreasing demand for natural aggregates.

2.2 Wadi Gravel

Despite being a potential supply of fine and coarse aggregate, substantial processing was necessary to remove gypsum and make the aggregates appropriate for use in concrete to avoid internal sulfate attack. However, the savings in transportation costs and greenhouse gas emissions from not importing gabbro or other aggregates from distant sources more than compensate for this disadvantage. "Wadi gravel — a new concrete aggregate in Qatar: Part 1 — investigation, processing, and trials," a paper published by Khalid et al. (2020), demonstrated the successful processing of local Wadi gravel from Mekaines using Qatar's existing advanced washing and crushing facilities to produce QCS 2014-compliant aggregate for use as a coarse aggregate in concrete. The research also indicated several promising things to consider when using crushed wadi gravel sand as an alternative through numerous

trials, test results, and petrographic analysis. However, it emphasizes the challenges in processing crushed wadi gravel sand to remove gypsum that has adhered to it. The studies give some recommendations for the quantities of wadi gravel that are required to replace traditional washed sand in concrete.

Based on the current state of washed sand in Qatar and the above-mentioned study, Qatar Sand Treatment Plant (QSTP) conducted some trials with various wadi gravel crushed sand approved proportions, with the following results and conclusions:

Table 1: Trial results for wadi gravel crushed sand

0-5mm Natural wadi crushed sand 100%				
	Mix design	**Qty %**	**Compressive Strength, N/mm^2**	**Average N/mm^2**
Trial#1	Cement-OPC	17.3		**31N/mm^2**
	0-5 Natural wadi crushed sand	33.0	22.6	
	Water	7.2	33.8	
	Admixture	0.09		
	5-10mm Gabbro Aggregate	12.4		
	10-20mm Gabbro Aggregate	30.0	35.8	
0-5mm Natural wadi crushed sand 70%+ 0-5mm Washed sand 30%				
	Mix design	**Qty %**	**Compressive Strength, N/mm^2**	**Average N/mm2**
Trial#2	Cement-OPC	17.1		**47N/mm^2**
	0-5mm Natural wadi crushed sand	22.8	46.1	
	0-5mm Washed sand	9.7		
	Water	8.5	49.1	
	Admixture	0.09		
	5-10mm Gabbro Aggregate	12.2		
	10-20mm Gabbro Aggregate	29.6	44.9	
0-5mm Natural wadi crushed sand 50%+ 0-5mm Washed sand 50%				
	Mix design	**Qty %**	**Compressive Strength, N/mm^2**	**Average N/mm^2**
Trial#3	Cement-OPC	17.1		**52N/mm^2**
	0-5mm Natural wadi crushed sand	16.2	52.0	
	0-5mm Washed sand	16.2		
	Water	8.5	50.8	
	Admixture	0.09		
	5-10mm Gabbro Aggregate	12.2		
	10-20mm Gabbro Aggregate	29.6	52.5	

1. Trial#1-Strength is good but the surface finish is unsatisfactory.
2. Trial#2-Strength is high and the surface finish is satisfactory.
3. Trial#3-Strength is too high and the surface finish is satisfactory.

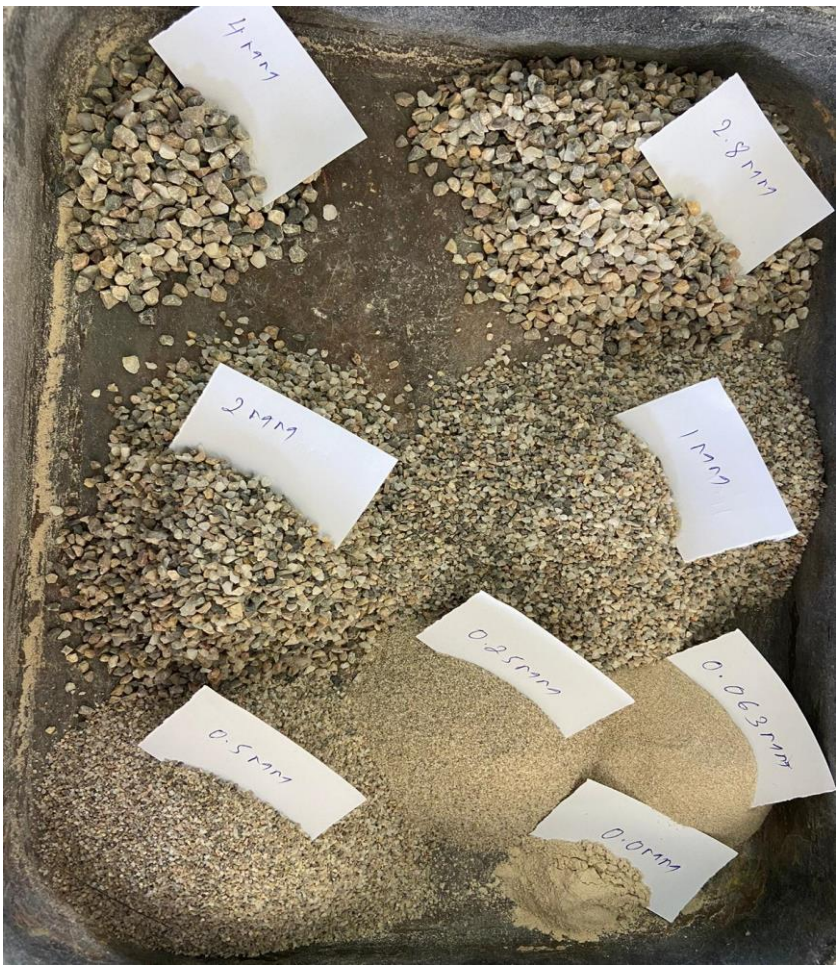

Fig. 1: Wadi gravel crushed aggregates of various sizes

If we propose to use the locally available wadi gravel as fine aggregate, local washed sand producers are prepared to invest and bring in specialized and cutting-edge technological equipment to crush, screen, process, and remove undesirable gypsum-bound deposits sticking to gravel.

