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The use of green materials and systems in UAE construction projects – A baseline study

ALY EL GAYAR
Civil Engineering Department,
University of Ottawa,
A519, Colonel By, Ottawa, Ontario K1N 9A7, Canada
E-mail: alyelgayar@gmail.com

SALWA MAMOUN BEHEIRY*
Associate Professor of Civil Engineering,
Civil Engineering Department,
The American University of Sharjah,
P.O. Box 26666, Sharjah, UAE
E-mail: sbeheiry@aus.edu

ALAA JABBAR
Project Engineer, Sumer Building Contracting,
University of Wollongong,
Blocks 5, 14 & 15, Dubai Knowledge Village,
P.O. Box 20183, Dubai, UAE
E-mail: alanizar_5@hotmail.com

HAMAD AL ANSARI
MSc Student, Engineering Systems and
Management Department,
Masdar Institute,
P.O. Box 54224, Abu Dhabi, UAE
E-mail: halansari@masdar.ac.ae

*Corresponding author

ABSTRACT

Purpose: Over the past decade, the United Arab Emirates (UAE) introduced several green regulatory guidelines, federal decrees and a considerable number of environmentally friendly initiatives. Hence, this study was designed to investigate the top green materials and systems used currently in the UAE construction industry as per the new laws dictate as well as see if professionals are switching over to incorporate more green materials, systems and/or designs.

Design/Methodology/Approach: The work involved reviewing internationally popular green materials and systems for construction, developing a questionnaire based on the literature review, surveying professionals in the seven UAE emirates, and ranking the findings based on the Relative Importance Index (RII).

Findings: Findings found the top used green materials and system in the UAE's construction industry. As well as identified that there is a communication gap between the design and implementation phases that is possibly hindering the use of more green materials and systems.

Originality/Value: This study sets a baseline to measure the UAE's progress over the coming years in terms of integrating more green construction materials, systems, methodologies and trends. procurement.

***Keywords*:** green materials and systems; United Arab Emirates; UAE; construction industry; energy and resource efficiency; sustainability; baseline studies.

INTRODUCTION: LITERATURE REVIEW

Preserving Earth's resources became a pressing matter over recent years. The main concern is preserving the environment for the future generations. The notion of Sustainable Development (SD) is one of the key answers to the environmental issues faced today. Moreover, global technological advancements and the sophistication of construction techniques helped facilitate the shift to constructing green buildings (Lu et al., 2013; Wu and Low, 2010). Robichaud and Anantatmula define the term Green building as

> "The process of building that incorporates environmental considerations into every phase of the homebuilding process. That means that during the design, construction, and operation of a home, energy and water efficiency, lot development, resource-efficient building design and materials, indoor environmental quality, homeowner maintenance, and the home's overall impact on the environment are all taken into account" (Robichaud and Anantatmula, 2011, p.49).

The world, however, relies on the consumption of natural resources, such as oil and natural gas, to continue carrying out its daily functions. Natural resources are finite and will eventually run out. The World Watch Institute conducted a study in the USA and found that the construction of a buildings consume approximately 17% of available fresh water flow, 40% of energy produced and 25% of the available harvested timber (Thovichit, 2007). Additionally, the techniques used today have many harmful by-products that are accumulating over time For example, during the construction of a project, carbon dioxide is produced in large quantities and is assumed to contribute up to 33% of the total carbon dioxide emissions in the USA.

Many green aspiring construction projects follow the criteria set up by the organisation of Leadership in Energy and Environmental Design (LEED). In addition to the published design criteria, LEEDs also provides guidelines on construction material based on harm to the environment. This alerts owners, designers, and constructors to the use of specific materials in green building construction (Baharetha et al., 2012; Lacouture et al., 2009).

