Building Sustainably

WASTE MANAGEMENT BEST PRACTICES FOR CONSTRUCTION SITES

Case Studies from FIFA World Cup Qatar 2022™ Stadiums

المنظمة الخليجية للبحث والتطوير
GULF ORGANISATION FOR RESEARCH & DEVELOPMENT

اللجنة العليا للمشاريع والإرث
Supreme Committee for Delivery & Legacy

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BEST PRACTICES FOR CONSTRUCTION SITES

Case Studies from FIFA World Cup Qatar 2022™ Stadiums

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Developed By:
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FOREWORD

Dr. Yousef Mohammed Alhorr
Founding Chairman,
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Over the past decade, we have witnessed Qatar's skyline transform like never before. Since the nation's winning bid for the FIFA World Cup Qatar 2022™, we saw the pace of construction further amplified as the country braced to host one of the world's most celebrated events. To welcome football fans in 2022, Qatar developed the required buildings and infrastructure projects such as stadiums, road networks, railways, hotels, residential buildings and commercial facilities. An inevitable outcome of this unprecedented development is waste generation resulting from construction and demolition activities across Doha.

Acknowledging such environmental consequences of construction practices at a very early stage, Qatar adopted green building principles for various types of projects as the nation embarked on its journey to deliver climate action during the FIFA World Cup 2022™, while also meeting its growing urbanization needs.

An integral part of key construction projects in Qatar is the Global Sustainability Assessment System (GSAS) – a green building certification system that guides and assesses projects by measuring their ability to deliver sustainable design features, construction practices and post-construction operational performance. The implementation of best practices and guidelines prescribed by GSAS helps fight global issues such as climate change and resource depletion.

GSAS Construction Management (GSAS-CM) certification addresses the issue of waste management alongside other environmental impacts of construction processes and practices carried out on sites by contractors and builders. Embracing green practices on site presents a range of opportunities beyond the obvious benefit of preserving the ecosystem. Reusing and recycling construction materials, for instance, not only reduce the construction waste ending up in landfills but also cut down the cost of new materials required for future use.

Over the years, application of GSAS-CM standards has improved the local environmental issues such as air quality, noise control and waste management. GSAS-CM certification guidelines have also been followed at the construction sites of all FIFA World Cup Qatar 2022™ venues. A part of this exercise involves sustainable waste management on stadium sites.

By documenting the best practices in construction waste management on stadium sites in this report titled "Waste Management: Best Practices for Construction: Case Studies from FIFA World Cup Qatar 2022™ Stadiums", we hope to benefit and support the entire construction community in its quest towards sustainable built environment.

FOREWORD

Sustainability formed a central tenet of Qatar's bid for the FIFA World Cup Qatar 2022™, helping it stand out among competitors.

When we started drawing up plans for the tournament, we had a nearly blank canvas – giving us a huge advantage to ensure that sustainability sat at the heart of all our FIFA World Cup Qatar 2022TM planning and delivery, before we first broke ground on any projects.

Working with our partners and stakeholders, we have delivered a number of the sustainability promises we made in our bid – key of which is building the infrastructure required for the tournament according to the highest sustainable building and construction standards. On stadium sites, this involved Qatari entities working with international partners to achieve sustainable design and construction – of which efficient resource planning and effective waste management form crucial elements.

Our collective efforts have helped minimize the impact that the construction of tournament venues had on the environment, and contributed to upscaling environmental consciousness across the industry. Along the way, we have set new benchmarks that we hope the rest of both the construction and mega-event industries locally and internationally can benefit from.

However, despite all of the progress we have made our work is not done, and maintaining this positive momentum will be key to the legacy we are aiming for the tournament to leave after 2022.

The Gulf Organisation for Research & Development (GORD) has been a key partner in helping us achieve the immediate positive environmental impact of the FIFA World Cup Qatar 2022™, guided by the GSAS certification system. Our collaboration will continue long after 2022 as we move to deliver our long term legacy planning aimed at ensuring that sustainable environmental development is maintained for generations to come, and reports such as this one will contribute to this.

We are pleased to share our second case study report with GORD on sustainable construction, focusing this time on waste management best practices and case studies from stadium sites across Qatar. We are certain the report will be an invaluable tool to many in the construction industry, and look forward to continued cooperation.

Eng. Bodour Al Meer

Executive Director - Sustainability,
Supreme Committee
for Delivery & Legacy (SC)

ACKNOWLEDGEMENTS

This report has been made possible through the continued efforts and support of many dedicated individuals and entities, including the Supreme Committee for Delivery & Legacy, GSAS Certified Green Professionals working at stadiums' construction sites, and the Gulf Organisation for Research & Development's technical and administration support teams.

1.0 INTRODUCTION

Infrastructure and development projects contribute to a country's growth, and consequently, to an increase in waste from construction activities. Construction waste often ends up in landfills, and it is then no longer possible to sort, reuse or recycle. Most construction waste can be a resource to other projects in the form of reuse, repurpose or recycle. This leads to a more sustainable economic and physical environment. Benefits of sustainable environment include preservation of limited landfill space, protection of natural environment, conservation of finite resources, reduction of energy required to produce raw materials, and minimization of financial costs of transportation and raw material purchase.

Usually, up to 70% of waste generated in most developing countries is from construction. Construction waste generally consists of a combination of soil, steel, concrete, plastic, wood, paper and cardboard, organic and/or general waste. In most projects, metals, paints and other potentially hazardous materials are also present and therefore efficient waste management is required. To maximize recycling, waste materials need to be sorted and arranged separately as per their material composition, e.g. wood, plastic and metal etc. This is a challenge on construction sites, where the waste is often combined and contaminated. In Qatar, with the goals set forth in Qatar National Vision 2030, Qatar National Development Strategy 2018-2022, and the FIFA World Cup Qatar 2022™, significant attention has been placed on construction waste. Since all stakeholders have intentions to pursue sustainability, substantial activities have been undertaken to reduce the amount of construction waste sent to the country's landfills.

More specifically for the Qatar 2022 event, the FIFA World Cup Qatar 2022™ Sustainability Strategy details the sustainability program for the preparations, staging and post-event activities for the FIFA World Cup Qatar 2022™. The environmental pillar of the Strategy includes objectives for green building and waste minimization.

1.0 INTRODUCTION

1.1 FIFA Endorsement and SC Commitment

For the FIFA World Cup Qatar 2022™, GSAS Design & Build 4 Star certification has been endorsed as the required green building rating system. The SC has gone beyond FIFA's minimum requirement by delivering GSAS Design & Build and GSAS Construction Management for all FIFA World Cup Qatar 2022™ stadium sites. Furthermore, the SC is implementing GSAS Operations certifications on the stadium sites and permanent office. The SC specified that GSAS Construction Management (CM) certifications should be achieved with a minimum rating of Class A for the construction sites of the stadiums. Most of the stadium construction sites have not only met this requirement but also exceeded it.

Table 1 presents the GSAS-CM certification ratings achieved by all FIFA World Cup Qatar 2022™ stadium projects.

Table 1: *GSAS-CM certification ratings achieved by all FIFA World Cup Qatar 2022™ stadium projects*

Stadium	GSAS-CM Rating
Al Bayt Stadium	Class A*
Al Janoub Stadium	Class A*
Ahmad Bin Ali Stadium	Class A*
Al Thumama Stadium	Class A*
Education City Stadium	Class A*
Khalifa International Stadium	Class A
Lusail Stadium	Class A*
Stadium 974	Class A*

2.0 WASTE MANAGEMENT IN GSAS CONTEXT

Waste generated by construction activities is assessed in GSAS-CM v2.1 in the criterion "[MO.1] Waste Management" under the Management and Operations category. This criterion identifies methods and measures to be implemented to reduce, collect, segregate, transport, recycle and dispose of waste generated on site. The degree of implementation of these methods and measures is determined based on the project documentation in the form of a Waste Management Report, as well as site audits conducted by auditors from GSAS Trust. Accordingly, a scoring level is awarded to the project as follows:

- Level 0, if the Waste Management Report does not demonstrate compliance with the minimum requirements of GSAS, meaning that the degree of implementing the stipulated GSAS methods and measures is less than 80%.
- Level 1, if the Waste Management Report demonstrates partial compliance with GSAS requirements. In other words, the Waste Management Report addresses the requirements of managing hazardous waste only.
- Level 3, if the Waste Management Report demonstrates full compliance with the requirements of GSAS, which includes the implementation of methods and measures related to reduction, segregation, collection, storage and disposal of construction waste.

