Utilization of Recycled Materials in Infrastructure Projects: Ashghal Approach

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Abstract

As a result of numerous infrastructure projects which have taken place in Qatar in the last decade, there has been an unprecedented increase in demand for construction materials. In addition, the huge program of infrastructure development has led to production of massive quantities of construction waste. Consequently, the Public Works Authority of Qatar (Ashghal) launched an initiative to use recycled materials in projects in line with Qatar National Vision 2030 and Qatar National Development Strategy 2018 – 2022. A roadmap was developed in 2018 considering the available resources and experiences. Recyclable materials which can be used in Ashghal projects were identified. Excavation waste, demolition waste, Reclaimed Asphalt Pavement (RAP), Wadi Aggregate, Crumb Rubber and Steel Slag were selected for reuse. Controlled logistic areas to store, manage and process recyclable materials were established. Moreover, guidelines and prequalification procedures were developed for both materials sources and recycled materials producers. Testing programs were carried out on these materials to identify their basic characteristics. Laboratory trials and field trials were carried out at selected projects. Field trials were monitored and assessed using the local construction specifications QCS 2014. Based on lab and field trials, customized specifications were developed for the utilization of the selected recyclable materials in Ashghal projects. These specifications establish the baseline for construction using the selected recycled materials and determine the criteria and methods needed for quality control. Furthermore, Key Performance Indicators (KPIs), were established for Ashghal project departments to monitor their performance in relation to recycling. Ashghal's phenomenal performance in utilization of recycled materials in the last three years is presented.

Keywords: Ashghal; Recycling; Construction; Materials; Specifications

1 Introduction

Environmental development, which includes environmental protection, is one of the pillars of Qatar National Vision (QNV) 2030. Qatar shall protect its environment through balancing the needs of economic growth and social development with the conditions for environmental protection (QNV, 2008). Consequently, Qatar National Development Strategy (NDS), developed to achieve the QNV 2030. NDS-2 (2018-2022), encouraged recycling of construction waste to make use of them as construction materials, which reduces the cost of imported materials and preserves the environment. A target was set to increase the proportion of recycled materials in projects to 20% of the total materials used by 2022 through implementing specific programs and projects (QNDS, 2018) as shown in Table 1.

Table 1: NDS-2 Intermediate Outcome 1, Target, Projects, and Implementing Agencies

Intermediate outcomes	Targets	Programmes/Projects	Implementing Agencies	Supporting agencies
Intermeditae Outcome 1: An infrastructe created by economic and sustainable materials	1.1 Increase the proportion of recycled materials in projects to 20% of the total materials used by 2022	Develop a manual on the exploitation of local materials and waste, including methods of sorting and labelling, and identifying areas of optimum exploitation after the necessary specialized studies have been conducted.	MME	Ashghal Qatar General Organization for standards and metrology QU
		Develop legislation and building specifications to encourage the recycling of waste that include methods of dealing with waste, binding ratios, incentives, and penalties		
		Established a material research center	Ashghal	MME

The unprecedented programs of urbanization and establishment of infrastructure in the State of Qatar have led to generation of massive amounts of construction waste. Construction waste accounts for more than 75% of all solid waste generated in Qatar and most of this waste is landfilled in the desert contaminating an increasingly large area of land (Reid et al., 2016). Reuse of this waste requires establishment of a robust waste management plan, which includes a set of regulations and legislations that cover waste collection, sorting, recycling and disposal (Hahladakis et al., 2020). Alternative eco-friendly materials shall be utilized in projects to replace natural and imported materials. Some recycled materials such as steel slag may outperform natural aggregates in some characteristics such as skid resistance and fatigue life (Ziauddin et al., 2002). In addition, Reuse of recycled materials such as reclaimed asphalt pavement (RAP) has economic and environmental benefits as it reduces the rate of depletion of non-renewable resources such as aggregate and asphalt binders (MS-2, 2014). Moreover, properly managed stockpile of RAP may have more consistent gradation than virgin aggregates (West, 2015). Ashghal recycling initiative has ultimately led to encouraging the use of crumb rubber modified bitumen in lieu of polymer modified bitumen especially in local road projects, which are overseen by Road Projects Department of Ashghal (Ezio et al., 2020).