For project stakeholders, cost is typically the first factor considered before deciding to proceed with a project investment. As they are familiar to suppliers, clients, designers and constructors, conventional construction materials and systems are typically priced lower than green-labelled materials and systems. This is one of the main reasons why sustainable materials are avoided. Parties' fear the 'presumed' unnecessary increase in the total cost of the project. This preconceived idea is a major hindrance to the construction industry's shift to sustainable construction. However, Green materials and systems are not always more expensive as a capital investment and more often than not they tend to reduce the life cycle operational and maintenance costs of the project. On the other hand, designers and contractors can be motivated towards the green shift if they are aware that waste prevention can be ultimately beneficial to all parties. Waste is a representation of lost profit in the long run because it is something that is bought; it cannot be utilised nor sold for salvage at obsolescence (Spiegel and Meadows, 2006).

The world does not rely on sources of renewable energy as much as it should. In 2006, 1.5% of the world's energy demand was provided by renewable energy sources. It is estimated to reach 1.8% by the year 2030. This estimated gradual rise is too slow for the world's need to reduce reliance on fossil fuels and shift to green resources. Similarly, Mekhilef et al. (2011) compiled data of the 'global industrial sector energy consumptions' between 2006 and 2010. This data was used to develop a model to predict the trend of the energy consumption by the industrial sector until the year 2030.

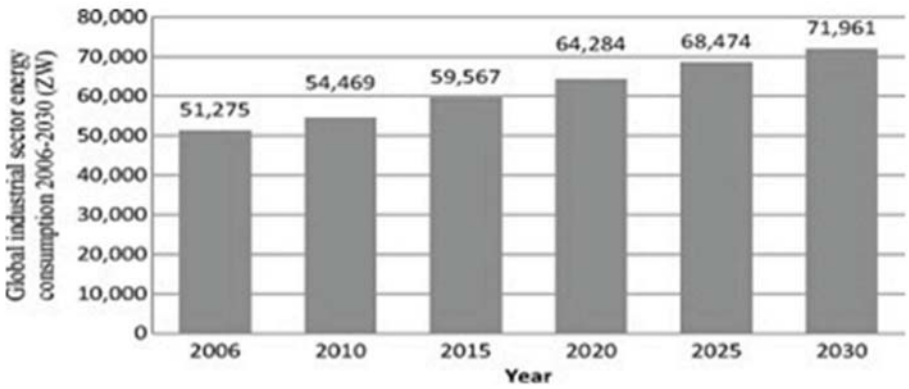

Figure 1 Global Industrial Sector Energy Consumption

Source: Mekhilef et al., 2011.

The UAE efforts

Pollution of the air quality and water sources, depletion of natural resources and raw materials, and the destruction of ecosystems are the three main reasons for the shift towards green construction (Spiegel and Meadows, 2006). In the United Arab Emirates (UAE), the public sector is exhibiting clear signs that it is attempting to restrict dependence on oil generated revenue and investing in research and development of renewable energy sources, technologies and applications.

Various governmental entities have been established in the UAE concerned with safeguarding the implementation of green concepts in new developments' design and construction. Such entities include Estidama, an initiative that falls under the Abu Dhabi Urban Planning Council (UPC). This governmental entity focuses on promoting responsible and SD. Estidama's objectives and goals align with the master plan that the UPC has set: the Abu Dhabi Vision 2030. The main purpose of Estidama is " to preserve and enrich Abu Dhabi's physical and cultural identity, while creating an always improving quality of life for its residents on four equal pillars of sustainability: environmental, economical, social, and cultural" (Estidama.org, 2012). Estidama recognises that the main two things needed for change are people's conceptions toward sustainability and the design approach. Project owners, designers, developers, constructors and even residents need to incorporate sustainable concepts into their design and planning processes. With these points underlined, this governmental entity established the Pearl Rating System, A LEED equivalent with the UAE's geographical and social characteristics incorporated. In addition, the rating system is applied during the design, construction, and/or the operational phase of a project's life cycle; thus, the Estidama Pearl Rating System works concurrently with the various project stages (Estidama.org, 2012).

Green materials and systems

Many green-labelled materials and systems became visible in the construction industry lately. These include occupancy sensors, solar and photovoltaic technology, HVAC regulators, etc. Occupancy sensors and light reduction controls are usually installed in green buildings together to maximise energy conservation. This allows the regulation of individual rooms for efficient heating, cooling and lighting to save energy. Occupancy sensors are crucial since buildings typically consume up to 40% of the total energy usage in an economy (Zidek et al., 2011). "The saving potential by occupancy sensors may amount to 61% of the annual power consumption" (Roisin et al., 2008).