The assessment of waste management is carried out over the full construction period and audits are conducted during three construction stages as follows:

- Stage 1: Enabling & Foundation
- Stage 2: Substructure & Superstructure
- Stage 3: Finishing

2.1 FIFA World Cup Qatar 2022™ Stadiums

Table 2 represents the status, as of December 2020, of FIFA World Cup Qatar 2022™ Stadium projects' awarded levels for GSAS-CM Waste Management criterion:

Table 2: *Awarded [MO.1] levels*

Stadium	Stage 1	Stage 2	Stage 3
Al Bayt Stadium	3	3	3
Al Janoub Stadium	3	3	3
Ahmad Bin Ali Stadium	3	3	3
Al Thumama Stadium	3	3	3
Education City Stadium	3	3	3
Khalifa International Stadium	3	2	2
Lusail Stadium	3	3	3
Stadium 974	3	3	3

2.0 WASTE MANAGEMENT IN GSAS CONTEXT

2.2 Waste Quantification

Shortage of construction waste data causes difficulty in planning the future of construction waste management. Quantification of construction waste is one of the valuable solutions that can be implemented. Quantification provides a necessary tool in evaluating the true size of construction waste produced on construction sites. There are various methods considered for quantifying the waste generation amount or rates. For example, based on statistical data concluded from interviews and questionnaires, or through sorted and weighed waste materials.

At the stadiums' construction sites, each contractor is required to implement a robust waste tracking system documenting the evidence of the waste being collected, transferred, diverted and disposed to a landfill. In this report, only the solid waste generated from construction activities has been considered in order to produce a fair comparison and analysis for the indicated projects. Therefore, waste related to the existing conditions of the site as indicated below have not been considered:

1. Waste from the demolition of existing structures, as there is no consistency in pre-existing structures within the projects, and therefore demolition waste quantities vary significantly.
2. The excavated material, as it varies significantly from project to project depending on the topography of the site.
3. Hazardous waste, including chemical, medical waste, and any contaminated soil on construction sites.
4. Liquid waste, including waste water and sewage.

2.3 Waste Management Data Analysis

Robust waste tracking has been recorded during the construction of all FIFA World Cup Qatar 2022™ stadiums sites as per GSAS-CM requirements. The data has been analyzed by GSAS Trust to produce key performance indicator (KPI) ratios that demonstrate the effectiveness of the waste management procedures implemented on the construction sites. The primary KPI is the percentage of waste diverted from landfills. Diverting waste from landfills is an important element to improve the use of resources and reduce the environmental impacts of waste management. Waste policies should be put in place to cover a wider life-cycle perspective on resource use, consumption and production, taking into consideration that prevention and recycling of waste are important elements in this life-cycle.

Furthermore, other data has been analyzed to produce some quantifiable ratios that can be useful for future projects to plan waste management. This includes the following:

- Waste per building area
- Food waste per worker and day
- Percentage of different waste streams

2.0 WASTE MANAGEMENT IN GSAS CONTEXT

2.3.1 Waste Diverted from Landfills

The main environmental impact of construction waste is related to landfills. Therefore, the percentage of waste diverted from landfills is considered as one of the most important KPIs. To achieve this target, all projects implemented waste management methods and measures following GSAS-CM Guidelines, and the well-known hierarchy of reduce, reuse, recycle and dispose to landfills when none of the other options was available.

Table 3 indicates solid waste diverted from landfills. Note that Khalifa International Stadium has not been considered because the stadium was refurbished, and not constructed from scratch.

A total of 79% of solid waste was diverted from landfills, indicating that the stadium sites have implemented effective waste management practices to reuse and recycle construction waste, as described under Section 3 of this report.

Table 3: *Percentage of waste diverted from landfill*

Stadium	Percentage of Waste Diverted from Landfill by Weight
Al Bayt Stadium	80%
Al Janoub Stadium	90%
Ahmad Bin Ali Stadium	84%
Al Thumama Stadium	71%
Education City Stadium	72%
Lusail Stadium	74%
Stadium 974	95%
Total	**79%**

2.0 WASTE MANAGEMENT IN GSAS CONTEXT

2.3.2 Further Analyses

Further analyses have been carried out with the objective to help future projects plan effective waste management. The conclusions can be used to inform other projects when estimating their waste generation during construction, and to properly dimension the waste segregation areas and number of skips necessary per waste stream, or even to inform waste haulers and recycling facilities. Additionally, these ratios can be considered baseline targets to achieve or exceed when creating strategies for waste reduction.

Ratio 1: Generated Waste per Gross Floor Area

Following the same rationale, the building gross floor area can be regarded as a useful parameter to estimate waste. Below, the ratio has been calculated by both weight and volume, as illustrated in Table 4 and 5.

As illustrated in the tables below, the average waste is 384 kilograms per square meter, which is equivalent to 0.437 m3 (437 liters) per square meter.

Table 4: *Waste per gross floor area by weight*

Stadium	Waste per Area (kg/m^2)
Al Bayt Stadium	223
Al Janoub Stadium	418
Al Thumama Stadium	400
Ahmad Bin Ali Stadium	356
Education City Stadium	315
Lusail Stadium	735
Stadium 974	239
Average	**384**

Table 5: *Waste per gross floor area by volume*

Stadium	Waste per Area (m^3/m^2)
Al Bayt Stadium	0.305
Al Janoub Stadium	0.457
Al Thumama Stadium	0.453
Ahmad Bin Ali Stadium	0.444
Education City Stadium	0.388
Lusail Stadium	0.758
Stadium 974	0.253
Average	**0.437**

2.0 WASTE MANAGEMENT IN GSAS CONTEXT

Ratio 2: Daily Generated Food Waste per Worker

This ratio combined with the anticipated worker schedule can be used to estimate the food waste that will be generated by the construction sites. This can be a useful ratio for projects with substantial workforce. Also, this specific ratio can help projects to:

- Reach agreements with composting facilities and waste haulers.
- Dimension the number and size of food skips and bins.
- Monitor food waste generation using it as a benchmark.
- Monitor the excess food supplied by the catering company to control both cost and waste.

During the stadiums' construction stages, the number of workers on some sites have peaked to well over 5,000. Table 6 presents daily food waste per worker. It is concluded that the average food waste per person and day is 0.349 kg (349 grams). This ratio is subject to the following variables:

- Number of meals served per day. This depends on working schedule and number of shifts.
- Efficient segregation of food waste from other waste streams. This results in reliable waste quantities.
- Disposable plates and cutlery versus steel trays and cutlery. The latter results in a more efficient segregation of food waste.
- Queue length and waiting time. Long queues encourage workers to get large food portions to avoid queuing for a second round.
- Awareness campaigns for reducing food waste adequately change behavioral patterns and consumers' attitudes.

Table 6: *Food waste per person and day*

Stadium	Waste Per Person (kg/day)
Al Bayt Stadium	0.466
Al Janoub Stadium	0.665
Ahmad Bin Ali Stadium	0.209
Al Thumama Stadium	0.373
Education City Stadium	0.371
Lusail Stadium	0.264
Stadium 974	0.095
Average	**0.349**

2.0 WASTE MANAGEMENT IN GSAS CONTEXT

Ratio 3: Percentage of Different Waste Streams

Another approach is to estimate the waste generated per stream. These percentages can be combined with other ratios to estimate the amount of waste generated per stream. Table 7 demonstrates waste streams percentage distributed by weight, while Table 8 demonstrates waste streams percentage distributed by volume.

It is noticeable that concrete accounts for the majority of the waste i.e. 70.5% by weight and 48.8% by volume. This means that reusing and recycling concrete waste is key to achieve a high percentage of waste diverted from landfills. General waste represents only 19% of the waste due to good waste sorting practices on site, which eventually results in reusing and recycling of the vast majority of waste.

Table 7: *Distribution of waste weight by stream*

Waste Type	Percentage (by Weight)
Concrete	70.5%
General Waste	19.2%
Metal	3.4%
Wood	2.6%
Food	2.2%
Plastic	1.5%
Paper & Cardboard	0.6%

Table 8: *Distribution of waste volume by stream*

Waste Type	Percentage (by Volume)
Concrete	48.8%
General Waste	19.4%
Food	9.7%
Metal	7.3%
Wood	6.8%
Plastic	5.6%
Paper & Cardboard	2.5%

3.0 IMPLEMENTED METHODS AND MEASURES

SC stadium construction sites are following the GSAS-CM guidelines, implementing waste management sustainable methods and measures. Described below is a selection of practices, ranging from standard practices to others that go beyond the standard waste reduction practices in the region. These measures are presented following the internationally accepted waste hierarchy of Reduce, Reuse, Recycle and Dispose; where disposal is considered when none of the other options is possible, as shown in Figure 1.