As stated in the roadmap, project departments of Ashghal were instructed to identify recyclable waste materials in their projects and thereafter retain and store it avoiding cross mixing and contamination of different types of materials. Such materials shall be transferred to Ashghal Central Storage Area, which is located at Rawdat Rashid as shown in Figure 1 (Ashghal Recycling Manual, 2021).

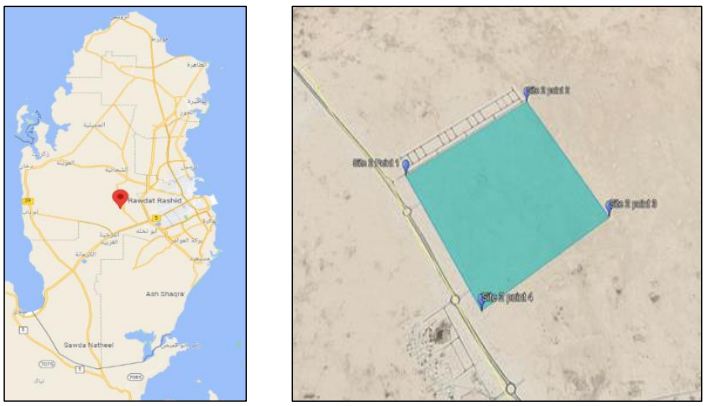

Fig. 1: Ashghal Central Storage Area for Recyclable Materials in Rawdat Rashid

2 Testing Programs

After launching Ashghal Initiative to use Recycled Materials in Projects on 5 November 2017 (Ashghal, 2017), which followed by Ashghal Recycling Roadmap on 9 May 2018 (Ashghal, 2018), the following materials were identified as the recyclable materials that can be used in Ashghal projects:

1. Excavation waste.
2. Demolition waste.
3. Reclaimed asphalt pavement (RAP).
4. Wadi aggregate.
5. Crumb rubber.
6. Steel slag.

These materials were selected based on the availability of considerable amounts and the ease of processing and recycling. Materials characterization program was carried out on recycled materials, which were collected from different sources. Based on the characteristics and compliance with the relevant specifications of Qatar Construction Specifications (QCS, 2014), the adequate utilization of each material was identified.

2.1 Demolition Waste, Excavation Waste and Wadi Aggregate

Total of 8 different blends were studied for fill and road subgrade materials and 5 blends for subbase materials. For fill and subgrade materials, the blend was considered successful based on compliance with fill and subgrade materials specifications, which are stated in Section 6, Part 3 of (QCS, 2014) as shown in Table 2. The successful blend consisted of Wadi Aggregate, which is a by-product of sand washing industry, Demolition Waste and Excavation Waste.

Table 2: Test Results of Fill and Subgrade Materials

Parameter	Test Standard	Result	QCS (2014) Specifications	
			Min.	Max.
Materials Passing 75.0mm	ASTM D6913	-	100	-
Materials Passing 0.075mm	ASTM D1140	7.0	-	30.0
Liquid Limit, %	ASTM D4318	Non-Plastic	-	30
Plastic Limit, %			-	-
Plasticity Index			-	10
Soaked CBR value, %	ASTM D1883	182	15	-
Swell, %		0.06	-	2.0

For road subbase materials, the successful blend following QCS (2014), Section 6, Part 4, consisted of 0-5mm, 5-10mm, 10-20mm and 4-50mm Demolition Wastes. Test results compared to (QCS, 2014) specifications are shown in Table 3. Subgrade, fill and subbase materials constituents are illustrated in Figure 2.

