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Review Article

Review of Research on and Implementation of Recycled Concrete Aggregate in the GCC

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The goal of sustainable construction is to reduce the environmental impact of a constructed facility over its lifetime. Concrete is the main material used in construction in the Gulf Cooperation Council (GCC). Therefore, it makes economic and environmental sense to use recycled materials in the making of new concrete for different applications. The objectives of this study are to summarize published research on the use of recycled concrete aggregates in new concrete mixes and examine its implementation in construction and industry in the GCC region. The study showed that while there is reasonable research on recycled concrete, the practical implementation in the region greatly lacks behind, especially due to the lack of economic viability and awareness of such applications at the current time.

1. Introduction

Members of the GCC in the Middle-East include the Persian Gulf states of Bahrain, Kuwait, Oman, Qatar, Saudi Arabia and the United Arab Emirates. The GCC countries occupy the area within the Arabian Peninsula, which is located in the southwestern region of the Asian continent. The strength of GCC countries lies in having 24–40% of World's conventional oil reserves and about 23% of world's conventional natural gas reserves. The weakness is related to having an arid weather, shortage of fresh water, and limited farming areas [1]. The Arabian Peninsula is a harsh environment with temperatures ranging between 7° and 47°C, and an average annual rainfall being between 70 and 140 mm [2].

Apart from the oil and gas sector, economy of most of the GCC countries depends to a large extent on the construction industry and infrastructure activities. This is due to recent initiatives undertaken by the local governments to diversify from an oil- and gas- dependent economy. Published statistics in the Arab Construction World magazine [3] indicate that the total value of real estate projects currently under construction in the GCC stands over US$2.39 trillion. However, the limited natural resources in the GCC have a great impact on this industry. Key aspects of the construction industry in the Gulf which have considerable effect on the environment are limited useable natural aggregates for making concrete, scarcity of fresh water sources, and lack of iron ore for producing steel.

The Gulf is often seen as a region that lacks many of the natural resources required for concrete production. Concrete consists of 4 main ingredients: water, cement, sand, and aggregate. Water is locally available but is, for the most part, desalinated. While in some countries concrete batching plants recycle the water they use for cleaning, in the Gulf it is very limited. Although cement is produced locally, the raw materials are often imported from other countries. At peak market levels, demand had exceeded supply so some quantities of cement had to be imported to supplement local need. With the exception of Bahrain, sand is sourced from within the GCC countries, whereas most of the coarse aggregate is sourced from the mountains located in limited areas within the Arabian Peninsula.

2. Sustainable Construction in the GCC

Sustainability can be defined as providing today's need without compromising the capability of future generations

to meet their needs. Sustainable construction aspires to apply this concept to the construction industry. This is accomplished by using less natural materials, consuming less energy, causing lower levels of pollution, and reducing waste while gaining the same benefits that can be achieved through the use of tradition construction methods and materials.

The issue of sustainable buildings in the GCC has become an important topic in recent years, with the United Arab Emirates (UAE) being the leader in this track following the announcement of the green building initiative in January 2008 by Sheikh Mohammed bin Rashid Al Maktoum, Ruler of Dubai. This was shortly followed by the launching of the Estidama initiative in May 2008 by Abu Dhabi's Urban Planning Council, the agency which is responsible for the future of Abu Dhabi's urban environment.

Regional studies estimate that the GCC countries collectively produce more than 120 million tons of waste every year, of which 18.5 percent is related to solid construction waste [4]. For example, recent statistics from Dubai Municipality show that construction and demolition waste accounts for 75% of the 10,000 tons of general waste produced daily in the city, of which concrete demolition rubbles represent 70% of this quantity. Rapid urbanization, growth in the construction sector, high population increase rates, diversified cultures, and floating populations are believed to be the main reasons for such high waste production in the country.

Based on the above, recycling solid waste materials for construction purposes becomes an increasingly important waste management option, as it can lead to environmental and economic benefits. Conservation of natural resources, saving of energy in production and transportation, and reduction of pollution are also the advantages of recycling. In particular, concrete is a perfect construction material candidate for recycling. Some materials, such as plastic, can be recycled once or twice, and glass can only be done if it is properly sorted. However, concrete can be recycled continuously as long as the specification is right.

