HERIOT WATT UNIVERSITY

CENTRE OF EXCELLENCE IN SMART CONSTRUCTION

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SHAPING TOMORROW TOGETHER

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Bulletin Editor

Dr. Mustafa Batikha

Centre of Excellence in Smart Construction (CESC)

The centre is undertaking internationally recognized research and industry engagement from our Dubai Campus, providing a creative environment for collaboration between multidisciplinary research teams, industry and UAE government to solve challenges facing the construction sector. More details about CESC can be found in the following link:
https://www.hw.ac.uk/research/facilities/centres/smart-construction.htm

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How to become a CESC member

The Centre of Excellence in Smart Construction (CESC) is seeking industry partners to transform the future of construction, and drive research and innovation in the sector. The partnership will be shared ownership between industry and academia with the goal of overcoming the challenges facing the construction sector and preparing the next generation of construction professionals, with the skills and knowledge to make a step change. Sharing information, skills and knowledge is key to advancing industry adoption of innovative solutions to these challenges. Industry-Academia partnerships succeed when both parties have a shared goal. CESC is committed to undertaking industry-relevant research, knowledge transfer, and stakeholder engagement that shape the future of the industry. CESC will partner with like-minded organizations to lead the transformation of the construction industry and benefit the economy and community. As a partner, an annual partnership fee will help to offset the cost of knowledge transfer and engagement activities and will initiate a research collaboration with global multi-disciplinary research teams at Heriot-Watt University (Dubai, UK and Malaysia). Partnership benefits include: membership on CESC non-Executive Board; joint research planning workshop to set research themes specific to your organization; bi-annual construction sector research bulletin in collaboration with CESC partners; seat at high-profile bi-annual round tables with agenda set jointly with industry partners; two delegate seats at CESC high-profile annual conference (and bronze sponsor status); discounts on our range of professional development and executive training courses; hyperlink to sponsor website on CESC home page website; branding/acknowledgment on CESC publications, events, newsletters. For more details please contact: cescdubai@hw.ac.uk

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Introduction

Although Heriot-Watt became a university in 1966, its heritage in providing a pioneer education goes back to 1822 as the world' first mechanics' institute designed to support the ordinary people by specialist education in science and technology. Today, through all our efforts and proud history from 1822, Heriot-Watt University has become a truly international university via five campuses: three in the UK, one in Dubai and one in Malaysia. All these campuses work towards spreading the values that Heriot-Watt was established for: inspire, collaborate, belong and celebrate. It is by sparking the curiosity to learn, to face the challenges and to find solutions. It is by working in partnership a diverse, inclusive and international community to shape the future together. In addition, it is to show our deep appreciation and celebrate the excellent achievements in our community. These values have been embedded in our Strategy 2025 at every level of our organization to define our work.

Our Strategy 2025 determines our vision in being world leaders in our specialization, in addition, our mission is to create and exchange knowledge that benefits society through education and research. In research, Strategy 2025 has set an aim to achieve the top 250 universities' ranking through new interdisciplinary research institutes, global research agenda, and new local and global collaboration between Heriot-Watt research teams and other society's sectors. Toward this, the Centre of Excellence in Smart Construction (CESC) has been launched on September 25, 2019, from our Dubai campus where its main goal is to provide a creative environment for collaboration between multidisciplinary research teams, industry and UAE government to solve challenges faced by the construction sector. Through an industry-led academic research platform, CESC aims to focus on three themes: Enabling Technologies, Sustainability, and Health and Safety. By enabling technologies, CESC teams will bring the latest trends in technology (e.g. BIM, 3D printing) to serve in the construction industry for improvements in productivity, quality, duration and cost. The sustainability issue will always have a place in all CESC work for reducing the human negative impact that comes from the current construction practice. Finally, CESC will lead the research toward the enhancement of health and safety performance during the construction for the welfare of the workforce.

Why the Dubai Campus?

Dubai campus was opened in 2005 as the first multidisciplinary campus of an overseas university in Dubai International Academic City. Today, Dubai campus has a student population of 3700 students in different studying degrees (B.Sc., M.Sc. and Ph.D.) and from more than 90 different countries. In 2019, the Knowledge and Human Development Authority (KHDA) of Dubai has ranked Dubai campus as one of just three five-star universities in Dubai. It is worth mentioning that Dubai campus is the only campus that has a variety of scientific disciplines in Dubai. Moreover, Forbes Middle East has named Heriot-Watt, Dubai campus, to be the best university in the middle east in 2019.