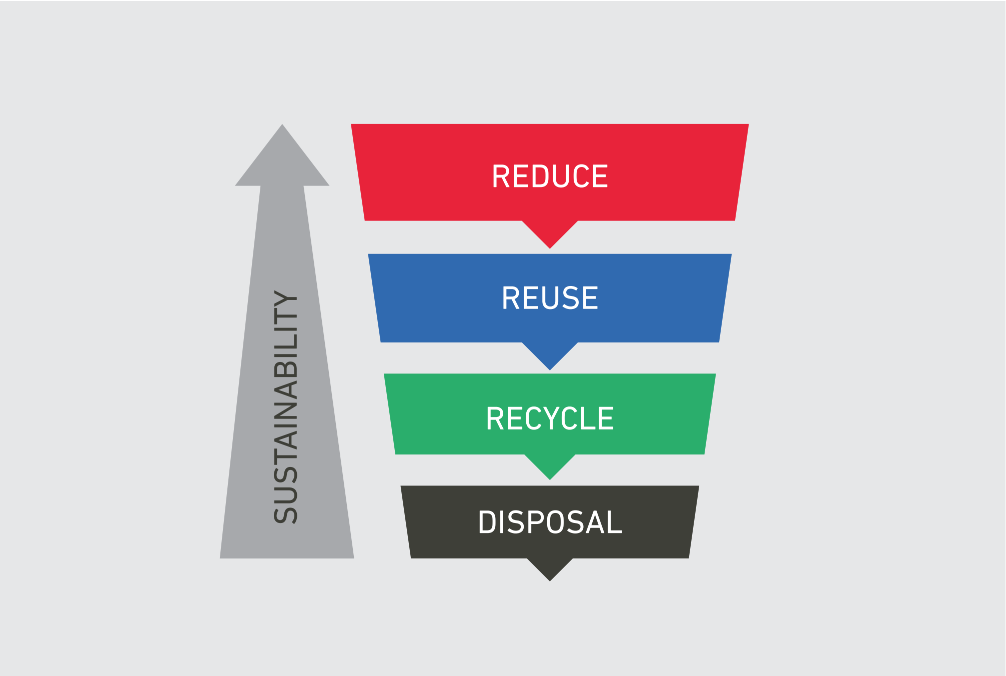


Figure 1: *Waste hierarchy*

Generic best practices implemented for waste collection, segregation, storage and measurement are presented prior to the details of the best practices implemented under each aspect.

Best Practice 1: Management Principles for Effective Waste Management

Waste Management in construction is a complex process that engages different stakeholders during different stages of the project. Hence, proper management of the teams and processes involved is paramount for success.

1. The Client

The SC has considered waste management as one of the key practices to achieve sustainability during construction. The SC included contractual requirements to develop and implement a Construction Environmental Management Plan (CEMP) and to achieve GSAS Construction Management certification, with at least Class A rating. The provisions included hiring professionals with GSAS-CM expertise by the contractor, project management and construction supervision teams.

All stadium projects report to the SC on a weekly and monthly basis, with waste management evidence as part of the reporting. The SC has additionally organized knowledge sharing meetings across all projects and dissemination of best practices reports to share lessons learned on waste management practices.

3.0 IMPLEMENTED METHODS AND MEASURES

2. The Designer

Developing a waste management strategy during the design stage is a valuable tool to identify waste prevention and reduction opportunities. The selection of materials can drastically reduce the amount of waste. In general, the selection of prefabricated materials decreases the amount of waste generated from the site. For example, Stadium 974 is the only stadium with mainly steel structure instead of concrete, and containers used as both partitions and façade. This has resulted in a significant reduction of waste quantities on site, as compared to the other stadiums.

The reuse of existing materials either from onsite or off-site sources can also reduce the waste significantly. Also, providing adequate time and funding for the project design allows the architects and contractors to plan and perform satisfactorily, thereby reducing the chances of design changes during the construction phase, which may entail additional demolition works resulting in an increase of waste.

3. The Contractor

Contractors have a leading role in the implementation of waste management measures, as they oversee the deployment of necessary resources. Success in achieving the goal requires an integrated approach from several departments within the contractor's organization. Therefore, full commitment from the Project Manager is paramount throughout the construction stages, as shown in Figure 2.

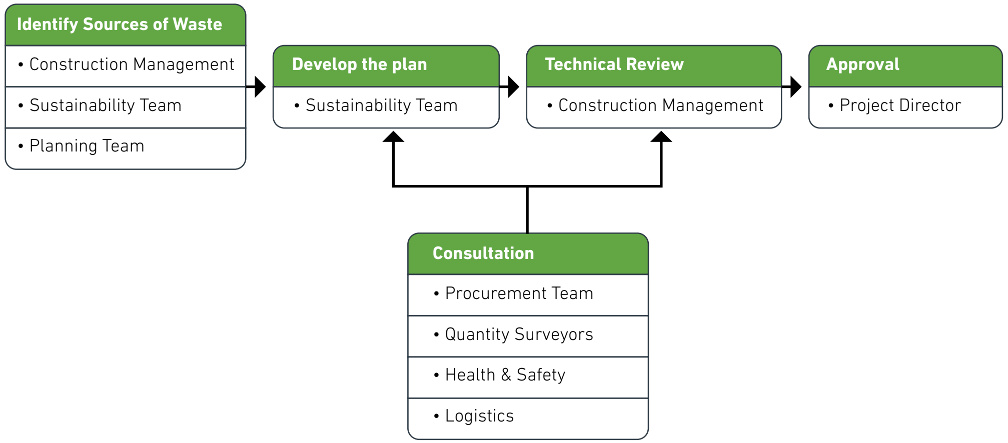


Figure 2: *Construction Waste Management Plan*

3.0 IMPLEMENTED METHODS AND MEASURES

Planning

At project commencement, the contractor's sustainability team should take the lead in developing a plan, which should consider the following as a minimum:

- Determining the procedures to collect, segregate and store the waste, in conjunction with the construction management and logistics departments.
- Locating and arranging the waste storage and segregation areas, in conjunction with the logistics department.
- Exploring reuse opportunities of the existing materials and buildings for temporary uses, including site offices, roads paving and welfare facilities, etc.
- Identifying recycling facilities for different waste streams on site.
- Exploring opportunities in the market for low-packaging materials, in conjunction with the procurement department.

Procurement and Subcontracting

It is recommended that the contractor installs a site-wide waste management facility to be used by subcontractors, instead of managing the waste separately. This way, the contractor can have a better control over all waste related activities, including collection, onsite segregation and storage. This can be contractually agreed to ensure subcontractors' compliance. However, if a subcontractor manages its own waste, the contractor should include provisions in the contract to ensure that the subcontractor complies with the GSAS-CM requirements and maintains an efficient waste management plan with a robust waste tracking system.

Construction Phase

During the construction phase the contractor is in charge of deploying the resources to execute and supervise the implementation of waste management practices. Key activities of the sustainability team are to:

- Ensure that the waste collection, segregation and storage process is smooth.
- Train the workforce on waste management practices.
- Supervise and audit the implementation of the measures and the waste tracking system.
- Make sure that the waste hauler and disposal facilities have their environmental permits up to date.
- Report to Project Management on the waste quantities and waste management measures.
- Continuously improve waste segregation practices.
- Ensure all recyclable materials are collected for recycling.
- Identify opportunities for onsite and off-site reuse of waste materials.

3.0 IMPLEMENTED METHODS AND MEASURES

4. Site Audits

GSAS Trust conducts four site audits per stadium. One of the main subjects for assessment is waste management measures. Audits help project teams to stay focused and perform continuous supervision of mitigation measures. The stages of the auditing system result in the improvement of proper waste management throughout the project life.

Figure 3: *Site audits team*

Best Practice 2: Waste Segregation

Waste can be segregated either at waste treatment centers or at source i.e. the construction site. Waste treatment centers, typically owned by the public authorities, use staff and equipment to segregate the mixed waste they receive, and eventually transport the segregated waste to their final recycling facilities. The alternative is segregating the different waste streams (wood, concrete, plastic, paper and cardboard, metal, food and hazardous chemicals, etc.) at the construction site, and transporting them directly to the recycling facilities. Usually, this is a more sustainable option for the following reasons:

- It makes the process more effective and reduces the environmental impacts, as less waste ends up in landfills.
- It makes the recycling process easier and overall more economical, as it does not require as much manual or mechanical sorting as mixed waste.
- It offers more financial benefits to the contractors, as they can create revenue streams from recycling facilities and industries that use the construction site waste as raw material in their product manufacturing.
- It avoids extra transportation, which reduces the associated CO_2 emissions.
- It reduces the soil and water contamination by avoiding hazardous waste to reach the landfills, which results in long-term public health issues.
- It raises awareness on the importance of waste segregation and recycling among the workers.

3.0 IMPLEMENTED METHODS AND MEASURES

Waste segregation on large construction sites like stadiums is a complicated process that requires different practices to be implemented on site. The size of the site, space constraints, substantial number of workers and the lack of waste management awareness are some of the challenges that are usually faced on site. Several measures have been implemented on the stadiums to accomplish effective waste segregation. Here are the main ones:

1. Selecting Waste Segregation Areas

As waste is generated across construction sites, not only at the widespread construction areas, but also at laydown areas, warehouses, canteens, welfare facilities and site offices, it needs to be collected across the site and transported to designated areas where it is stored until it is collected by the waste hauler. The waste haulers should be able to have easy access to the waste storage areas where the waste should be already segregated and ready for collection.