However, sustainability requires commitment and investment by all parties involved in the construction industry, both governmental and private. Lack of proper planning can lead to delays in implementation, as has happened in February 2011, when Abu Dhabi Municipality suspended the Estidama (meaning "sustainability" in Arabic) building requirements related to energy, but kept the other mandates, which represent 10% of all the requirements. The cited reason for the suspension was due to contractors' lack of preparation for meeting the strict requirements in their projects [5].

3. Objectives and Scope

The objectives of this paper are to review the published research and development studies on recycled concrete aggregate in the GCC region, examine the current use of such material in construction, and recommend suitable strategies for wider applications.

Several GCC researchers have addressed the use of recycled waste material in concrete and disseminated their work through publications. In addition, there have been some efforts to implement the results of research into practice. This paper provides a collective summary of the published technical studies by universities, research institutions, private entities, and governmental agencies that deal with recycled concrete aggregate. It also includes the current state of practice and implementation in the area of recycled concrete in the region.

4. Published Research

This section presents a review of published research on the utilization of recycled concrete aggregate in producing new concrete in the GCC countries.

4.1. Sustainability Issues in the GCC. Kartam et al. [6] discussed the current status of construction and demolition waste disposal system in Kuwait and identified the potential problems to the environment, people, and economy. They investigated alternative solutions to manage and control this waste in an economical, efficient, and safe way. They also described the feasibility and challenges of establishing a construction and demolition waste recycling facility in Kuwait.

The need for green buildings in Bahrain was investigated by Alnaser and Flanagan [7]. According to the authors, sustainable construction implementation is limited in the country due to the lack of awareness of the public in sustainable technology, lack of markets importing sustainable technologies, and client concerns about the profitability and pay-back period. The study revealed that local contractors were the most enthusiastic about implementing green building projects. As a followup to the previous study, Alnaser [8] discussed some of the current sustainable buildings in Bahrain, United Arab Emirate, and Kuwait. To encourage sustainable buildings projects in these countries, the author felt that it is necessary to create the conditions and incentives that would encourage stakeholders in the sector to actively pursue such projects, through governmental policies, economic incentives, rating systems, and coordination with key partners, such as the financing sector.

Kayali et al. [9] reviewed the available industrial waste products that can be used in making sustainable concrete and their relevance to the Middle East, with particular attention to the GCC. The feasibility of using various waste materials, including recycled concrete, is judged with reference to the relevant environment. The authors believe that the inclusion of recycled waste in the production of high-performance concrete can be a significant contribution to a sustainable industry. They concluded that it is the duty of the engineer to judge whether one or more of available waste materials should be used in the production of new concrete on a particular project.

In a paper by Galbraith [10] on structural sustainability, the author outlined the role of structural design in sustainable buildings and its implication within the Gulf region. He identified the available sustainable design techniques in the construction industry and categorized them according to their cost impact.

Lately, Bahrain took the initiative to hold a Green Building Forum in 2010 in Manama [11]. The forum's objective was to discuss the challenges facing the construction industry, with consideration of the environmental concerns, including sustainable building materials, smart buildings, and other topics related to sustainable construction. Another conference on concrete sustainability was recently held in Dubai, covering solutions for sustainable concrete manufacturing and construction [12]. During the conference, various experts addressed sustainable development initiatives, recycled materials, Carbon footprint and embodied energy, and performance-based concrete.

4.2. Recycled Concrete Aggregates. The literature search showed extensive research in the area of recycled concrete aggregates in many GCC countries. One of the earliest research on recycling concrete rubble as aggregate material for construction was carried out by Khan and Rasheeduzzafar in Saudi Arabia [13]. They utilized laboratory tests to investigate the strength, failure mechanism, and durability characteristics of the recycled aggregate concrete. Their study showed that for low W/C ratios the recycled aggregate concrete has 30% lower strength than conventional concrete with natural aggregate. Also, the recycled aggregate concrete showed lower modulus of elasticity and durability characteristics.