As Dubai owns its remarkable reputation of being one of the fastest-growing cities in the world through large-scale projects and the busiest world city in construction, Dubai campus research activities have grown toward supporting this massive construction sector of Dubai. Today, Dubai campus has 41 Ph.D. students in multidisciplinary areas. Every year, the Dubai campus registers between 2 to 3 research students with successful completion of their Ph.D. study. All this is beside the massive number of research dissertations produced annually in both UG and M.Sc. levels where many high-quality dissertations have been turned into research papers. Today and with CESC themes and the industry partnership, it is expected that a huge growth of our research Dubai-campus community will be achieved by 2025.

Aim of this Bulletin

The bulletin of CESC aims to engage both academia and industry to highlight the latest developments and trends which can cause a significant future impact in the construction sector toward the three themes of CESC.

The CESC Bulletin is for everyone because the construction environment is an important part of our life. This Bulletin keeps you up to date on scientific advances in the construction area and highlights the activities and events of our CESC centre.

Acknowledgement

The Editor would like to sincerely thank the authors contributed to this bulletin issue. Their immediate response to my invitation is highly appreciated. Also, the editor values the help by Ms Yara Mouna, Ph.D. student at Heriot-Watt University, in the production of this bulletin.

Sustainability will be the Biggest Trend of the Construction Industry in 2020

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https://meconstructionnews.com/39275/sustainability-will-be-the-biggest-trend-of-the-construction-industry-in-2020

Abstract: According to a study titled World Urbanization Prospects and published by the United Nations (UN) 4.1 billion people or 55% of the world population were living in urban areas in 2017. Across high-income countries such as those in the Middle East, more than 80% of the population live in urban areas. And by 2050, close to 7 billion people worldwide are projected to live in urban areas.

This naturally means enormous pressure on our resources. If quality of life is to be maintained in the backdrop of rapid urbanization, the goal must be to develop resource-efficient cities. In fact, one of the targets for global development as stated in the UN's 11th Sustainable Development Goal (SDG), is to "make cities inclusive, safe, resilient and sustainable".

A large part of this onus lies on the construction industry. Sustainable construction plays a huge role in providing the necessary spaces and landscapes for human harmony and balance.

Ammar Kaka, Provost and Vice Principal of Heriot-Watt University Dubai shares some ways by which construction can be made sustainable in order to cope with the urbanization demands of 2020.

Use of low-impact construction materials

Almost all forms of human habitation damage nature to some extent. Similarly, the process of manufacturing construction materials also requires a lot of energy which result in CO_2 emissions. According to the Global Status Report 2017 (published by UN Environment and the International Energy Agency), buildings and construction together account for 36% of global final energy use and 39% of energy-related carbon dioxide (CO_2) emissions.

The use of low-impact construction materials can go a long way towards minimizing this damage. Such materials can also be recycled or re-purposed, which in turn minimize the ecological footprint. As a general guideline, materials that do not need to be manufactured in a factory or transported over large distances will have the lowest environmental impact. Such materials are found to occur naturally and are biodegradable. Some examples are timber, clay, lime, rammed earth, cob, straw, hemp and stone. While materials such as bricks, cement, metal, plastic and concrete are extremely easy to use and profitable, they have a high environmental impact (unless they are reclaimed).

Use of renewable energy sources

From the production of materials to the building process itself, the construction industry is responsible for a large part of energy consumption. In the area of commercial construction, roughly 90 percent of all energy used during the lifespan of a building goes to its operation and utilities.

If the construction sector increases the use of renewable energy sources such as wind energy, hydro energy and solar energy and shifting to energy-efficient equipment and machinery, this will optimize energy savings as well as reduce fuel footprint. Some ways by which this can be done is by building structures that use natural light, usage of smart windows that block UV rays and ultra-energy-efficient HVAC systems and water heaters which run using rooftop solar panels.

Focusing on space efficiency

Efficient use of space produces considerable environmental and economic benefits, and nowhere is this more important than in the case of urbanization. The construction sector can achieve space efficiency in several ways such as: maximizing the use of daylight in the interiors, incorporating requirements for space efficiency into project briefs and design, systematically collecting and updating space and cost information as well as setting targets that are monitored, incorporating space efficiency concepts into the estate strategy and minimizing surface area by excluding conservatories, extensions, and porches in the design. Space efficiency can ensure the size of the structure stays small, reduces the need for construction materials and allows a greater number of people to live in the same space together harmoniously.

Technology to improve quality of living

A decline in the quality of life is usually the first challenge of urbanization. Yet this is not stopping the movement of people to the cities. The need of the hour is construction that fulfils the twin demands of comfort and convenience. Therefore, one of the biggest challenges that the construction sector today is grappling with is how to use existing spaces and resources to deliver a high standard of living.