There are two main approaches to segregate the waste. The first approach is to segregate the waste across the site and transport it to the waste storage areas. However, this requires many bins and the participation of all workers in the segregation process. This requires adequate awareness about waste segregation practices among all workers. The second approach, which was followed on stadium sites and proved to be more effective, is to collect the mixed waste across the site and transport it to the waste storage areas. Once there, dedicated teams of workers segregate the waste into different containers.

Figure 4: *Sorting waste on site*

3.0 IMPLEMENTED METHODS AND MEASURES

2. Labeling Waste Stream Containers

Different waste stream containers, usually skips, were labeled in different languages along with images to help the waste segregation teams identify the correct skip for each type of waste. Color codes were also used for the same purpose.

Figure 5: *Containers labeling*

3. Covering Light Waste Skips

To avoid light waste like plastic or paper to be blown away by wind, plastic and paper skips on site were covered with netting. However, as mandated by law, all skips were covered during transportation to protect waste from falling.

Figure 6: *Covered onsite skips*

Figure 7: *Covered skips during transportation*

3.0 IMPLEMENTED METHODS AND MEASURES

4. Storing Hazardous Waste Separately

Hazardous waste, like paints, oil, chemicals and clinical waste were stored separately on site. The waste was collected by an authorized hauler, and eventually incinerated following the local regulations. Further description of this measure is given in this report under the Disposal section.

5. Collecting Waste from High Floors

Collecting and transporting waste from high floors inside the stadiums to the waste storage areas for segregation is a challenging task. Typically, chutes fixed to the building structure are used to transport the waste down the façade. However, the shape of the stadiums' façades are not regular like traditional buildings, so chutes were not a practical solution in many cases.

Some stadiums, like Lusail, created platforms and used the vomitorium openings as loading spots to place the waste containers and then use the tower cranes to lift them and place them safely on the ground.

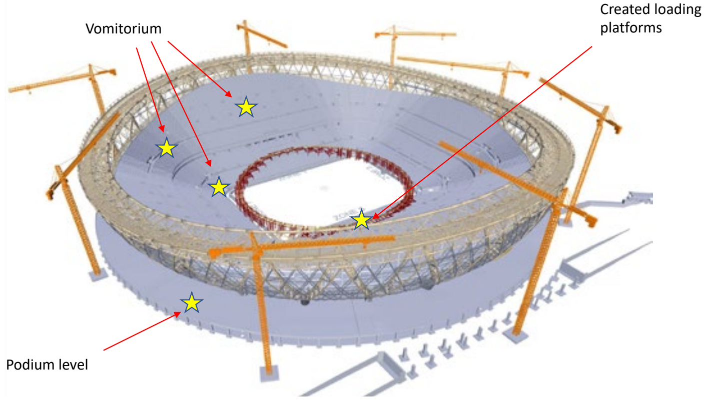


Figure 8: *Loading spots at Lusail Stadium*

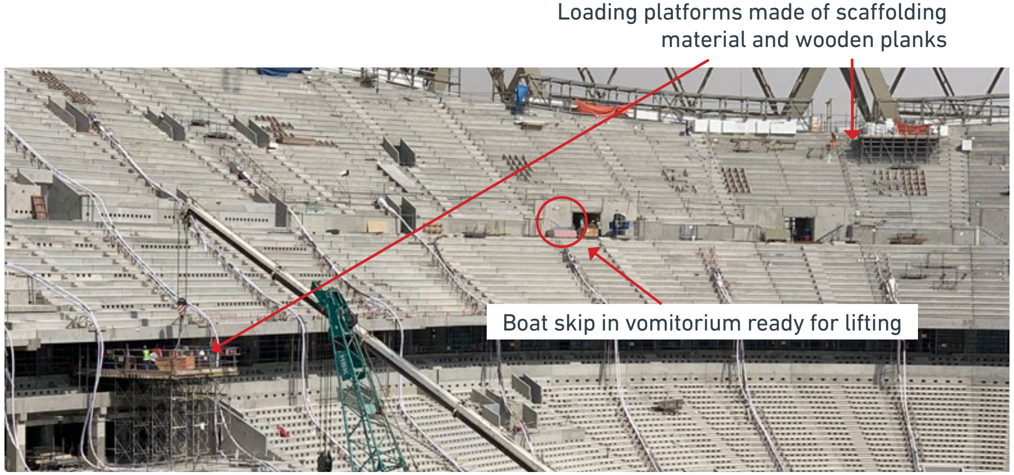


Figure 9: *Loading platforms at Lusail Stadium*

3.0 IMPLEMENTED METHODS AND MEASURES

6. Hiring Authorized Waste Haulers

Only authorized waste haulers by the local authorities are entitled to transport waste from the construction site to the disposal facilities. Note that not all the waste haulers are authorized to transport all waste streams, so multiple waste haulers are sometimes necessary.

7. Disposing Waste at Authorized Recycling Facilities

There is a wide range of recycling facilities available in Qatar. Some of them offer free collection and some even pay for the collected waste. For stadium sites, the following waste streams were considered to be most commonly disposed at recycling facilities:

- Concrete
- Metal
- Wood
- Plastic
- Paper & Cardboard
- Glass
- Electronic Waste
- Apparels
- Oil
- Batteries
- Tyres

8. Waste Tracking System

As the contractor must provide evidence of the recycled waste quantities under the GSAS-CM requirements, a robust waste tracking system had to be implemented. The contractor should collect evidence of the waste being collected from site and being disposed at the recycling facility. GSAS-CM establishes that the following documentation should be included in the waste tracking system:

a) Evidence of Waste Collection

- Every time a skip is collected from the site, a Collection Waste Transfer Note is issued and signed by both the generator (the contractor) and the collector (the waste hauler). The Collection Waste Transfer Note should include at least the name of the project, name of the waste hauler, date, type of waste and quantity.

- Typically every month, the waste hauler issues an invoice including a log listing the quantities per waste stream.

3.0 IMPLEMENTED METHODS AND MEASURES

b) Evidence of Waste Disposal

- Every time a skip is disposed at the recycling facility, a Disposal Waste Transfer Note is issued and signed by both the waste hauler and the recycling facility. The Disposal Waste Transfer Note should include at least the name of the project, name of the waste hauler, name of the recycling facility, date, type of waste and quantity.
- Typically every month, the recycling facility issues a certificate including a log listing the quantities per waste stream.

The combination of these documents tracks the whole route of the waste. This system helps the contractor ensure that the hauler is actually transporting the waste to the designated recycling facility, and not dumping the waste elsewhere. It is important to appreciate that contractor is paying the hauler not only to collect the waste from site, but also to dispose it at the designated recycling facility. Therefore, it is advisable for the contractor to make it mandatory for the haulers to submit the full documentation before releasing the payments.

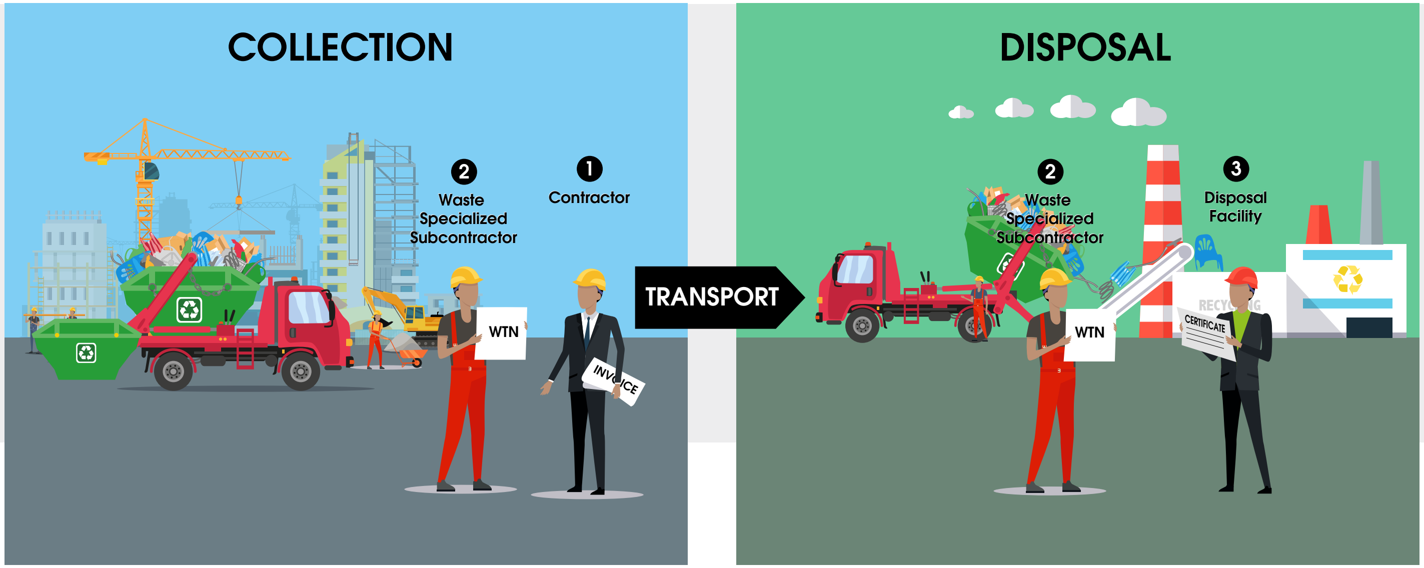


Figure 10: *Collection and disposal tracking*

3.0 IMPLEMENTED METHODS AND MEASURES

Best Practice 3: Waste Weighting

Keeping a robust waste tracking system is of great significance, not only to track the waste from the site to the disposal facility, but also to maintain records of waste quantities. As the saying goes "You can't fix what you can't measure", having a knowledge of the waste quantities per stream can really help taking the right waste management decisions.