Table 3: Test Results of Subbase Materials

Parameter	Test Standard	Result	QCS (2014) Specifications	
			Min.	Max.
Materials Passing 50.0 mm	ASTM C136, ASTM C117	100.0	100	100
Materials Passing 37.5 mm		99.1	90	100

Materials Passing 19.0 mm		81.2	70	90
Materials Passing 9.5 mm		46.9	45	75
Materials Passing 4.75 mm		35.3	30	60
Materials Passing 0.600 mm		12.4	10	30
Materials Passing 0.075 mm		4.1	0	12
MDD, Mg/m^3	ASTM D1557	2.16	2.05	-
Soaked CBR value, %	ASTM D1883 BS 1377-4: 1990	250	70	-
Swell, %		0.04	-	1.0
Liquid Limit, %	ASTM D4318	Non-Plastic	-	25
Plastic Limit, %			-	-
Plasticity Index			-	6

Fig. 2: (a) Subgrade/Fill Materials Blend **(b)** Subbase Materials Blend

2.2 Reclaimed Asphalt Pavement (RAP) Materials

Major emphasis has been put on Reclaimed Asphalt Pavement (RAP) derived from milling of bituminous courses. This is due to the abundancy of this material in the fast-growing Qatari infrastructure network and the need to replace the imported bituminous courses constituents such as the aggregate and bitumen with less costly materials. A field trial was carried out to assess the feasibility of producing and laying hot asphalt mix containing 15% RAP. Test results of a sample collected from the field trial is shown in Table 4.

Table 4: Results of Asphalt Mix Containing 15% RAP Compared with QCS Specifications

Parameter	Result	Target JMF[1]	QCS Limits
Bulk specific gravity, G_{mb}	2.542	-	-
Bulk density (kg/m^3)	2534	-	-
Maximum Theoretical Density, G_{mm}	2.718	2.738	-
Air voids (%)	6.5	6.6	4.5 - 8.0
Stability (kN)	18.40	13.2	≥ 9.5
Flow (mm)	2.75	2.6	2 - 4
Quotient (kN/mm^2)	6.69	5.1	≥ 4.75
Air voids @ 400 blows (%)	4.8	4.0 / 5.1	≥ 3.4

[1] Job Mix Formula

Based on the evaluation of the field trial and the results obtained from laboratory testing, it was concluded that the production and laying of asphalt mix containing 15% RAP is compatible with the Contractor's plant layout and field equipment. The produced asphalt mix met QCS requirements and the desired level of compaction in the field consistently. Paving operations of the asphalt mix with 15% RAP are shown in Figure 3.

Fig. 3: Paving Operations of Asphalt Mix with 15% RAP

2.3 Crumb Rubber

Crumb rubber is the product of reducing scrap tyres into uniform grains after removing the reinforcing materials such as steel and fibre along with any other type of contaminants. Plant trials showed that asphalt mixes containing crumb rubber modified bitumen (CRMB) can comply with QCS, Section 6, Part 5 requirements. Test results of two plant trials are shown in Table 5.

Table 5: Results of Asphalt Mixes containing CRMB produced from Plant Trials

Parameter	Plant Trial 1	Plant Trial 2	QCS Limits
Optimum binder content, OBC (%)	4.1	4.1	3.4 – 4.4
Air voids, V_a (%)	7.2	6.5	5.0 – 8.0
Voids in mineral aggregate, VMA (%)	15.6	15.4	≥ 14.0
Voids in filled with asphalt, VFA (%)	54	58	50 – 75
Stability (kN)	13.5	18.5	≥ 13.0
Flow (mm)	2.5	2.5	2 - 4
Quotient (kN/mm^2)	5.40	7.40	≥ 5.25
Air voids @ 400 blows (%)	4.4	4.5	≥ 4.0
Retained stability (%)	94	90	≥ 75
Tensile strength ratio, TSR (%)	81	84	-
Filler to bitumen ratio	0.95	0.76	0.75 – 1.35
Rut depth from HWT test (mm)	4.7	7.2	-

2.4 Steel Slag

Ashghal, in collaboration with Qatar Steel Company and TRL, constructed trial sections in Qatar Steel premises in the Mesaieed Industrial Area. Two sections were constructed with asphalt courses containing 20% and 40% steel slag aggregate. Loose samples from the hot mixes were collected and tested. Test results compared with QCS requirements are shown in Table 6. After monitoring the trial sections and testing of the extracted samples, the study concluded that steel slag can be used as coarse

aggregate (5-20 mm) to replace gabbro in asphalt base mixes; however, the Ministry of Environment has limited the use to a maximum of 20% in asphalt base courses and in non-structural ancillary concrete such as soakaways, manholes and cable covers (Hassan et al., 2017). Paving operations of asphalt mix with 20% steel slag are shown in Figure 4.