Here is where technology comes in. The significant and rapid developments taking place in the digital sector cannot be ignored. Artificial intelligence, robotics, the internet of things (IoT), 3D printing, blockchain and big data are all too impactful to be ignored and will transform how buildings are constructed and operated to address the new requirements fueled by urbanization. Smart construction comprises two main themes: smart buildings and infrastructure; and the way in which these are designed, procured and built.

On the smart building front, the majority of developments are focused on making buildings more environmentally sustainable. They learn occupants' energy needs, respond to changing weather conditions and automatically adjust themselves to maximize efficiency. The potential for smart buildings therefore is massive. In fact, studies by the McKinsey Global Institute estimate that IoT has a total potential economic impact of $3.9 trillion to $11.1 trillion a year by 2025, and that includes in the area of urbanization.

Designing a nearly Zero Energy Mosque in Dubai

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Abstract: This research study investigates the energy performance of an existing mosque located in Dubai. Operational data are collected and measured to assess the current building envelope performance. Furthermore, numerical analysis is used, and the mosque's annual energy demand is modelled in IESVE. The baseline model is calibrated and used to evaluate passive and active retrofit solutions, in line with international and local standards of the Dubai Green Building Regulations and The Passive House. On-site solar systems are also explored, to offset the high energy use intensity of the mosque and to enable it to achieve the UAE nearly Zero Energy Building standard of 90kWh/m2/year.

Keywords: *Hot climate, Energy efficiency, Retrofit, Nearly Zero Energy Buildings.*

1 Introduction

The UAE government has launched several initiatives including UAE vision 2021, Dubai integrated energy strategy 2030, and UAE 2050 energy goals, to promote the use of clean energy and ensure sustainable development within the country (UAE Vision 2021, 2018). In the light of these goals, the concept of Nearly Zero Energy Buildings (nZEBs) was introduced to provide a stepping-stone to the realization of a net positive built environment and a decarbonized global economy. According to Emirates Green Building Council Report, an nZEB is defined as 'a highly energy-efficient building which has an annual energy use intensity (EUI) of 90 kWh/m²/year and supplies most of its electricity demand through renewable energy sources produced on-site or off-site' (Emirates Green Building Council, 2017). In the built environment, Energy Use Intensity (EUI) is a popular indicator of energy performance. It considers site energy and can be calculated by dividing annual energy consumption by the total conditioned floor area of the building (Emirates Green Building Council, 2018).

According to Dubai Supreme Council of Energy (DSCE), 25% of the existing building stock in Dubai is inefficient in its electricity consumption and has a high energy saving potential (Di Gregorio & Zahr, 2015). This energy-saving potential can be realized by introducing a retrofit program for existing buildings, which focuses on targeting the main consumption drivers such as cooling, lighting and building envelope performance. There are about 6,747 mosques in the UAE (IACAD, 2018). In order to make UAE energy goals a reality, existing mosques have to be retrofitted to become more sustainable and low-energy buildings. In this context, retrofitting is defined as substantial physical changes made to a building, in order to provide it with a component or feature that enhances its performance, operational cost or sustainability (Dixon, 2014).

This paper will present a study on the energy performance and retrofit strategies for an existing mosque, in Dubai, United Arab Emirates. In the gulf region, mosques are large volume air-conditioned public buildings encased in a heavy building envelope. Their interior surfaces are mostly finished with reflecting materials such as plaster and marble, and the floor is covered with thick carpets (Budaiwi, 2012). The energy performance is evaluated through on-site data collection and numerical model analysis. The proposed retrofit strategy can reduce the energy demand of the mosque and achieve the nZEB standards of the UAE.

2 Methodology

2.1 Case study mosque

As a case study building, the Abdul Rahman Siddique Mosque which is located in Palm Jumeirah, Dubai, has been selected (Figure 1). It was constructed in 2007 and has the capacity to accommodate approximately 843 worshippers. The data collected are annual electricity bills, architectural floorplans, sections and elevations, lighting system, HVAC, power and water supply layouts, building material details and finishes. The next step is to develop strategies to reduce the mosque's EUI. For this, a number of active and passive energy-saving measures are employed and simulated in IESVE to determine their impact. For evaluating passive strategies, four design cases are formed, based on Dubai Green Building Regulations, The Passive House Standards, and shading strategies.

Fig.1. Abdul Rahman Siddique Mosque, Palm Jumeirah

3 Mosque Energy Performance

The mosque annual energy consumption for 2016 and 2017 is presented in Figure 2. Overall an increase of 12.17% is noted between the two years. However, Figure 2 shows that the energy consumption trend remains consistent between the two years. The energy use of the mosque is due to the cooling, lighting systems and small power.