Al-Mutairi and Haque [14] used old demolished concrete in Kuwait to replace 50 and 100% of the coarse aggregate and seawater to replace 25, 50, and 100% of the tap water in a standard concrete mix having moderate target strength. The recycled concrete was cured in seawater for a period of 28 days. The results indicated that even with 100% usage of recycled concrete aggregate, design strength of 35 MPa was attainable. Highest concrete strength was obtained when the mixing water consisted of a blend of 25% seawater and 75% tap water.

Rahal [15, 16] tested the mechanical properties of recycled aggregate concrete with a compressive strength 20–50 MPa and compared the results to those of concrete made with natural aggregate. The results showed that the compressive strength, indirect shear strength, and modulus of elasticity of recycled aggregate concrete were all within 10% of those of natural aggregate concrete having the same mix proportions.

AlMutairi and AlKhaleefi [17] investigated the flexural behavior of plain concrete containing crushed old concrete as replacement for natural coarse aggregate. Plain concrete beams made with 0%, 50%, and 100% recycled coarse aggregate were tested as simple beams with third-point loading. When compared with the ACI standard, the obtained modul of rupture values were within the acceptable levels. Furthermore, statistical analyses of permeability tests indicated that the concrete was not greatly affected by the use of the recycled aggregates in the mix.

Al-Harthy et al. [18] conducted laboratory tests to examine the strength and durability of recycled aggregate concrete. The results showed that concrete strength is enhanced with the replacement of normal aggregates by recycled aggregate content of up to 30%, thereafter the strength decreases with further increase in recycled aggregate. However, replacement of natural aggregate by recycled aggregate was found to decrease the workability of the concrete due to the high absorption characteristics of the recycled aggregate.

Tabsh and Abdelfatah [19] studied the strength of concrete made with recycled concrete coarse aggregate. The toughness and soundness laboratory tests on the recycled coarse aggregate showed higher percentage loss than natural aggregate, but remained within acceptable limits. The compressive and splitting tensile strengths of concrete made with recycled coarse aggregate depend on the mix proportions. In general, the strength of recycled concrete was 10–25% lower than that of conventional concrete made with natural aggregate due to increase in water demand to maintain the specified slump. In a follow-up study, Abdelfatah et al. [20] utilized admixtures in concrete mixes containing demolished concrete as replacement for natural coarse aggregates to compensate for the need of additional water required to increase the workability. The results showed that the use of superplasticizers, instead of additional water, was able to increase the compressive strength of recycled aggregate concrete to a level around the same as that of the control mix containing natural aggregate. This finding is not in agreement with the results obtained by Gull [21] when testing low strength concrete utilizing recycled concrete aggregate.

Mirza and Saif [22] studied the effect of silica fume on recycled aggregate concrete characteristics. The percentages of recycled aggregate replacements of natural aggregate used by weight were 0, 50, and 100%, whereas the percentages of silica fume replacements of cement used by weight were 5, 10, and 15%. The results showed that the compressive and tensile strengths values of the recycled concrete aggregate increased as the recycled aggregate and the silica fume contents increased. The study also indicated that in order to accommodate 50% of recycled aggregate in structural concrete, the mix needs to incorporate 5% of silica fume.

Recently, Elchalakani [23] investigated the strength and durability of recycled concrete made from recycled aggregate and wastewater in the UAE. Experimental tests employing standard cubes and cylinders to assess the compressive strength and small beams to evaluate the flexural strength were utilized. The study showed that the effect of recycled aggregate and recycled water on axial and bending strength was found moderate but had a significant effect on durability. To enhance the durability of recycled concrete, the author recommended using ground granulated blast furnace slag and fly ash for any future building construction in the Gulf.

There have been some studies that considered the utilization of recycled concrete aggregate in different construction applications than in production of new concrete. For example, Al-Ali et al. [24, 25] investigated the suitability of using recycled concrete aggregates as subbase for pavement construction. A test model was built in the laboratory to assess the recycled material pavement performance under various loads and to comparatively measure its behavior against the natural aggregate layers. The experimental program considered ranges of pavement loads, material gradations, compositions, and layer thicknesses. The results

showed that the deflection of the pavement under load is generally less with the recycled concrete aggregate than that with the natural aggregate. Therefore, there is a good potential for using recycled concrete aggregate as a subbase layer in roadway pavement construction.