Table 6: Results of Asphalt Mix containing 20% and 40% steel slag aggregate

Parameter	20 % Slag	40% Slag	QCS Limits
Air voids, V_a (%)	8.2	7.0	4.0 – 8.0
Voids in mineral aggregate, VMA (%)	16.3	15.2	≥ 13.0
Voids in filled with asphalt, VFA (%)	49.6	53.8	50 – 70
Stability (kN)	16.6	18.1	≥ 9.5
Flow (mm)	2.9	2.6	2 – 4
Quotient (kN/mm^2)	5.7	7.0	≥ 4.75
Air voids @ 400 blows (%)	4.7	4.1	≥ 3.2

Fig. 4: Paving Operations of Asphalt Mix with 20% steel slag

3 Developing Specifications and Guidelines

After launching Ashghal Recycling Initiative, lack of materials specifications, manufacturers' and suppliers' prequalification procedures were identified as challenges for implementation. After selecting the potential recyclable materials, which can be used in Ashghal projects, it was required to prepare guidelines related to permissible uses of materials, materials handling in processing plants, materials control in projects, technical specifications, quality control measures and supplier's prequalification. Hence, recycling specifications and guidelines were developed by Quality and Safety Department taking into consideration the conducted laboratory and field trials, Ashghal technical requirements, joint research projects, the best regional and international practices and Qatar Construction Specifications. Hence, the following technical documents were issued for implementation:

1. Roadmap for Implementation of Ashghal Initiative of Recycling in Construction Projects.
2. Ashghal Recycling Manual.
3. Reclaimed Asphalt Pavement (RAP) Management Guidelines.
4. Recycled Materials for Road Works. Public Works Authority (Ashghal) Issue, (QCS, 2018), Section 6, Part 9.
5. Factory Production Control of Bituminous Mixtures – Part A: Technical Guidance.

6. Pre-qualification Guidelines for Crumb Rubber and Crumb Rubber Modified Binder Producers.
7. Guidelines for Mix Design and Quality Control of Asphalt Mixes with Crumb Rubber Modified Binders.

4 Ashghal Performance in Recycling

For corporate performance monitoring in relation to recycling, Quality and Safety Department (QSD) established KPIs for different recycled materials to ensure Ashghal will achieve the maximum value and cost savings. The established KPIs and targets are shown in Table 7. As requested by Ashghal top management during the 2019 Full Year Performance Review, Quality and Safety Department conducted a review on the applied recycling processes to provide challenging targets for recycling KPIs. Consequently, the established KPIs, which were segregated for each material type, were provided for implementation and reporting by project departments starting from 2020. Segregation of KPIs allowed an enhanced monitoring of recycling performance for each recyclable material in Ashghal projects.

Table 7: Key Performance Indicators per Recycled Materials type

No.	KPIs for Recycling	Target (%)	Overall Average (%)
1	Percentage of RAP in asphalt	1	20
2	Percentage of recycled materials in Subbase and Road Base layers	20	
3	Percentage of recycled materials in Fill and Subgrade materials	20	
4	Percentage of Crumb Rubber in asphalt	0.1	
5	Percentage of recycled aggregate in masonry blocks, kerb and paving blocks	1	
6	Percentage of recycled aggregate in non-structural concrete	1	
7	Percentage of recycled aggregate for cable and pipe bedding & surround	1	