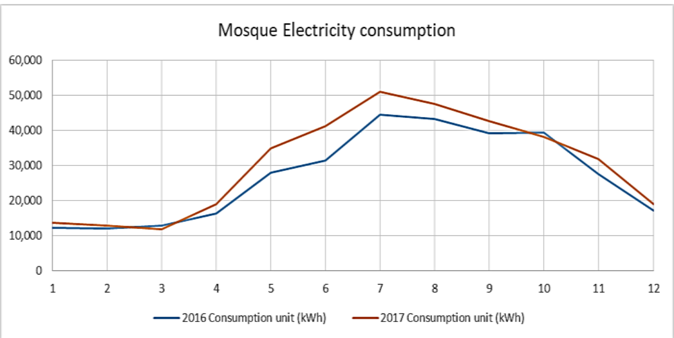

Fig.1. Mosque actual energy consumption for the year 2016 and 2017

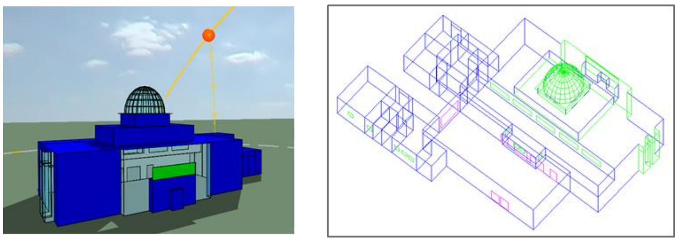

Fig.3. IESVE model of Abdul Rahman Siddique Mosque. Left image: 3D model with sun path and shadows. Right image: Axonometric view of the model geometry

3.1 IESVE Baseline Model

In order to perform a comprehensive energy assessment, the IESVE software is used as a simulation tool. It provides a dynamic simulation of the modelled building, as shown in Figure 3, and gives an accurate estimation of the building's annual energy consumption and carbon emissions (IESVE, 2018).

4 Retrofit Strategies

4.1 Passive design cases

The Dubai Green Building Regulations and Specification (GBRS) (Dubai Municipality, 2017) and the Passive House Standards provide guidelines to improve the building envelope performance (International Passive House Association, 2018). These guidelines are used to develop passive energy-saving strategies for the mosque. The IES baseline mosque model was run separately for four cases, which are:

Case 1a: Building external fabric U-values, shading coefficients and infiltration rates as per the Dubai GBRS.

Case 1b: Enhancing case 1a with the use of strategic shading

Case 2a: Building external fabric U-values, shading coefficients and infiltration as per the Passive House standards.

Case 2b: Enhancing case 2a with the use of strategic shading.

Table 1 sets out the design criteria followed by the above given passive design cases:

Table 1. Dubai GBRS and Passive House standards

		Dubai Green Building regulations and specifications	Passive House Standards
Thermal transmittance U-values (W/m²K)	Roof	0.3	0.15
	Walls	0.57	0.15
	Windows	1.9	≤ 0.8
Glazed Element	Shading coefficient (SC)	0.32	0.57
Air infiltration		< 10 m³/h/m²	< 0.6 x room volume per hour
		~ < 0.167 ach	0.042 ach

4.2 Active strategies

The following active strategies are applied to the best performing passive design case, as presented in Table 2:

Table 2. Active energy saving strategies

	Active strategy	Method
1	Replacing existing lights with LEDs	The existing mosque lighting fixtures are replaced with LEDs,
2	Motion sensors and dimmers	The Lighting power density (W/m²) is reduced by 10%.
3	Cooling set point temperature	The cooling set point for every room, except for the plant room, is increased by 1°C to 24°C
4	Programmable thermostat	With the application of a programmable thermostat, the HVAC system is only operational during prayer times,

4.3 Results

Case 1a provides a reduction in energy consumption by 13.92%, while case 2a provides energy reductions of 23%. As the shading approach for cases 1b and 2b is kept the same, both cases provided 2.2% of energy reductions due to shading. The passive house standards are stricter as compared to Dubai green building regulations. Hence, the results for case 2a show far greater energy-saving potential than case 1a. Therefore, the most efficient passive energy-saving method is the one presented by case 2b, which is applying the concept of the Passive House standards to the existing mosque, adding external shading devices like overhangs and diagonal shading fins. Active energy-saving strategies are applied to passive design case 2b. Overall, by applying all four active strategies to passive design case 2b, the annual electricity consumption of the mosque decreases by 20.4%. However, the mosque's EUI is 151 kWh/m² and it is still higher than the one required to achieve the UAE nearly zero energy target, which is 90 kWh/m²/year. After applying both active and passive measures, there's still a need to reduce the mosque's energy consumption by approximately 40%, which corresponds to 92,500 kWh annually, as shown in Figure 4.