Another application of the use of recycled concrete aggregate is in the production of sand lime brick in Kuwait, which was considered by Al-Otaibi and El-Hawary [26] and Al-Otaibi [27]. The study evaluated the specific gravity, compressive strength, and absorption characteristics of the brick. It showed that the brick that is made from recycled concrete aggregate has properties that are within the specifications requirements.

5. Industry and Governmental Initiatives

Even though there is a considerable body of research related to using recycled concrete aggregate in the production of concrete mixes, the industrial implementation in the GCC countries of these technologies is still in its infancy. Some of the implementations are initiated by governmental agencies, and some other implementations are carried out by the industry.

The government of Kuwait has recognized the problems caused by the construction demolition waste. In order to reduce the area needed for landfills, the government of Kuwait approved the Environment Protection Industrial Co (EPIC) to start a construction waste recycling plant, with a daily capacity of about 7–20 thousand tones of construction waste [28]. Furthermore, the Arab International Industrial Projects company was established in 2005 with the objective of improving the environmental conditions in Kuwait. One of the projects for this company is concerned with cutting the production costs of new concrete and reducing the need for land fill space. For this purpose, concrete rubbles and old asphalt concrete are crushed to different sizes to be used as aggregate for some projects. The produced aggregate can be used in many projects, such as drainage and rain pipes packaging, base and subbase layers for road construction, asphalt concrete mixes for road paving, and ordinary nonreinforced concrete mixes [29].

In the process of producing sustainable concrete in Qatar, efforts towards using recycled aggregate and waste concrete are underway. In a report sponsored by Mobile-Baustoffe GmbH company, Blanco-Carrasco et al. [30] studied the benefits and potential implementation of using waste concrete and recycled aggregate. Among the cited applications by the authors is the use of crushed recycled concrete in nonstructural applications such as road base or subbase construction, core filling, embankments, backfills, and blinding slabs. Another effort to help Qatar in adopting green building design and construction is the establishment of the Qatar Green Building Council (QGBC), which is a private institution concerned with the promotion of environmentally sustainable practices [31]. One of the members of QGBC is the Khalid Cement Industries Company (KCIC), which is implementing an environment management system that allows the company to recycle water and concrete and apply a waste management plan [32]. A Domestic Solid Waste Management Center, which was initiated by Ministry of Municipal Affairs and Agriculture in Qatar, is under construction and will be opened in March 2011. The center is capable of recycling a total of 2,300 tons of mixed domestic waste and a total of 5,000 tons of construction waste per day [33].

In order to help the companies to interact and promote waste recycling, the Riyadh Exhibitions Co. Ltd has been organizing the International Recycling and Waste Management Exhibition, with the 3rd exhibition being organized in 2011 [34]. A recycling plant has been constructed in Jeddah, which has a sorting capacity of up to 1,200 tons/day; however, the plant does not recycle any construction material [35]. The limited implementation of recycled concrete in construction in Saudi Arabia has prompted some activists, such as Sultan Faden who is the head of the Founding Group of the Saudi Green Building Council, to call on municipalities in Jeddah and other cities to launch recycling factories, and to appeal for stronger regulations to protect mountains from crushers in the Kingdom [36].

The UAE seems to be one of the most active countries in the Gulf region when it comes to the application of concrete recycling. As part of the governmental efforts to promote recycling of construction materials, Dubai Central Laboratory has signed an agreement with Emirates Recycling and Dubai Municipality to study and evaluate construction demolition waste. Since this waste is usually ignored by contractors, the project aims at finding useful applications to use construction rubbles [37]. In Abu Dhabi, the city has supported several projects regarding green buildings and environmentally friendly construction material. For example, a new crushing plant in Al Dafra has been newly opened with the capability of crushing waste material and turning them into aggregate that can be used to replace natural aggregate in making concrete [38]. Unibeton Ready Mix is another company that supports the production of green concrete, which has been used in the Masdar City in Abu Dhabi. The company used 1.8 million tons of recycled aggregate in 20% of the needed concrete used in the City [39]. Another application is carried out by Al-Falah Ready Mix and Emirates Beton as they have capabilities to produce concrete that is environmentally friendly, by using recycled aggregate and other recycled waste materials aiming to zero waste from production and maximum usage of the waste material [40, 41].