The use of solar power for thermal water heating in domestic and industrial sectors has been rising with an estimated 30% annual growth rate. The benefits of integrating solar thermal water generators in domestic and commercial buildings include the reduction of costs and energy consumption. A case study conducted in Nepal claims that by installing solar water heaters in a school of 850 students, its monthly electricity bill was reduced by the equivalent of 1200 Euros (Mekhilef et al., 2011). Similarly, photovoltaic systems are also gaining momentum in the construction industry for their significance in supplying green energy. As for costs, the price for photovoltaic systems and panels has been falling over the past few years by up to 86%, making the system a viable and affordable alternative to integrate in projects. For instance, photovoltaic systems reached an installation capacity of 300 KW in the year 2005 in China, and the total photovoltaic installations throughout the country is estimated to be 1 MW, which is still a small amount but is an improvement (Mekhilef et al., 2011).

Heating, Ventilation, and Air Conditioning Systems (HVAC) are usually installed as a single unit to control the temperature of a building. Economiser controls are a budding green technology used to control energy loss from HVAC systems. This is implemented by controlling the amount of fresh air being supplied to the system from the outside. The results of several simulations using this system show that an estimated 66% or 1951 MWh of energy is saved annually (Mathews et al., 2001).

Insulating materials are used in different capacities in building construction to reduce energy loss. From cavity wall insulation to tarpaulin roof insulation to cork, which is a material that is commonly known to be a traditional insulator is used in construction as filler or in boards form. Additionally, paper insulation is recycled paper that goes through a chemical process to make it fire resistant. However, unlike cork insulation, paper insulation can only be used as a filler material (Jelle, 2011). Furthermore, other techniques such as window glazing provide more insulation than single layered conventional windows. This is the main advantage for using double or triple glazed windows.

Insulation may reduce cooling and heating costs by approximately 5–10%. On average, installing double glazed windows saves about 7.31% energy while installing triple glazed windows saves 4.04% energy (Rahman et al., 2010).

Alternatively, reclaiming, reusing and recycling construction materials saves resources and preserves raw materials. Yet, the major effects that should be taken into consideration when reclaiming materials are the indirect financial and environmental costs of reworking, refinishing and installation (Calkins, 2009). A prime example of a reclaimed and recycled material is concrete. Concrete can be reclaimed from the remains of demolished buildings and can undergo a recycling process to make it reusable as a coarse aggregate. The process is similar to that of natural aggregates, which includes: crushing, removal of contaminants, washing, etc. There are various applications for recycled concrete and the process presents a safe and economical opportunity (Aïtcin and Mindess, 2011).

Water management systems are also very important, as water is gradually becoming a very vital and scarce resource. There are several examples of systems, implemented in hotels and large buildings that capitalise on using alternative source of water to reduce dependence on fresh water. These examples include designated collectors and transportation pipes that are placed on roofs for rain water collection. The accumulated rainwater is then stored in tanks for further usage in watering plants (Kirk, 1996).

RESEARCH METHODOLOGY

The methodology for this research encompassed extensive literature review to find any previous studies conducted or published papers regarding sustainable construction materials and systems. The literature review is the premise for which the questionnaire development was based upon. A cross-reference between compiled sources established a list of ten commonly used sustainable construction materials and systems used worldwide. The list was based upon the advantages each material or system had and how much it contributes to SD. Ease of installation, economical feasibility and availability were taken into consideration, because materials and systems selection has to be based upon average construction companies' abilities to obtain and install them. Many of the materials and systems on the survey are also a part of the Estidama's Pearl Rating System, acknowledging that these items can and are being used in the UAE as well as worldwide. After the literature review, the questionnaire was created based upon the research followed by data collection. Collected data was processed using the statistics program SPSS and then materials and systems ranking was determined by manual calculation of the Relative Importance Index (RII). Questionnaire creation, data collection and results analysis are discussed thoroughly in the following section.