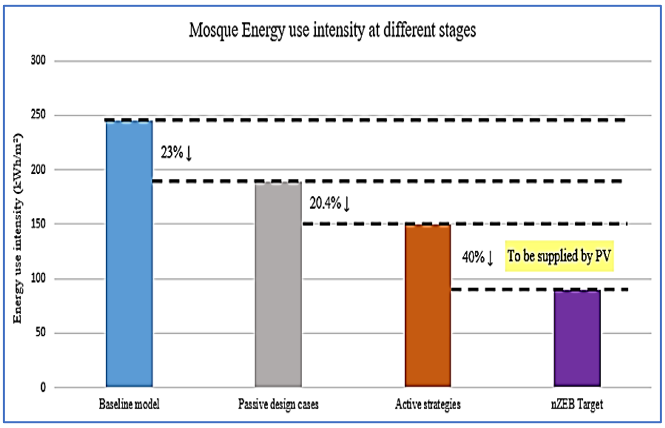

Fig. 2. IES mosque's EUI at different stages of retrofit solutions. Reductions in energy consumption due to each stage is also shown in percentages.

4.4 On-Site Solar System

The entire mosque provides a roof area of approximately 1,227.5 m². Through the mosque's IESVE model and the software's solar analysis capabilities, the power generated from the solar panels can be estimated accurately. Monocrystalline solar panels of power output 330 W, and module efficiency 17.03%, are installed on the flat roof of the main prayer hall, men restrooms and the staircase the roof. Furthermore, placing the solar panels on the roof contributes to blocking direct heat radiation and lowers the cooling load of the associated rooms. Through the IESVE model, the exact number of solar panels required to achieve a 40% reduction in energy consumption was calculated to be 179. This results in an EUI of 89.91 kWh/m² and the mosque's total energy demand from the national grid reduces to 137,568 kWh. Therefore, with the help of on-site solar power generation, the mosque can become a nearly zero energy building as per the UAE nZEB recommendations.

Acknowledgements

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Sustainable Materials in Construction

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Abstract: In this paper, a highlight of recycled materials to be used in construction is done to confirm sustainable construction. The efficiency of using GGBS, Silica Fume, Fly Ash, recycled aggregate, ceramic waste, plastic waste and cold-formed steel is briefly described in terms of sustainability, durability and mechanical properties. In the end, recommendations for the industry to keep supporting research on utilizing these waste materials are made until they are authorized for use in the construction.

Keywords: GGBS; Silica Fume; Fly ash; Recycled Aggregate; Plastic Waste; Ceramic Waste; Cold-Formed Steel.

1 Supplementary Cementous Minerals SCM in Concrete

The use of Supplementary Cementous minerals (SCM) in concrete such as Ground Granulated Blast Furnace Slag (GGBS), Silica Fume (SF) and Fly Ash (FA) which are by-products of steel, silicon and coal production, respectively, has become very commonly familiar in the construction industry especially for their additional environmental advantages for being industrial by-products waste that can be reused. Many studies have proven SCM's superiority of enhancing the microstructure of concrete mix toward less porosity caused by SCM pozzolanic reaction that allows more durable and sustainable overall concrete product [1].

According to extensive research, the use of optimum substitutional levels of 55-65% for GGBS, 30%-70% for FA and 5-10% for SF can actually have various influences on the physical properties of concrete mix in terms of slump, compressive and tensile strength [2,3].

Although many studies addressed that using GGBS and FA has a lower compressive strength at early stages, the strength gain for long terms are higher than that of the control mix or with SF involved [4,5].

From another point of view, the use of these SCM in concrete has higher potentials in terms of long term properties' enhancement rather than physical properties such as chloride penetration, drying shrinkage, carbonation and Al kali attack resistance, providing longer structural element life cycle [3,6,7].

In addition to the previous improvement SCM can provide to the concrete mix, other studies focused on the positive environmental influence of using a high substitutional level of SCM combination towards less CO_2 emission caused by concrete production as seen in Figure 1 where Ci, the CO_2 intensity in kg per m^3 concrete to the concrete compressive strength in MPa, can decrease sharply at substitutional level 15-20%. Also, Figure 1 shows that using GGBS and SF causes lower CO_2 intensity in concrete than FA. Moreover, the efficiency of GGBS and SF on reducing CO_2 intensity is much higher for low strength concrete up to 30MPa than high strength concrete [8].