Compared to volume, weight is considered a more accurate method to measure waste. Therefore, at Ahmad Bin Ali Stadium, a weighing station was installed at the site for weighing the waste before it departed from the site. The weighing pads were located near one of the gates, through which the entry and exit of all vehicles was controlled. After collecting the waste, all trucks stopped at the weighing station to measure the weight of the full truck. The ticket with the weight of the waste issued by the weighing equipment was attached to the Waste Transfer Note issued by the waste hauler.

Figure 11: *Weighing station*

Figure 12: *Weighing ticket*

3.0 IMPLEMENTED METHODS AND MEASURES

Best Practice 4: Waste Collection and Transportation

A waste hauler should be hired at the commencement of the construction phase. It is advisable to engage the waste hauler in the arrangements of the waste transportation routes and storage areas. The contractor should ensure that a robust waste tracking system is implemented and followed by the waste hauler and the disposal facilities.

In principle, the waste hauler has the responsibility of collecting the waste from the construction site, transporting it and disposing it at the authorized facility, preferably a recycling facility. As such, the waste hauler must submit waste collection and disposal records to the contractor.

The waste hauler is also responsible for:

- Providing, in a timely manner, enough skips for the needs of the contractor.
- Providing skips which are watertight and flytight. For food and hazardous waste, the skips should also be equipped with close-fitting lids to prevent the escape of any of their contents and prevent the offensive odors.
- Keeping covers closed except when waste is being loaded or unloaded.
- Keeping waste hauling vehicles in good running order and in a clean, sanitary condition at all times.
- Obtaining and renewing the permits required by the local authorities, and submitting them to the contractor.

3.0 IMPLEMENTED METHODS AND MEASURES

3.1 Reduce

The practices described in this section aim to reduce the waste generated from construction sites, which is the most effective way to mitigate the environmental impacts associated with construction waste.

Best Practice 5: Reduce Single-Use Plastic

Single-use plastic bottles, bags, food containers and plates are used extensively by workforce on site to carry food and beverages, resulting in massive plastic waste. Two examples of practices to reduce the single-use plastic waste from the stadiums are:

- Disposable plastic lunch boxes and plates used by workers to carry food have been replaced by stainless steel boxes.
- Plastic bottles for drinking water have been avoided at offices by installing water dispensers and making glasses and flasks available for the staff.

Figure 13: *Best practices for elimination of single-use plastic*

3.0 IMPLEMENTED METHODS AND MEASURES

Best Practice 6: Reduce Packaging Materials

A significant part of the construction waste comes from the construction materials packaging, especially in the form of plastic, cardboard and wood. The stadium projects have applied the strategy of ordering materials in bulk, whenever possible, and low-packaging materials, like concrete blocks tied with thin straps.

Best Practice 7: Reduce Materials Request

Adequate storing practices combined with good housekeeping help avoid reordering, materials surplus, and eventually waste. The SC stadiums have implemented proper storage and housekeeping practices that managed to:

- Keep the construction materials well preserved and fit for use.
- Maintain a tidy site and storage area to make the construction materials readily available and easy to find.
- Keep accurate records of the materials stored on site to avoid reordering.

Figure 14: *Construction materials packaging*

Figure 15: *Proper storage and housekeeping*

3.0 IMPLEMENTED METHODS AND MEASURES

Best Practice 8: Reduce Food Waste

Stadium construction requires a significant workforce. The labor on some of the sites has peaked over 5,000 workers, who have at least one meal per day on site. Therefore, the food waste generated is significant, and it must be responsibly managed.

At Ahmad Bin Ali Stadium, food waste reduction was implemented. Food waste reduction measures included:

- Controlling the menu served. There were workers from diverse cultures and different culinary preferences. Therefore, different menus were set to cater to different tastes, thereby reducing the food waste.
- Controlling the quality of food. If the quality of food is satisfactory, the food waste will be reduced. As part of the GSAS-CM guidelines, surveys were conducted among the workers to check their satisfaction with the welfare facilities on site, including the quantity and quality of food served.
- Controlling the demand and supply, monitoring the leftovers and ordering the supply accordingly.
- Dimensioning the catering service to avoid long queues. Workers tend to get large food portions to avoid waiting again in long queues for a second round.

In addition, food waste segregation was undertaken to ultimately reduce waste. Food waste segregation measures included the following:

- Steel trays were used to avoid single plastic use plates and facilitate the food segregation.
- Different bins were placed at the mess halls, for food and for plastic.
- Campaigns were conducted to raise awareness about waste segregation.
- Special training on food waste management was provided for cleaners and caterers.
- Food waste was stored in skips, collected by the waste hauler on a daily basis. The trucks were weighted before leaving the site to monitor the food waste quantities.

Figure 16: *Food segregation containers*

3.0 IMPLEMENTED METHODS AND MEASURES

3.2 Reuse

Aligning with the circular economy principle of designing out waste and pollution, the materials that are considered as waste for construction activities can also be considered as raw materials for other processes. The practices described in this section result in waste diversion from landfills by reusing it either on or off site.

Best Practice 9: Reuse of Demolition Waste

Ahmad Bin Ali Stadium has been built on the location of the former Al Rayyan Stadium. An engineering study concluded that the old stadium's structure was not fit for reuse, as had been the case with Khalifa International Stadium. The SC decided to have the old stadium deconstructed instead of demolished to divert most of the materials from landfills, stockpiling the segregated materials at an adjacent plot. The SC set a challenging target for the contractor to divert at least 80% of the total waste generated, including the waste construction materials from the existing stadium, which was successfully met.

A waste management strategy was developed during the design stage to identify waste prevention and reduction opportunities. Part of the strategy consisted of identifying reuse opportunities for the materials inherited from the existing stadium. The materials were tested for their acceptability by the Qatari standards, stipulated in Qatar Construction Specifications 2014 (QCS 2014) and the design specifications. The main reused onsite materials were:

- Crushed concrete mixed with excavated material, reused for backfilling under the grade slab and for levelling the precinct area.
- Part of the asphalt, reused in levelling parking areas and temporary roads.
- Sand reused for trenches' bedding material.
- Existing sport lights carefully taken down and reused at the temporary training pitches next to the venue.

3.0 IMPLEMENTED METHODS AND MEASURES

As the site was not large enough to accommodate all the inherited materials, opportunities of offsite reuse were identified as follows:

- Fill material for the Al Khor quarry.
- Levelling material for Mesaieed landfill.

The waste quantities were identified and tracked by using an onsite weighting station, a stockpiles survey and a robust waste tracking system. The final quantities show that more than 97% of the total waste, including that from the deconstruction of the existing stadium, was diverted from landfills.