The Emirate of Sharjah also has its share of activities in the sustainable construction field. Recently, a new waste recycling plant was opened in the industrial area of Sharjah. The plant receives concrete and other construction waste material from various places within the Emirate and processes them to be used again for construction purposes [42].

In Oman, the applications of concrete recycling are limited [43]. However, a royal decree has been issued in 2009 to appoint the Oman Environmental Services Holding Company to execute the task of implementing the government's policy with regard to the waste sector. In addition to the management of landfills allover Oman, the company has initiated several projects to develop facilities for the

management of medical waste, hazardous waste, electronic waste, and a tire recycling plant [44].

Generating about 3000 tons of waste in Bahrain each day has motivated the initiative to plan for a recycling factory that will process the majority of that waste, as announced in 2008 by Majeed Milad, the chairman of the Manama Municipal Council [45].

6. Conclusions

The study leads to the followings conclusions.

(1) There is an adequate body of research work on recycled concrete aggregate and its uses in the GCC, predominantly conducted by individuals in research and academic institutions.

(2) Most of the surveyed research considers the mechanical and strength characteristics of recycled aggregates with little focus on durability issues.

(3) There are few studies regarding the economic feasibility and financial implications of recycling and re-use of concrete rubbles in construction applications.

(4) Research on the environmental impacts of using such recycled material in construction has been rarely addressed in the region.

(5) Real-life applications of using recycled construction waste are still in their infancy and need some major efforts to attract investors to this industry.

(6) There are limited legislations and policies to encourage recycling and use of demolition waste in the GCC.

(7) No governmental standards and specifications for processing and use of recycled aggregate are currently available in the region.

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References

[1] M. Jefferson, "Energy for sustainable development: global context and rational options for the GCC," in *Proceedings of the 2nd Seminar on Potential of Alternative Energy in the GCC*, Arabian Gulf University, Manama, Bahrain, April 2007.

[2] M. F. Al-Rashed and M. M. Sherif, "Water resources in the GCC countries: an overview," *Water Resources Management*, vol. 14, no. 1, pp. 59–75, 2000.

[3] ACW, Arab Construction World, Vol. 27, Issue 4, April 2009, http://www.acwmag.com/index.aspx?all_lk_id=142&magazine_id=2#.

[4] The Gulf Today Newspaper, 19 May, 2010, http://p4papyrus.blogspot.com/2010/05/gulf-countries-generate-222-million.html.

[5] Al-Ittihad Newspaper, 3 February, 2011, http://www.alittihad.ae/details.php?id=12034&y=2011.

[6] N. Kartam, N. Al-Mutairi, I. Al-Ghusain, and J. Al-Humoud, "Environmental management of construction and demolition waste in Kuwait," *Waste Management*, vol. 24, no. 10, pp. 1049–1059, 2004.

[7] N. W. Alnaser and R. Flanagan, "The need of sustainable buildings construction in the Kingdom of Bahrain," *Building and Environment*, vol. 42, no. 1, pp. 495–506, 2007.

[8] N. AlNaser, "Towards sustainable buildings in Bahrain, Kuwait and United Arab Emirates," *The Open Construction and Building Technology Journal*, vol. 2, no. 1, pp. 30–45, 2008.

[9] O. Kayali, M. Haque, and J. Khatib, "Sustainability and emerging concrete materials and their relevance to the Middle East," *The Open Construction and Building Technology Journal*, vol. 2, no. 1, pp. 103–110, 2008.

[10] K. Galbraith, "Structural sustainability in the gulf—fact and fiction," in *Proceedings of the 8th World Congress, Council of Tall Buildings and Urban Habitat (CTBUH '08)*, Dubai, UAE, March 2008.