QUESTIONNAIRE DEVELOPMENT AND DATA COLLECTION

Upon finalising the initial list of green materials and systems, further research was conducted to investigate the degree of use of these materials and systems in the UAE construction ind ustry. The list of green materials and systems that was finalised and used for the purpose of this study, and included in the survey, is the following (Table 1):

- occupancy sensors
- solar thermal water generation systems
- recycled materials
- cork insulation
- triple/double glazed windows
- paper insulation
- light reduction controls
- HVACe
- indoor water management and
- solar photovoltaic

Table 1 Defined list of materials and systems with corresponding references

Material/System Name	*Definition*	*References*
Occupancy sensor	A device that detects the occupancy of space and turns the lights on or off automatically depending on the presence of people in that area	Krarti (2000), Thumann and Mehta (2008) and Estidama.org (2012)
Solar Thermal Water Generation Systems	A system that harvests solar energy to heat up water for buildings rather than utilising electricity like with typical water heaters	Muguti et al. (1999), Mendler et al. (2006), Thumann and Mehta (2008), Spence and Kultermann (2011), Moskovitz (2013) and Estidama.org (2012)
Recycled Materials	Salvaged materials from previously built buildings where they are gone through a recycling process to become reusable	Mendler et al. (2006), Calkins (2009) and Spence and Kultermann (2011)
Cork Insulation	A type of insulation that is made entirely of corks	Mendler et al. (2006) and Spence and Kultermann (2011)
Triple or Double Glazed Windows	Window panels that are separated by air or gas to reduce the heat transfer between the atmosphere outside and that in the building in order to save energy	Krarti (2000), Thumann and Mehta (2008), Spence and Kultermann (2011) and Moskovitz (2013)
Paper Insulation	Insulation that is made of recycled paper and has gone through chemical processes to make it fire retarding and insect repellent	Spence and Kultermann (2011)

Table 1 Defined list of materials and systems with corresponding references *(Cont.)*

Material/System Name	*Definition*	*References*
Light Reduction Controls	A system that optimises the usage of energy by automating the usage of lights through an entire facility	Krarti (2000), Frej et al. (2005), Thumann and Mehta (2008) and Estidama.org (2012)
HVACe	Technology to regulate indoor environmental comfort. This includes heating, ventilating and air-conditioning	Muguti et al. (1999), Krarti (2000), Thumann and Mehta (2008) and Moskovitz (2013)
Indoor Water Management Systems	Systems installed in buildings to regulate and reduce water wastage which includes sensor faucets	Krarti (2000), Thumann and Mehta (2008) and Moskovitz (2013)
Solar Photovoltaic	Photovoltaic materials, found in solar cells, which convert energy from sunlight directly into electricity	Muguti et al. (1999) and Moskovitz (2013)

The purpose of the survey was to obtain the experiences of various engineers in construction companies in the UAE in terms of their usage of green construction materials and systems. The selected measuring scale implemented on the survey creation is the Likert-Type Scale. Likert-Type Scale is one of the most popular methods to measure attitudes by the use of summated rating. This type of attitude scale is very reliable and is a valid instrument for the measurement of people's attitude as it is used to conduct various forms of research. The scale usually consists of five options where the typical responses range between the extremes of 'Strongly Agree' to 'Strongly Disagree', with three more intermediate options. This type of scaling system makes it possible to quantify the responses on various items and can be summed separately to give a total score for an individual item (Arnold et al., 1967).

The survey was created to measure four things:

1. frequency of green construction materials and systems use in construction today in the UAE;
2. frequency of consideration to use green materials and systems in the design phase of a project;
3. frequency of seeing green materials and systems being installed in projects across the UAE and
4. whether or not there is a significant rise in use of green materials and systems in the UAE construction industry over the past five years.

An additional question was asked to check what ideas engineers in the field had to help encourage the use of green materials and systems.

After the creation of the survey, collecting data form various construction companies across the UAE was the next step. To ensure that

the survey would be answered by an adequate sample that represents the majority, specific criteria was set to determine which companies to give the questionnaire to and collect data from. The criteria included that the company must have been established in the UAE for at least six years and must have worked on at least 10 projects ranging from medium to large-scale projects. A total of 38 project manager engineers were interviewed from 38 different companies across the UAE. Each individual interviewed had served a number of years with the company and has supervised multiple various sized projects with their respective company.