It is worthily mentioned that one of the barriers of using SCM in concrete production is the uncertainty in their long-term availability where it mainly depends on the level of steel, silicon and coal production [9]. Moreover, SF is still hardly used due to its extremely high cost and low quantity production that makes it an extremely limited availability in the market [10].

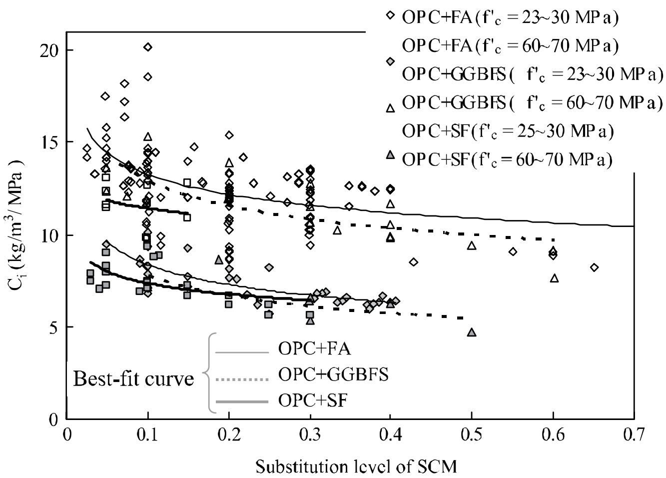

Fig. 1. Effect of substitution level of SCM on CO_2 intensity (C_i) [8].

2 Coarse Recycled Aggregate in Concrete

It is well known that for the last decade, using Recycled Aggregate Concrete (RAC) has captured many research concerns and studies for their advantages in finding solutions towards saving landfills that recently are increasing due to construction demolition [11]. Also, for being a good solution in terms of saving raw natural sources of aggregates that are expected to run low according to the extensive demand for natural aggregates in the concrete industry [12] as seen in Figure 2.

The demand of using Recycled Aggregates (RA) in concrete has become unavoidable due to the previous reasons although using RCA still has concerns regarding structure safety and durability where this weak performance can be attributed by many studies to a concentration of stress along with Internal Translon Zone (ITZ) interface which increases the tendency of failure. Also, the presence of old ITZ attached to RA surface can affect bonding strength and leads to decrease strength, acid resistance and increases carbonation [13].

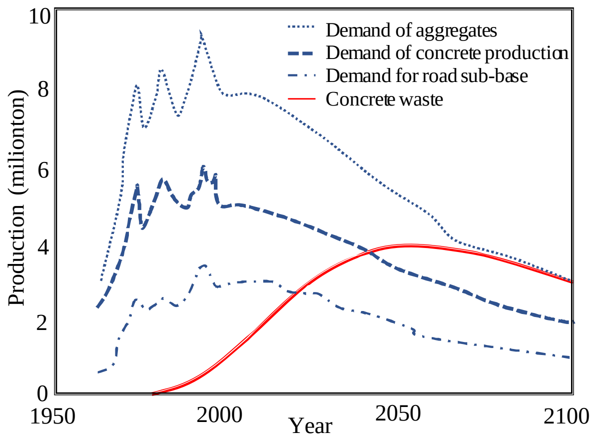

Fig. 2. Estimation of concrete waste and aggregate demand in Japan [11].

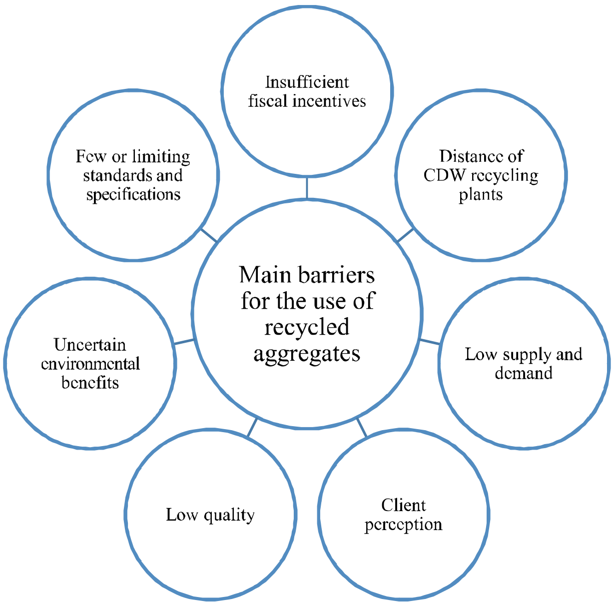

Fig. 3. Main barriers prevent wider use of RA in construction [16].