[11] Green Building Forum, Manama, Bahrain, May 2010, http://www.tradearabia.com/news/CONS_174322.html.

[12] Concrete Sustainability Conference, National Ready Mix Concrete Association, Dubai, UAE, December 2010, http://www.concretetechnologyforum.org/2010CSCDubaiProceedings.

[13] A. Khan and Rasheeduzzafar, "Recycled concrete—a source for new aggregate," *Journal of Cement, Concrete and Aggregates*, vol. 6, no. 1, pp. 17–26, 1984.

[14] N. Al-Mutairi and M. N. Haque, "Strength and durability of concrete made with crushed concrete as coarse aggregates," in *Proceedings of the International Symposium on Recycling and Reuse of Waste Materials*, pp. 499–506, Scotland, UK, September 2003.

[15] K. Rahal, "Mechanical properties of concrete with recycled coarse aggregate," *Building and Environment*, vol. 42, no. 1, pp. 407–415, 2007.

[16] K. Rahal, "Mechanical properties of recycled aggregate concrete," in *Proceedings of the Proceedings of the ACI-Kuwait Chapter 2nd International Conference on Design and Sustainability of Structural Concrete in the Middle East with Emphasis on High-Rise Buildings*, M. M. El-Hawary, N. Al-Mutairi, K. N. Rahal, and H. Kamal, Eds., 306, p. 299, Kuwait, March 2007.

[17] N. Z. AlMutairi and A. M. AlKhaleefi, "On flexural strength and permeability of recycled concrete as coarse aggregates," in *Proceedings of the ACI-Kuwait Chapter 2nd International Conference on Design and Sustainability of Structural Concrete in the Middle East with Emphasis on High-Rise Buildings*, M. M. El-Hawary, N. Al-Mutairi, K. N. Rahal, and H. Kamal, Eds., 162, p. 153, Kuwait, March 2007.

[18] A. Al-Harthy, R. Taha, A. Al-Saidy, and S. Al-Oraimi, "Properties of Recycled Aggregate Concrete," in *Proceedings of the ACI-Kuwait Chapter 2nd International Conference on Design and Sustainability of Structural Concrete in the Middle East with Emphasis on High-Rise Buildings*, M. M. El-Hawary, N. Al-Mutairi, K. N. Rahal, and H. Kamal, Eds., 318, p. 309, Kuwait, March 2007.

[19] S. W. Tabsh and A. S. Abdelfatah, "Influence of recycled concrete aggregates on strength properties of concrete," *Construction and Building Materials*, vol. 23, no. 2, pp. 1163–1167, 2009.

[20] A. Abdelfatah, S. W. Tabsh, and S. Yehia, "Alternative ways of making concrete with recycled coarse aggregate," in *Proceedings of the 4th International Conference on Applications of Traditional and High Performance Materials in Harsh*

Environments, Institute of Materials Systems, Sharjah, UAE, March 2010.

[21] I. Gull, "Testing of strength of recycled waste concrete and its applicability," *Journal of Construction Engineering and Management*, vol. 137, no. 1, pp. 1–5, 2011.

[22] F. A. Mirza and M. A. Saif, "Mechanical properties of recycled aggregate concrete incorporating silica fume," in *Proceedings of the 2nd International Conference on Sustainable Construction Materials and Technologies*, Coventry University and The University of Wisconsin Milwaukee Centre for By-products Utilization, Ancona, Italy, June 2010.

[23] M. Elchalakani, "Strength and durability of recycled concrete made from recycled aggregate and wastewater," in *Proceedings of the International Concrete Sustainability Conference*, The National Ready Mixed Concrete Association and Grey Matters Consultancy, Dubai, UAE, December 2010.

[24] A. Y. Al-Ali, A. M. Alshamsi, and Y. E. Hawas, "Structural performance of recycled concrete aggregates for road construction," in *Proceedings of the 1st International Conference on Quality Control and Quality Assurance of Construction Materials*, Dubai, UAE, October 2001.