Analysis and results

The compiled data was inputted in the statistics program SPSS and used to generate a Descriptive Statistics Table and Frequency Tables for each material/system for each question. SPSS codes were created to stand for every material due to SPSS inability to accept long names for categories. The code that was developed is merely the first letters of the material or system followed by the number of question to separate data points. Table 2 displays the codes, as SPSS understood them, and the descriptive statistics associated with every material for every question. Moreover, the data was analysed using the RII to determine the rankings of the green materials and systems. The RII is a technique commonly used for data analysis that indicates which options on a survey are given high importance and which get low importance, thus, determining the ranking of the options listed in a survey. The technique uses the weight that is specified during the survey design via the Likert-Type scale and the frequencies of each result to compute the relative importance of the material or system based on the responses.

The formula for computing the RII is as follows:

$$RII = \frac{\sum_{i=1}^{5} W_i X_i}{\sum_{i=1}^{5} X_i}$$

Equation 1 RII (Al Jurf and Beheiry, 2012)

Where

"W_i response weight to the ith respond equals 1, 2, 3, 4, 5, respectively.

i response index equal 1, 2, 3, 4, 5, which are for: very low influence, low influence, medium influence, high influence and very high influence, respectively.

X_i frequency of the ith response for a factor" (Al Jurf and Beheiry, 2012).

RESULTS

The following tables (Tables 2–6) are the statistical results for the survey obtained from SPSS:

Descriptive statistics

Table 2 Descriptive statistics of total survey sample results

	N	*Median*	*Mean*	*SD*
OS1	38	3	2.82	1.205
SWGS1	38	2	2.18	1.036
RM1	38	3	2.74	1.223
CI1	38	3	2.79	1.417
TDGW1	38	5	4.21	1.143
PI1	38	2	2.50	1.371
LRC1	38	3	2.84	1.285
HVACe1	38	5	4.47	1.006
IWMS1	38	3	3.16	1.220
SP1	38	1	1.82	1.159
OS2	38	3	2.47	1.606
SWGS2	38	2	2.11	1.448
RM2	38	2	2.26	1.465
CI2	38	2	2.21	1.545
TDGW2	38	4	3.32	1.919
PI2	38	2	1.97	1.365
LRC2	38	3	2.71	1.707
HVACe2	38	5	3.55	1.955
IWMS2	38	3	2.66	1.760
SP2	38	1	1.89	1.539
OS3	38	3	3.16	1.386
SWGS3	38	3	2.82	1.249
RM3	38	3	2.95	1.314
CI3	38	3	2.84	1.424
TDGW3	38	4.5	3.79	1.473
PI3	38	3	2.58	1.426
LRC3	38	3	3.08	3.08
HVACe3	38	5	4.21	1.277
IWMS3	38	3.5	3.32	1.454
SP3	38	1	2.55	1.446

Frequency tables

Table 3 Frequencies of materials and systems common use by companies from survey question #1

Materials	*Scale*					
	0=No Answer	*1=Never*	*2=Rarely*	*3=Some-times*	*4=Often*	5=Always
OS	0	6	10	10	9	3
SWGS	0	11	14	9	3	1
RM	0	5	13	13	1	6
CI	0	9	8	10	4	7
TDGW	0	1	3	6	5	23
PI	2	7	12	8	5	4
LRC	0	9	4	12	10	3
HVACe	0	1	2	2	6	27
IWMS	0	5	5	12	11	5
SP	0	20	11	4	0	3

Table 4 Frequencies of consideration of materials and systems by companies from survey question #2

Materials	*Scale*					
	0=No Answer	*1=Never*	*2=Rarely*	*3=Some-times*	*4=Often*	5=Always
OS	6	5	7	10	5	5
SWGS	6	8	8	11	2	3
RM	6	3	15	7	3	4
CI	6	6	12	7	2	5
TDGW	6	2	4	6	2	18
PI	6	8	13	4	6	1
LRC	6	5	3	11	6	7
HVACe	6	2	3	2	4	21
IWMS	7	4	5	8	7	7
SP	7	13	4	8	3	3