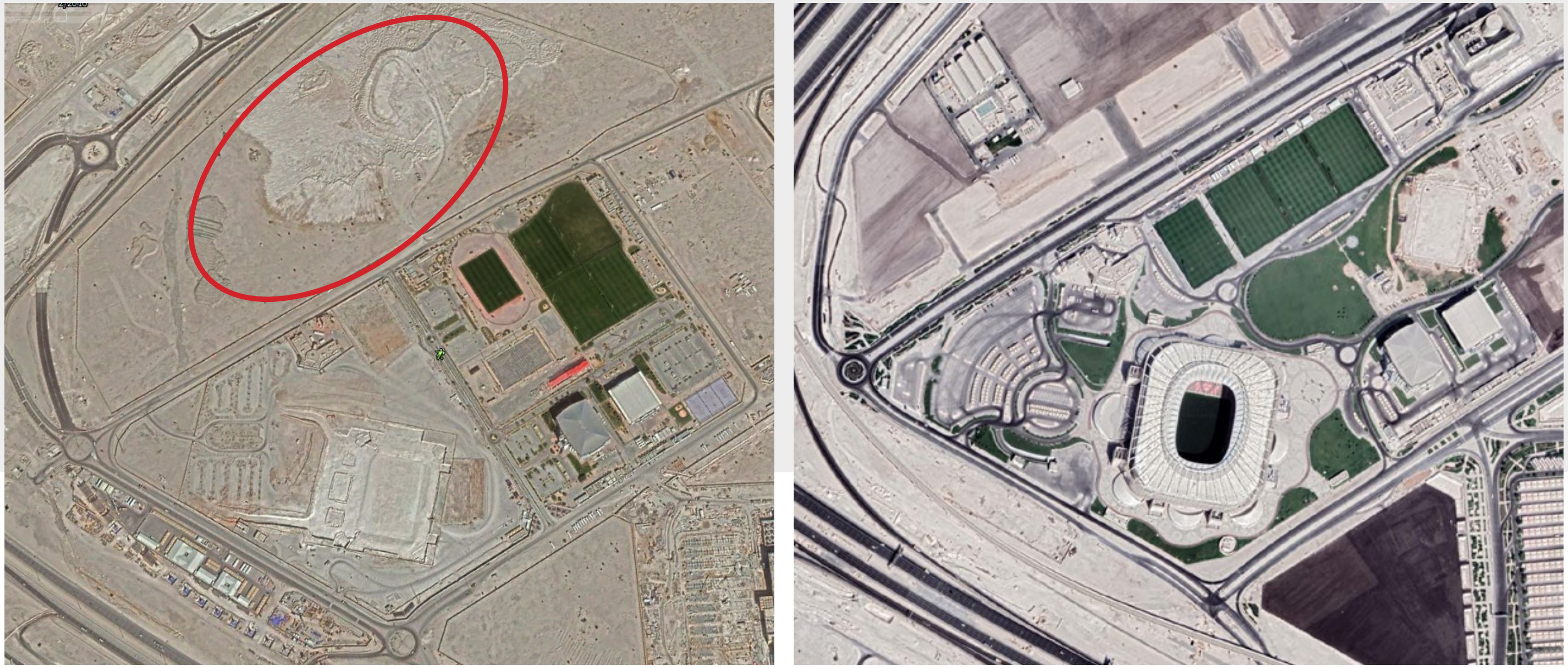


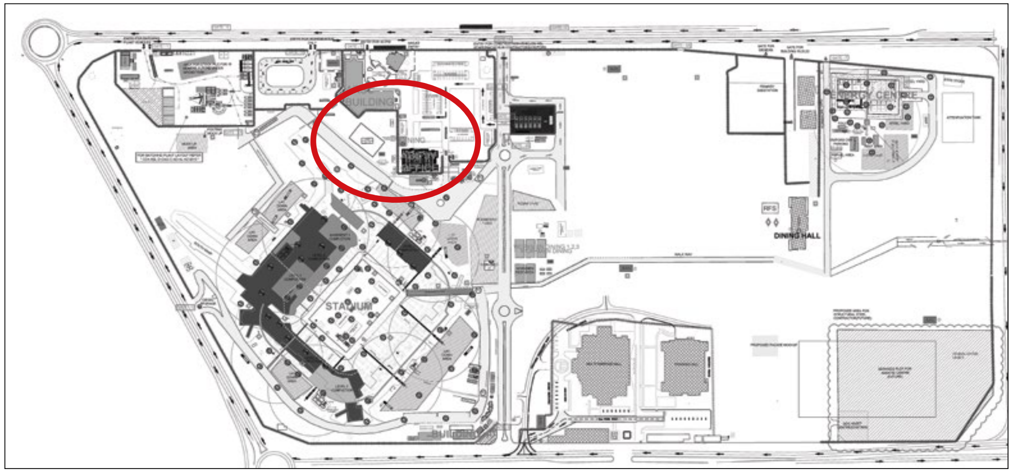
Figure 17: *Reused materials stockpiles*

3.0 IMPLEMENTED METHODS AND MEASURES

Best Practice 10: Reuse of Existing Buildings for Site Offices

Construction sites commonly require installation of onsite facilities, including offices and welfare facilities, etc. Typically, prefabricated portacabins serve as site offices, and they are usually transported from site to site several times until they eventually wear off and become waste. At some of the stadium sites, an even more sustainable practice was deployed, as some existing buildings were reused as site offices during the construction. This practice avoids the use of imported portacabins, and the demolition of the existing buildings while also being more economical.

Ahmad Bin Ali Stadium site contained buildings in usable condition. Such buildings or portions could be used permanently. The existing Al Rayyan Sports Club (ARSC) building was used as the Client and Project Management site office. The reuse of the existing primary structure did not require significant strengthening or alterations to make it structurally viable. However, some associated systems and components were upgraded to be more energy and water efficient, including the HVAC and sanitary facilities. Following the completion of the stadium, the building was refurbished to be used as office space again during stadium operations.



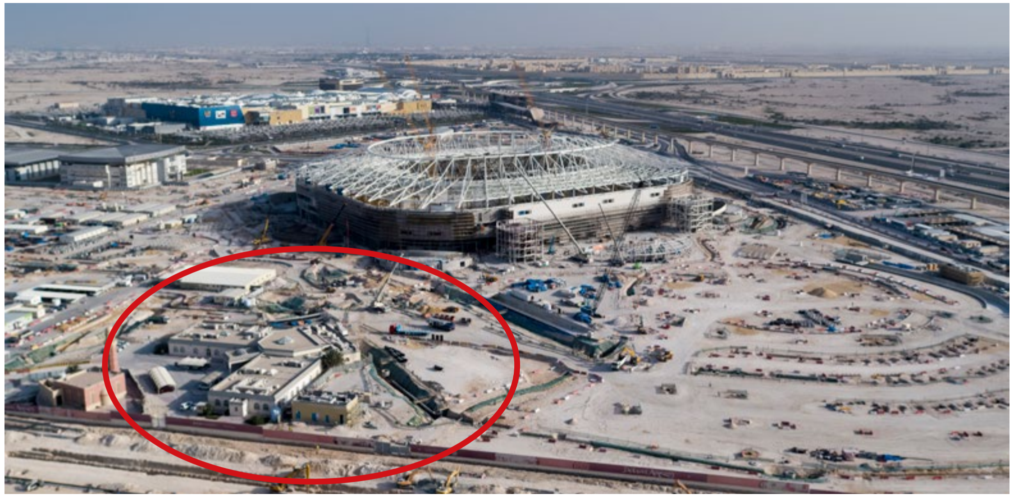


Figure 18: *Al Rayyan Sports Club*

3.0 IMPLEMENTED METHODS AND MEASURES

At Stadium 974 site, eleven existing buildings are being used by different parties, including the client, contractor, consultants and others. The buildings are currently used as offices to accommodate the staff working onsite, mess halls for workers, plus one mosque for prayer. The existing buildings' total buildup area is nearly 7,000 m^2. The use of these buildings has saved the project around USD2.9 million otherwise required for constructing new buildings, and avoided thousands of tons of waste that would have been generated due to the demolition process.

Figure 19: *Existing buildings in use at Stadium 974 site*

Figure 20: *Existing buildings in use at Al Thumama Stadium site*

Some existing buildings within Al Thumama Stadium construction site have been kept and used for other purposes. For example, an existing building currently serves as a site office for the entire construction period. Meanwhile, the chillers and pumps from the existing energy center serves the client's office AC system. Another building is occupied by the MEP subcontractor. Finally, the showcase stadium is temporarily occupied by the Gulf Organisation for Research & Development (GORD) and is serving as an innovation center for conducting scientific research.

3.0 IMPLEMENTED METHODS AND MEASURES

Best Practice 11: Reuse of Limestone in Cyclopean Concrete

At the Education City Stadium site, an area had to be refilled to reach the founding level. The initial idea was to fill it with mass concrete that would serve as bedding for the foundations. The contractor developed a methodology to utilize the excavated limestone boulders in cyclopean concrete, which conserved resources and minimized the construction activities' environmental impact, including the disposal of 6,500 m^3 of boulders to a landfill. This practice also reduced 518 tons of CO_2 emissions, estimated from the transportation of the boulders to a landfill, and concrete to site, in addition to the production of cement for the concrete.

Figure 21: *Use of Cyclopean concrete at the Education City Stadium*

Best Practice 12: Reuse of Dewatering Lagoon

A lagoon was built at Stadium 974 to hold and treat water from dewatering. As the lagoon should be impervious to prevent any stored water from reaching the soil or groundwater, it was lined with High Density Polyethylene (HDPE) at the bottom and sides. Once the dewatering activities were finished, the lagoon had to be fully dismantled and the ground restored to its original condition.