Research studies have offered many promising options to overcome the weak quality and performance of RA and other barriers shown in Figure 3, by pretreating RA [14], adding SCM to concrete which proved to improve the performance of RAC [5,15] or concentrating on enhancing RA production processing to reduce the level of RA contamination [11].

In UAE, Bee'ah Company in Sharjah processes 500000 tons annually of the Construction and Demolition Waste where 70% (1000 tons daily) is being recycled. Much Research at Heriot-Watt University shows that the produced RA from Bee'ah company is of promising quality to be used in structures. However, the durability of the RAC can be enhanced using one of the methods described above.

3 Plastic Waste in Concrete

Nowadays, plastic bottle factories are producing approximately 515 million tonnes of plastic per year. However, this number is even expected to increase as shown in Figure 4 for its lightweight comparing to glass bottles. This makes the plastic more recommended for consumers and transportation [17].

Plastic waste has been attempted to be used in concrete. However, many studies observed that using Polyethylene Terephthalate (PET) from water bottles addressed an improvement in concrete's flexural strength, impact resistance and workability [18-19].

According to many researchers, PET was added to the concrete mix in different studied into two main forms whether using plastic as replacement material of aggregate, sand or cement in a form of powder (or particles), or as an additional ratio of volume content to the concrete mixture in a form of fiber. However, no surprise that many studies [20-21] have addressed that the bulk density of plastic aggregates is much lower than that of natural ones. This brings the advantage of using plastic for producing a lightweight concrete. At Heriot-Watt, research is still under process for using plastic waste in concrete to reduce the environmental impact of that waste.

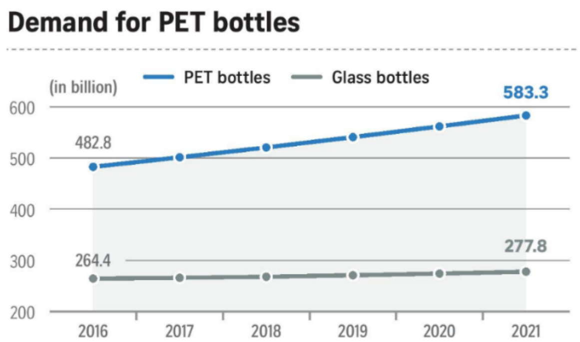

Fig. 4. Estimated plastic production comparing to glass by 2021 [17].

4 Ceramic Waste in Concrete

The ceramic production worldwide exceeds 12.3 billion m^2 [22] where Ceramic Waste (CW) was evaluated at 30% due to manufacturing and transportation, in which it remains not useful utilized and scatters on a large land field rising aesthetic destruction to the surrounding space. On another hand, Ceramic Waste Powder (CWP) is obtained from the final polishing process of ceramic tiles where CWP is estimated to be at a rate of 19 kg per m2 of ceramic tiles [23]. This brings 234 million tons of CWP globally. Therefore, utilizing CW in concrete has an advantageous solution for sustainable concrete. On the other hand, it was shown that using CW enhances the durability of concrete, but it is recommended that the replacement of concrete ingredients by CW doesn't exceed 30% not to cause lower concrete strength. By a project done with a fund by EXPO 2020 under the "University Innovation Program", research work has been done on using CW in concrete with 100% coarse aggregate replacement by

Recycled Coarse Aggregate (RCA). At the end of this project, a Beneficial Index (BI) was obtained for each mix, as seen in Eq. (1), to obtain the benefit of the replacement in terms of the mechanical properties, cost and CO_2 emissions together.

$$BI = \frac{Compressive\ strength}{Cost \times CO_2 emissions} \quad (1)$$

Equation (1) leads that higher BI means concrete of high compressive strength, low cost and low CO2 emissions. Figure 5 shows the relative differences between the beneficial index for each mix done in that project in comparison with the control mix.

It can be seen that M8 of 20% replacement of cement by CWP, 20% substitution of Natural Fine Aggregate by CFA and 100% replacement of natural coarse aggregate by RCA can lead to 66% benefits with 46MPa cylindrical compressive strength, 22% lower cost and 23% lower CO_2 emissions than the conventional concrete. Moreover, M8 offers 47% replacement of the concrete ingredients by recycled waste to reduce the landfills and save the natural resources.