Table 5 Frequencies of witnessing use of materials and systems across the UAE from survey question #3

Materials	*Scale*					
	0=No Answer	*1=Never*	*2=Rarely*	*3=Some-times*	*4=Often*	5=Always
OS	1	4	8	7	11	7
SWGS	1	4	11	11	7	4
RM	1	5	8	9	11	4
CI	1	7	9	6	10	5
TDGW	1	3	3	8	4	19
PI	1	11	6	9	7	4
LRC	2	6	4	8	11	7
HVACe	1	1	3	2	8	23
IWMS	1	5	4	9	9	10
SP	1	10	10	6	6	5

Table 6 Frequencies of witnessing a rise of green construction across the UAE from survey question #4

		Frequency	*%*	*Valid %*	*Cumulative %*
Valid	N/a	3	7.9	7.9	7.9
	No	4	10.5	10.5	18.4
	Yes	31	81.6	81.6	100.0
	Total	38	100.0	100.0	

Relative Importance Index (RII)

For each question in the survey, a corresponding RII was computed to rank the green materials and systems. For the first question, the RII ranked the green materials and systems based on the frequency of their use in recent projects, depending on responses by contractors (Figure 2). The RII for the second question indicates the ranking of how often the green materials and systems are considered in the design phase of the project (Figure 3). The third question's RII ranks the green materials and systems on the basis of how frequent contractors' views other companies using these materials and systems in projects across the UAE (Figure 4). The fourth question did not involve ranking materials, but inquired to get the general subjective thoughts of contractors on the current progress of green construction in the UAE (Figure 5).