At Stadium 974, the contractor managed to reuse most of the materials used in the construction of the lagoon, as follows:

- The soil used for the bund was recovered from the dewatering lagoon and reused to build the permanent stormwater lagoon on site.
- The sediments settled in the lagoon were tested and found suitable for reuse on site. Overall, 6,000 m^3 of soil from the bund and sediments was recovered.
- The HDPE lining was removed carefully, cleaned, folded and stored for further reuse. A total of 4,360 kg of HDPE was recovered.

3.0 IMPLEMENTED METHODS AND MEASURES

Figure 22: *Reuse of dewatering Lagoon at Stadium 974*

3.0 IMPLEMENTED METHODS AND MEASURES

Best Practice 13: Reuse of Milled Asphalt and Crushed Concrete for Paving

Hauling roads are necessary for large construction sites like stadiums. Sand and clay-based roads are among the main dust generators at construction sites, and therefore, best practices are needed to eliminate the potential dust. Typically, water is sprayed on such roads for dust suppression. However, paving hauling roads is a more effective way of dust suppression, and results in saving large quantities of water and roads maintenance.

Milled asphalt is a waste material sourced when re-paving roads. During the process, the asphalt is milled into small fragments that can be easily spread and compacted as a final layer on hauling roads. This is a very cost-effective way to divert waste from landfills. The same applies to concrete from demolition works, it can be crushed and extended as a cover layer for the hauling roads.

Education City Stadium paved the hauling roads and pedestrian pathways with milled asphalt from another construction site. Stadium 974 paved some hauling roads with asphalt and some with crushed concrete, both from onsite demolition works.

Figure 23: *Reuse of milled asphalt and crushed concrete for paving at Stadium 974 and Education City Stadium*

3.0 IMPLEMENTED METHODS AND MEASURES

Best Practice 14: Reuse of Damaged AAC Blocks and Stones

The damaged Autoclaved Aerated Concrete (AAC) blocks and stones from stadium excavation were stored and reused at Al Bayt Stadium in Al Khor City. During blockworks activities, some blocks were damaged or cut and became waste. The project team managed to find a reuse opportunity for them. Once the prefabricated bleachers were installed, some areas had to be filled with mass concrete. Instead, the broken blocks were used as a filler, partially replacing the mass concrete. Not only was some waste diverted from landfills, but the production of concrete and the cost were also reduced.

The rest of the damaged AAC blocks (5,500 m^3) were crushed and reused on site as a sub-base material for external parking areas. Many boulders resulted from the excavation works at the stadium. Some were prepared and reused as built material for the walls of a restaurant.

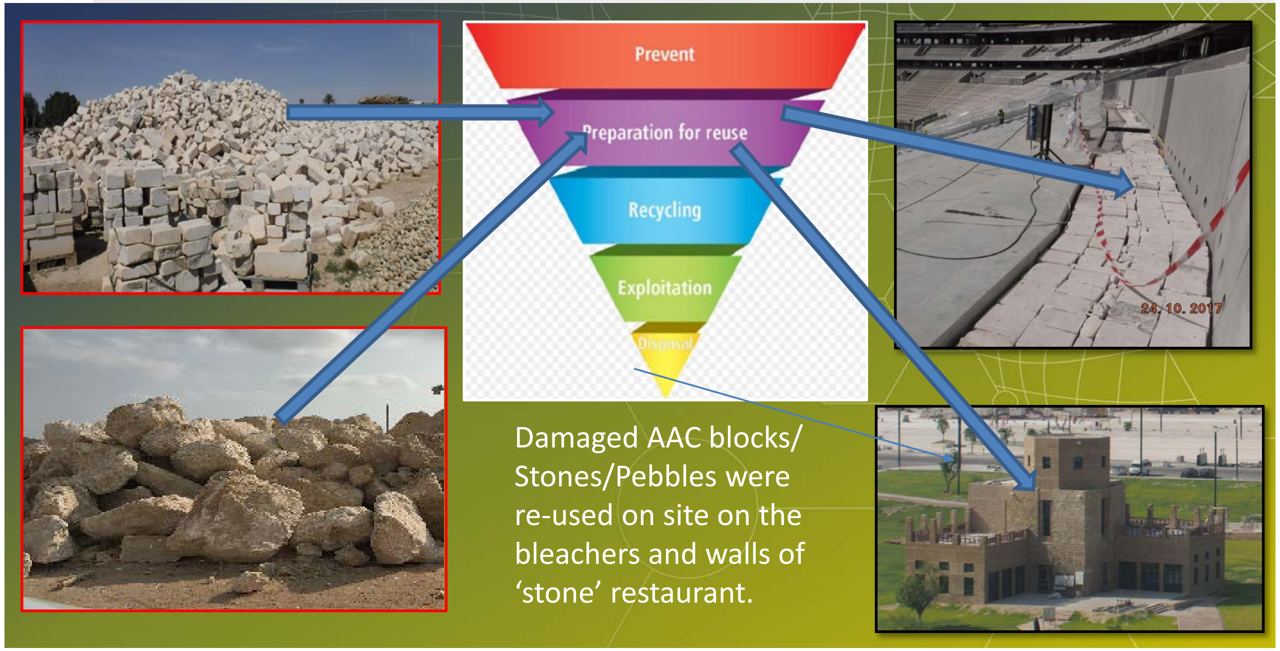


Figure 24: *Reuse of damaged AAC blocks and stones at Al Bayt Stadium*

3.0 IMPLEMENTED METHODS AND MEASURES

Best Practice 15: Reuse of Plywood

Plywood is a very common construction material. It is often used as formwork for concrete. Once the concrete has enough resistance, the plywood is removed and reused as formwork several times, until it wears off and is not suitable for formwork anymore. However, it is still suitable for many uses in a construction site and offices, including:

- Temporary signage
- Tables and benches for the mess halls
- Shelves and crates to be used at the warehouses
- Temporary pieces of furniture like boxes for fire extinguishers, sand buckets for smoking areas and stands for laptops, etc.
- Temporary fencing around noisy equipment

These practices were implemented across the stadiums resulting in economical benefits for the project. For example, the cost of making a single laptop stand from used plywood is QAR8, which is only 17% of the price of a new stand.

Figure 25: *Reuse of plywood practices*

3.0 IMPLEMENTED METHODS AND MEASURES

Best Practice 16: Reuse of Wooden Pallets and Cable Drums

Wooden pallets and cable drums pose a significant portion of wood waste on site. Pallets are used as packaging for many different materials including pavers, blocks and pieces of MEP equipment, while cable drums are used to pack large quantities of cable. Both fit-for-reuse pallets and drums were sent back to the suppliers with some of them reimbursing the cost, which resulted in an economic benefit for the projects. It is therefore advisable to avoid damaging pallets and drums during operations, and make arrangements with the suppliers for the reuse.

Figure 26: *Reuse of cable drums and pallets*

Best Practice 17: Reuse of Wood Waste in Rest Areas

Significant amounts of wood waste is generated from construction activities, mainly formwork, carpentry, and pallets used for packaging construction materials. Temporary welfare facilities on site are a good opportunity for wood reuse, as they require furniture including, tables, benches and chairs, etc. that can be assembled from used timber. A representative example is the rest area in Lusail Stadium, where both benches and roof have been mounted from reused timber.

Figure 27: *Reuse of wood in Lusail Stadium's rest areas*

3.0 IMPLEMENTED METHODS AND MEASURES

Best Practice 18: Reuse of Wood Waste on Off-Site Food Kiosks

As the circular economy opportunities for reusing waste, off-site opportunities should also be considered. Al Bayt Stadium team found an opportunity at the Al Khor Carnival Festival, organized by Aspire Zone, to reuse the wood waste from the construction site in building food kiosks for the event. The kiosks were also designed to be folded for easy dismantling, transportation and reassembly at a different location for further reuse.