2.3 Marine Sand

Due to the high chloride content of marine sand, more processing, washing, and cleaning are required to meet applicable specifications. Given the current situation, marine sand can be considered one of the viable alternatives to washed sand. Another study was conducted and published by Al Kuwari and Khaled (2015), for the Ministry of Environment, Science, and Technology Park. Advantages and disadvantages of marine sand are detailed below:

Advantages of Marine Sand

1. Marine sand particles are rounded or cubical.
2. The grading of sea sand is finer than that of river sand.
3. It contains no silt or organic materials.
4. It is readily available, but requires cleaning.
5. Material grading and consistency are uniform.
6. Reasonable cost of mining.
7. Countries with access to the sea such as Qatar can make extensive use of this natural resource.

Disadvantages of Marine Sand

1. Corrosion of reinforcements.
2. Cost and time for processing sea sand.
3. Production may require larger capital investment.
4. The mining of marine sand has an environmental impact, which can be mitigated.
5. May contain seashell.
6. Higher chloride content.

Table 2: Test results of marine sand

e	TEST REQUIREMENT	QCS 2014 S.5, P.2 PERMISSIBLE LIMITS	WASHED SEA SAND
1	Clay Lumps and Friable Particles (%)	2 % max	2%
2	Oven Dried (mg/m^3)		2.22 (mg/m ^{3})
3	S.S.D (mg/m ^{3})		2.38 (mg/m ^{3})
4	Apparent (mg/m ^{3})	2.0 min	2.66 (mg/m ^{3})
5	Water Absorption (%)	2.3 max	2%
6	Sand Equivalent Value (%)	60% min	90%
7	Shell Content (%)	3 % max	2%
8	Acid-soluble Chlorides (%)	0.06 % max	0.04%
9	Acid-soluble Sulphate^2 (%)	0.40 % max	0.35%
10	Material Fine Than 0.063 mm (%)	3 % max	2%
11	Bulk Density Un-Compacted (mg/m ^{3})		1.05 (mg/m ^{3})
12	Bulk Density Compacted (mg/m^3)		1.17 (mg/m ^{3})
13	Sand Color		Grey

2.4 Imported Crushed Limestone Sand

The UAE and Oman Musandam (Oman) limestone is considered among the best quality in the world. This imported limestone is widely used in ready-mix concrete plants and the manufacture of cement precast products. M/s Readymix Qatar is already using imported limestone from Musandam (Oman) for the “Nakhilat Ship Repair Yard Project” in Ras Laffan in Qatar. Test results comply with (QCS, 2014).

2.5 Imported Crushed Gabbro Sand

Gabbro is a coarse-grained, dark-colored, intrusive igneous rock. It is usually black or dark green in color and is made up mostly of the minerals plagioclase and augite. Gabbro, due to its durability and strength, has a wide range of applications in the building industry. It is brought into Qatar from the UAE and Oman. Before being utilized as fine aggregates in concrete, crushed gabbro must be treated to eliminate filler. In the face mix of the paving blocks, processed crushed gabbro was used. Cost, on the other hand, is a major issue determining the use of crushed gabbro sand, necessitating serious consideration of other materials such as wadi gravel.

2.6 Imported Processed Washed Sand

The Public Works Authority's Road Project Department (RPD) explored the possibility of importing washed sand from the region (Iran, Kingdom of Saudi Arabia KSA, etc.) via a few ready mix plants and precast manufacturers, but doing so would require approval from multiple government agencies and would most likely be expensive from Iran, but the option is open from Al Hofuf, KSA.

3. Conclusion

This paper proposes that using alternative materials (recycled aggregates and Wadi gravel) will provide Qatar with numerous advantages, including enhancing environmental protection, productive use of otherwise waste materials, reducing natural aggregate imports, cost savings, new business opportunities, and a reduction in greenhouse gas emissions. Simultaneously, alternatives such as sand imports from Al Hofuf, KSA, and the usage of marine sand (while mitigating environmental issues) should be explored for future demands.

Producers of washed sand should be permitted to utilize different proportions of available materials, including washed sand, imported limestone, crushed wadi gravel sand, and crushed gabbro sand, particularly for precast elements and non-structural concrete subject to QCS compliance.

All government bodies, including all PWA departments, QSD, the Central Laboratory, and universities, should hold discussions on the above proposals and develop application-focused specifications, particularly for structural, non-structural, precast, and marine structures. Depending on the importance of the structural members, different alternative options should be made available to ready mix and precast producers, while also taking critical requirements compliance, such as durability, into consideration.

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