[25] A. Y. Al-Ali, A. M. Alshamsi, and Y. E. Hawas, "Recycled concrete put on the test," *Gulf Construction Journal*, vol. 13, no. 2, pp. 15–22, 2002.

[26] S. Al-Otaibi and M. El-Hawary, "Potential for recycling demolished concrete and building rubble in Kuwait," in *Proceedings of the International Conference on Achieving Sustainability in Construction*, pp. 229–236, Scotland, UK, July 2005.

[27] S. Al-Otaibi, "Producing lime-silica bricks from crushed concrete fines," in *Proceedings of the International Conference on Sustainability in the Cement and Concrete Industry*, Lillehammer, Norway, September 2007.

[28] http://www.cleanmiddleeast.ae/articles/43/recycling-construction-waste-in-the-middle-east-commercial-operation-with-environmental-benefits.html.

[29] Arab International Industrial Projects K.S.C.C., 2011, http://www.best100.org/page.aspx?ID=682e327e-a9b6-428f-bd5a-a4091996b556.

[30] M. Blanco-Carrasco, F. Hornhung, and N. Ortner, *Qatar: Green Concrete Technology*, Mobile-Baustoffe GmbH Company, 2010.

[31] Arabian Business Magazine, 2009, http://www.arabianbusiness.com/qatar-green-building-council-on-way-79664.html.

[32] Khalid Cement Industries Company, 2011, http://www.kccqatar.com/en/news/latest-news/61-khalid-cement-marketing-manager-.html.

[33] Domestic Solid Waste Management Center, 2011, http://www.zawya.com/projects/project.cfm/pid150607090305?cc.

[34] Trade Shows Biz.com, 2011, http://www.tradeshows-biz.com/trade_event/recycling-waste-management-saudi-arabia.html.

[35] Jeddah Recycling Plant, 2011, http://www.recycleinme.com/rim-salum/home.aspx.

[36] Arab News, 2011, http://arabnews.com/saudiarabia/article98429.ece.

[37] Gulf News, 2011, http://gulfnews.com/news/gulf/uae/environment/sharjah-waste-treatment-plant-to-boost-recycling-1.105756.

[38] Arabian Business Magazine, 2011, http://www.arabianbusiness.com/rubble-turns-road-304142.html.

[39] Global Village Encyclopedia, 2011, http://www.gvpedia.com/Abu-Dhabi/Unibeton-Top-Ready-Mix-Company.aspx.

[40] Global Village Encyclopedia, 2011, http://www.gvpedia.com/Abu-Dhabi/Unibeton-Top-Ready-Mix-Company.aspx.

[41] Emirates Beton, 2011, http://emiratesbeton.com/achivements.php.

[42] Gulf News, 2011, http://gulfnews.com/news/gulf/uae/environment/sharjah-waste-treatment-plant-to-boost-recycling-1.105756.

[43] R. Taha, A. Al-Rawas, K. Al-Jabri, A. Al-Harthy, H. Hassan, and S. Al-Oraimi, "An overview of waste materials recycling in the Sultanate of Oman," *Resources, Conservation and Recycling*, vol. 41, no. 4, pp. 293–306, 2004.

[44] Oman Environmental Services Holding Company, 2011, http://www.oeshc.co.om/.

[45] Bahraini TV, 2011, http://bahraini.tv/2008/08/29/waste-management/.

[46] British Standards Institution, BS 8500-1, *Concrete-Complimentary British Standard to BS EN 206-1. Part 2: Specification for Constituent Materials and Concrete*, London, UK, 2006.

[47] AASHTO MP 16, *Standard Specification for Reclaimed Concrete Aggregate for Use as Coarse Aggregate in Hydraulic Cement Concrete*, American Association of State and Highway Transportation Officials, Washington, DC, US, 2010.

[48] CSIRO, *Guide for Specification of Recycled Concrete Aggregates (RCA) for Concrete Production*, Ecorecycle, Victoria, Australia, 1998.

[49] RILEM, "Specifications for concrete with recycled aggregates," *Materials and Structures*, vol. 27, no. 173, pp. 557–559, 1994.