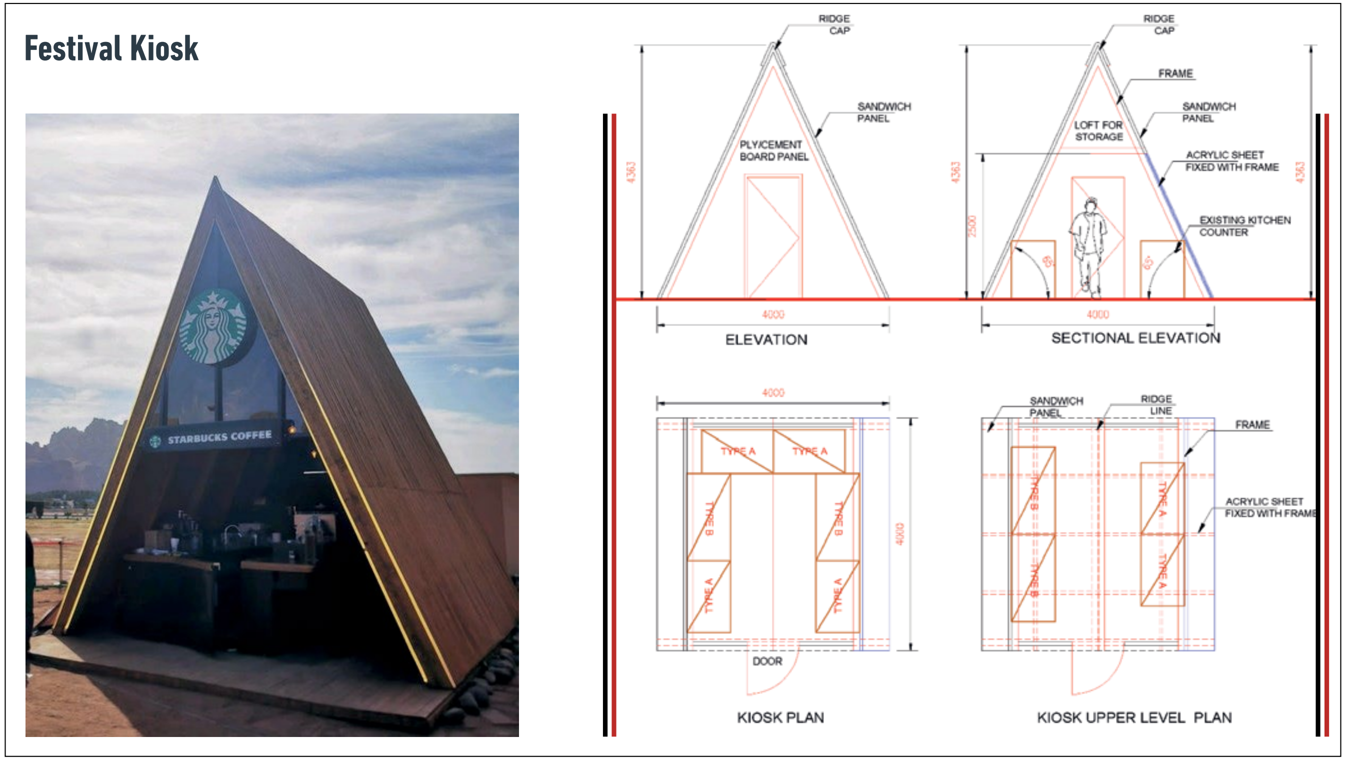


Figure 28: *Reuse of wood on food kiosks*

3.0 IMPLEMENTED METHODS AND MEASURES

3.3 Recycle

The measures described under this section aim recycling waste at authorized recycling facilities. The concept of circular economy is considered, as in the reuse related practices. The only difference is that the waste needs to be processed to be made suitable for other uses.

Best Practice 19: Recycling of Different Construction Waste Streams

Hundreds of thousands of construction waste has been diverted from landfills, sent to recycling facilities and processed into products entering the circular economy. Different construction waste streams were segregated on site and sent to different recycling facilities. Here are the main ones:

- Concrete waste was disposed at recycling facilities to be crushed and prepared for further reuse as backfilling material at other construction sites.
- Wood waste was disposed at recycling facilities to be further reused in carpentry.
- Metal scrap was disposed at different dealers' facilities. The metal was eventually shredded, sorted and refined into new products typically used in the industry.
- Plastic was sent to different recycling facilities where it was treated and used in the manufacturing of several plastic products.
- Paper and cardboard were disposed at recycling facilities where they were treated and converted into new paper rolls used not only in Qatar, but also internationally.

3.0 IMPLEMENTED METHODS AND MEASURES

Best Practice 20: Recycling of Oil

Oil waste generated from construction sites typically comes from the maintenance of equipment, vehicles and machinery. An opportunity was identified to recycle the waste oil to a refined usable oil with the support of a local oil refining company, which was able to handle, collect, transport, recycle and dispose of all types of used oils, sludge, oily water and contaminated fuel from various storage arrangements.

The waste oil generated from construction sites is treated through a mechanical oil transfer system. The manual transfer and chances of the operational spill during transfer are minimized. The waste oil is recovered/ refined through a dehydration and vacuum distillation process. The refined oil (base oil) is then exported to India, Pakistan, China and Malaysia for the production of lubricating oil under another brand. The byproducts (heavy residue) recovered are used in the asphalt industry. The product is marketed as a BIT-4000 with zero-waste disposal.

Figure 29: *Waste oil recycling*

3.0 IMPLEMENTED METHODS AND MEASURES

Best Practice 21: Recycling of Wood into Mulch

Wood waste is mainly generated from plywood used for formwork and timber from carpentry works and from pallets. An opportunity was identified by the Stadium 974's team to recycle timber into mulch, as plywood is not suitable for mulch production.

Accordingly, the timber waste is being segregated on site, stored in designated wood waste skips, and transported by a licensed contractor on a call basis for recycling. The wood mulch is eventually used as ground cover for gardening.

Figure 30: *Wood recycling*

3.0 IMPLEMENTED METHODS AND MEASURES

3.4 Disposal

When none of the recommended reduce, reuse or recycle practices are possible, disposal of waste is the only option left. A few implemented disposal practices are described below.

Best Practice 22: Disposal of Hazardous Waste Management

Hazardous materials and chemicals are part of the materials needed to complete the construction of the stadiums. Therefore, hazardous waste is also generated from the sites. There are several types of hazardous waste at a construction site, that must be segregated separately, collected by an authorized waste hauler and disposed at an authorized facility.

At the stadiums, the following types of hazardous waste have been disposed of: clinical supplies, paints, oil, fluorescent tubes, batteries, tyres, bentonite and contaminated soil. Different containers to segregate them have been labeled accordingly.

Special safety measures have been considered at the hazardous waste areas, including fire prevention systems and spill kits. The dedicated personnel have been trained in spill prevention, and spill drills have been conducted. Spill prevention measures have been implemented, including installation of bunds around the hazardous waste area, and the use of dip trays.

Figure 31: *Hazardous waste storage*

Figure 32: *Hazardous waste labeling*

3.0 IMPLEMENTED METHODS AND MEASURES

Best Practice 23: Disposal of Face Masks

During the COVID-19 pandemic, the use of face masks have been made mandatory. Consequently, thousands of masks are disposed at the stadium sites every day, making masks a waste problem.

At Lusail Stadium, dedicated biowaste bins have been placed along the footpaths to provide convenient disposal points for masks and gloves to be disposed of when leaving the site. The bins are tightly secured with plastic bags designated for collecting masks for safe disposal, and are collected following the regulations by the local authorities.

Figure 33: *Face masks disposal*

4.0 CHALLENGES

Management of waste from large construction sites is a complicated process. Many challenges have been faced along the way, and some opportunities for improvement have been identified. Below are the key highlights of some identified challenges:

1. Waste management on site requires constant effort and use of resources including space, labor and machinery. Sometimes, these resources were required for construction management operations, the core of the construction business. Therefore, it was at times challenging to find enough available resources necessary for smooth waste management operations. Commitment and engagement from project management were paramount to overcome these difficulties.

2. Sorting and segregation of waste requires consistent effort for successful implementation. Adequate resources should be made available from the start of the project.

3. Recycling systems for many materials do not yet have the required capacity for the amounts of waste generated.

4. The waste tracking system implemented by the projects could have been more comprehensive. Most of the disposal facilities do not provide effective documentation with clear strategies. It is advisable that waste tracking documentation systems are widespread across all the stakeholders. The guidance of the local administration is paramount for effective implementation.

5. Food waste management has been particularly difficult due to the lack of awareness about food waste management strategies, especially because workers come from different backgrounds. Raising awareness even about the basics of waste management has been an arduous task.

5.0 CONCLUSION

Hosting an event such as the FIFA World Cup Qatar 2022™ brings a significant responsibility to manage potential environmental and sustainability impacts. With the extensive construction program required to host the event, it was important to ensure that waste management on site was a key consideration in site activities.

Significant progress has been made on site, through focus on the waste hierarchy of reduce, repurpose, recycle and diversion from landfills. Existing knowledge has been supplemented by the implementation of a documented waste management system on site; first to quantify waste generated, recycled, reused and disposed for each stream and then to track the process and create an auditable tracking system.

An impressive average of 79% of construction waste was diverted from landfills in Qatar. The majority of the waste generated on site consisted of concrete, emphasizing the importance of having significant opportunities available to reduce, reuse and recycle it. Segregation of waste at the source proved to provide increased chances of finding recycling partners.

This report highlights some of the best practices used on SC stadium project sites, to contribute to a growing body of knowledge, legacy and experience in the construction sector. We very much encourage others to consider these best practices as well as the GSAS Construction Management certification to reduce, segregate, collect, store and dispose construction waste.

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