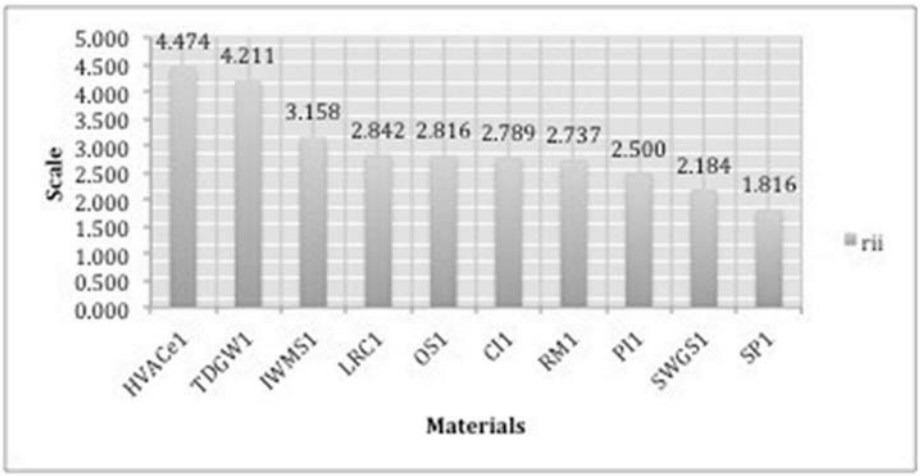

Figure 2 Question #1 Rankings

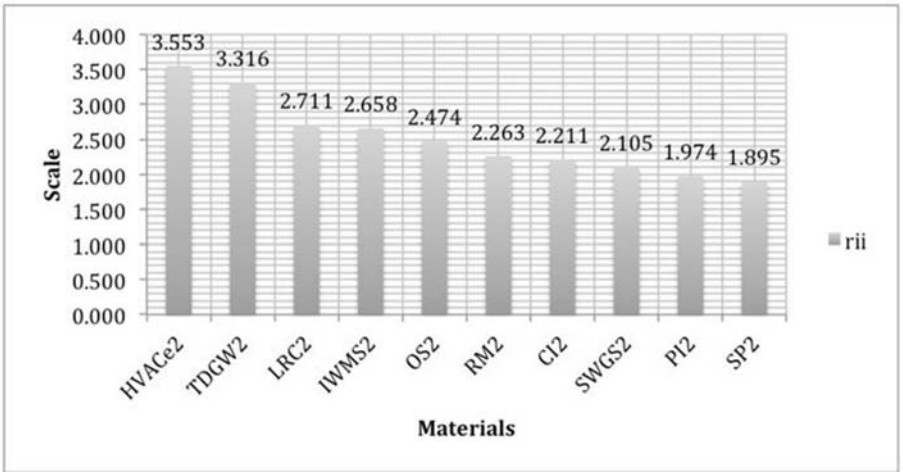

Figure 3 Question #2 Rankings

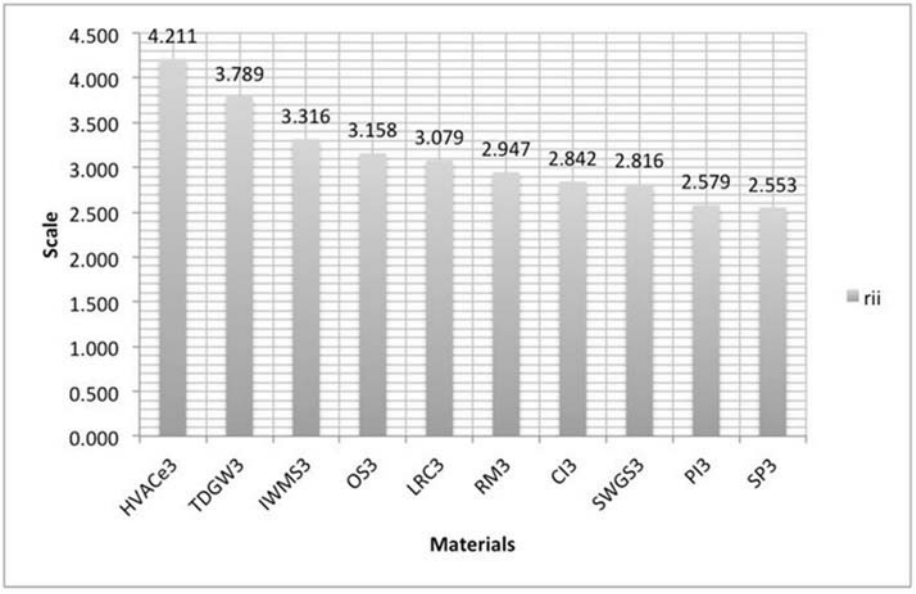

Figure 4 Question #3 Averages

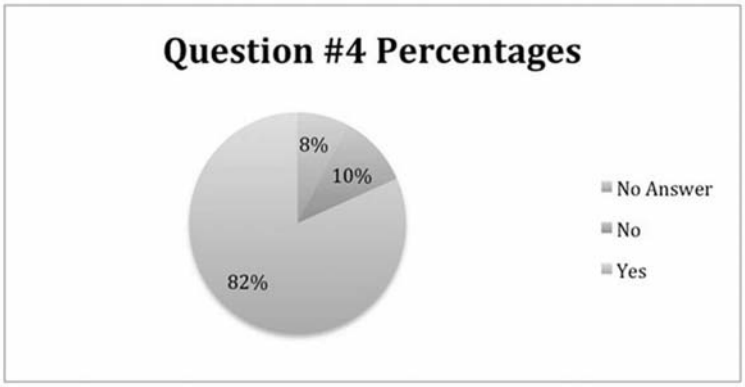

Figure 5 Question #4 Percentages

DISCUSSION

As shown in Table 7, it is evident and logical that HVACe would be the top used system in the UAE given the climate conditions of the region. Air conditioning is very costly due to high-energy consumption levels, but integrating an economising system optimises air-cooling, reduces energy consumption and ultimately reduces costs. In the long run, installing HVACe is an investment and many contractors have recognised this. Typically coupled with the HVACe system are triple and double glazed windows as they optimise air-cooling by preventing heat transfer between the outside and inside environments. This preserves the cold air inside buildings and reduces the amount of cooling an air conditioner has to do and, in turn, reduces energy consumptions and costs. Indoor Water Management Systems such as sensor faucets help reduce water wastage, which is a scarce resource in the UAE. Desalination is an expensive process; thus, optimising water use and reducing wastage can conserve valuable water and cut desalination expenditures.