Ashghal performance in recycling is monitored every quarter. Data received from project departments is collected and reviewed by Quality and Safety Department and then reported to Ashghal top management. Quantities of recycled materials used in Ashghal projects are reported in line with the performance indicators. During 2021, 41,553 tons of RAP were used in hot asphalt mixes out of 1,798,651 tons placed in Ashghal projects. 914,701 tons of recycled unbound road base materials were used out of total 1,915,643 tons total materials used. In addition, 13,556,350 tons of subgrade and fill materials were reused out of total 16,485,304 tons. 1,190 tons of crumb rubber was utilized to modify bitumen replacing the imported polymers. 38,407 tons of recycled aggregate were used in concrete blocks out of 3,345,146 tons used. For non-structural concrete, 44,892 tons of recycled aggregate were utilized in concrete mixes out of total 2,118,697 tons of aggregate used. Nevertheless, 605,405 tons of recycled bedding and surrounds materials were utilized for pipe and cable bedding out of total 3,079,833 tons of materials used in projects. Hence, during the last year, Ashghal was able to use 15,202,498 tons of recycled materials out of 28,743,274 tons total materials, which were identified as recyclable materials. Hence, about 52.9% of the total materials consumed in projects,

was successfully recycled and reused. Summary of year 2021 recycling performance is shown in Figure 5.

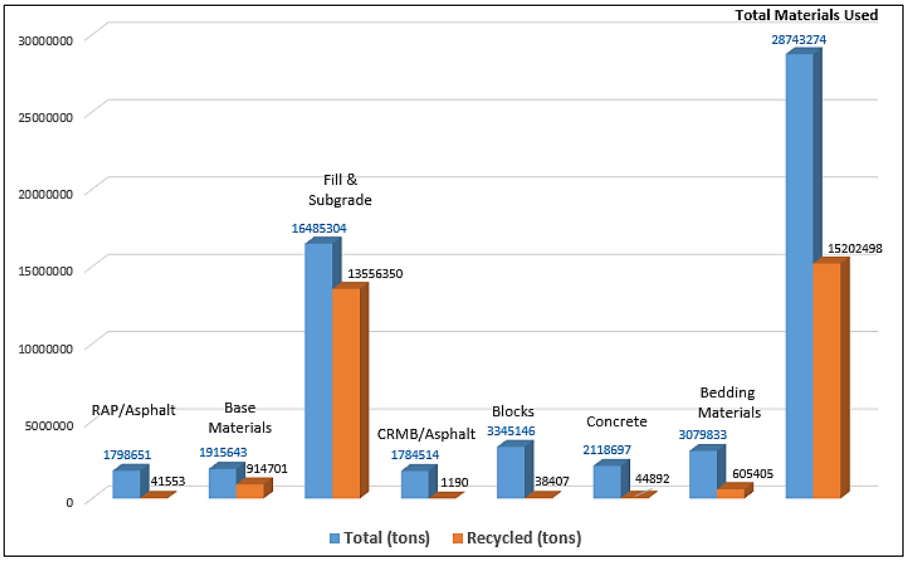

Fig. 5: Ashghal Recycling performance during 2021

Recently, the target of the percentage of materials to be recycled in Ashghal projects was suggested to be increased from 20% to 30% of the total consumed materials. Implementation of the new target is expected to start within 2023.

5 Conclusion

Based on the illustrated approach, which was followed by Ashghal to use recycling materials in projects, the following can be concluded:

1. Implementation of recycling plan in public works projects is facilitated and supported by the country strategy and vision.
2. Lack of local specifications, regulations and legislations that cover waste handling, recycling and reuse pose major challenges for the utilization of recycled materials in projects.
3. Developing specifications was facilitated through conducting lab experiments, performance testing schemes and field trials.
4. Based on Ashghal experience, up to 15% RAP can be added to hot mix asphalt with no need to modify the standard job mix formula and without addition of rejuvenators.
5. A well-designed blend of 15% Wadi aggregate, 30% recycled demolition waste and 55% recycled excavation waste was found to comply with QCS (2014) requirements for subgrade and fill materials. This blend can fully replace the natural burrowed materials.
6. Natural road subbase materials can fully be replaced by a graded recycled demolition waste blend as it was found to comply with (QCS, 2014) requirements.
7. Public Works Authority (Ashghal) of Qatar has successfully achieved 52.9% recycling rate in 2021 by recycling and reusing of 15,202,498 tons out of 28,743,274 tons of the recyclable materials consumed in infrastructure projects.

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