Table 7 RII results in descending order

Material/System	*RII*	*Material/System*	*RII*	*Material/System*	*RII*
HVACe1	4.47	HVACe2	3.55	HVACe3	4.21
TDGW1	4.21	TDGW2	3.31	TDGW3	3.78
IWMS1	3.15	LRC2	2.71	IWMS3	3.31
LRC1	2.84	IWMS2	2.65	OS3	3.15
OS1	2.81	OS2	2.47	LRC3	3.07
CI1	2.78	RM2	2.26	RM3	2.94
RM1	2.73	CI2	2.21	CI3	2.84
PI1	2.50	SWGS2	2.10	SWGS3	2.81
SWGS1	2.18	PI2	1.97	PI3	2.57
SP1	1.81	SP2	1.89	SP3	2.55

Furthermore, Light reduction controls and occupancy sensors are two systems that compliment each other and work well together in reducing electricity consumptions. Dubai is a business hub and, as such, many of the commercial buildings consume a lot of electricity. Light reduction controls and occupancy sensors optimise the intensity of the light emitted by the bulb depending on the surrounding environment and switch off any lights with the absence of people from rooms, corridors and/or hallways. Cork insulation is used in the UAE in foundations to prevent vibrations; even though cork insulation is used to prevent heat or cool loss, it is not applicable in the UAE as walls are made of concrete. The least used on the list is recycled materials and this could be due to many reasons. The processes to recycle and salvage concrete do exist, but might be unfamiliar to many contractors. Ironically, the systems that utilise the most abundant renewable resource readily available, solar energy, do not make it on the list of the top 7 and, in fact, are the lowest two materials used. Solar Thermal Water Generation System and Solar Photovoltaic were ranked 9th and 10th, respectively.

Moreover, there is a discrepancy between the results of question #1, #3 and question #2. Question #1 and #3 display a similar pattern of frequency and rankings; however, the frequencies of question #2 were significantly lower. The reason for this discrepancy is due to the fact that while the construction managers were answering the survey some of them skipped the second question and did not answer it. In this study, a 'No Answer' had a weight of zero and when the RII was computed, this lowered the results relative to the sample of 38. When asked why they skipped the question, some construction managers stated that they could not answer it as they were not involved in the design phase of the project and thus did not know which materials and systems were considered and which were not. Further studies are suggested to look into which green materials and systems are regarded in the design phase. As for UAE's progress in shifting to green construction, Figure 5 indicates that most of the engineers in the UAE have seen significant progress in the green movement through the construction industry over the past five years and are hopeful for further rapid improvement.

RECOMMENDATIONS

From the results of this study, it is recommended that UAE construction projects place more emphasis on integrating green materials and systems in the early design phase. This warrants the early involvement of contractors or constructors. As the results indicated, some of the construction managers did not answer the second question related to the design phase of the project because they were unaware of what was done in that phase. Additionally, the UAE should target more solar

energy powered systems, as solar energy is abundant during daytime in the summer and winter and should be harnessed to generate electricity for the various needs of buildings to reduce electricity costs.

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BIOGRAPHICAL NOTES

Aly El Gayar is completing his Masters of applied science in civil engineering at the University of Ottawa concenrating on sustainable infrastructure and project management, as well as currently working at the university as a teaching assistant. Poster presenter at the 6th Materials Education Symposium – Cambridge University, UK (April 2015).

Salwa Mamoun Beheiry is an Associate Professor of Civil Engineering at the American University of Sharjah (UAE). Her research interests revolve around sustainable infrastructure and capital project performance. She is also a recipient of various prestigious honours and awards throughout her academic and industrial career. Before starting her doctoral program at UT Austin, she worked with Independent Project Analysis Inc. in Ashburn, Virginia, as analyst/consultant. She obtained her PhD in Civil Engineering from the University of Texas at Austin, a Master's of Science from the George Washington University and a First Class Honours Bachelors of Science from Reading University (UK).

Alaa Jabbar is an Engineering management masters of science student at the University of Wollongong, Dubai.

Hamad Al Ansari has completed his masters of applied science in Engineering Systems and Management Department at Masdar Institute, Abu Dhabi and currently works there as a researcher.