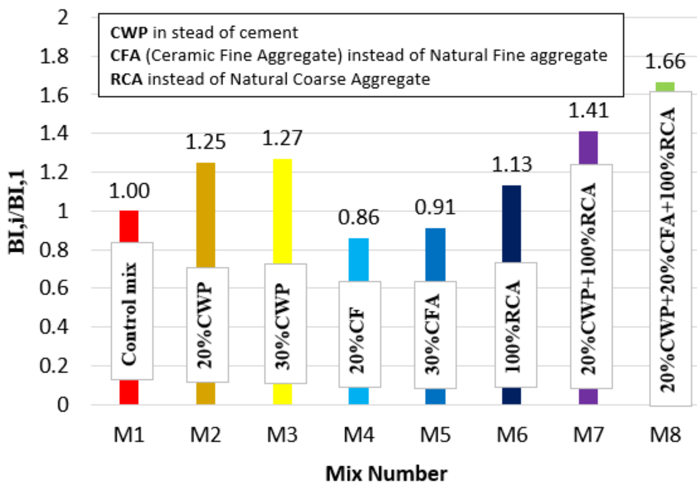

Fig. 5. The relative differences in the Beneficial index for each mix in comparison with (M1).

5 Cold-Formed Steel (CFS) in Construction

CFS is a thin steel strip (up to 3mm thickness) manufactured in coils of width about 1m. The sustainability of CFS is that it can be made of recycled junk cars. This offers to save our planet resources and reducing landfills and CO_2 emissions. For example, it was found that the consumption of aggregates for concrete is to reach 48.3 billion tons worldwide in 2015 with an expected increase of 5.2% yearly [24]. To build a house from wood, an average of 40 to 50 trees are required, while you need 6 recycled junk cars for the same house using CFSS [25]. On the other hand, the precise trimmed and shaped of the CFS to the exact dimensions causes no waste in comparison with other construction materials. Moreover, using recycled junk car in producing CFS reduce the CO_2 emissions if we know that producing cement for concrete frees a minimum of 500kg CO_2/t cement [26] and new steel producing (e.g. steel reinforcement, hot rolled steel sections) releases 2000kg CO_2/t in comparison with about 200 CO_2/t for the CFS from scraps. Besides of sustainability, the lightweight of CFS requires no heavy-duty construction equipment, less manpower and crews. This makes CFS is a valuable material in terms of Health and Safety issues in the construction site.

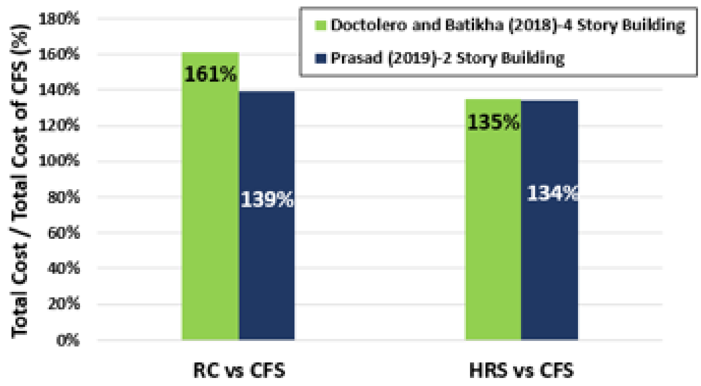

Fig. 6. CFS vs RC and HRS in terms of the total construction cost.

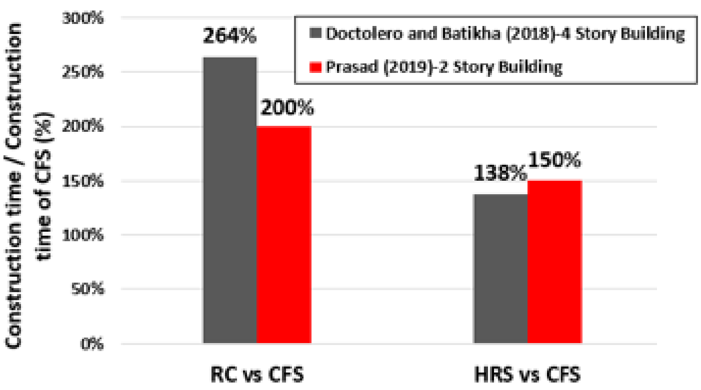

Fig. 7. CFS vs RC and HRS in terms of the Construction Duration

Recent studies at Heriot-Watt University [27, 28] show the high capability of CFS in building in terms of its lightweight, economic and construction duration. For example, in the case of 2-story building, Figure 6 shows that CFS offers less total construction cost by 39% and 34% in comparison with Reinforced Concrete (RC) and Hot Rolled Steel (HRS) respectively, while Figure 7 displays that CFS presents low construction duration by 100% and 50% than RC and HRS respectively.

Fig. 8. ORA House from CFS in SDME-2018 competition.

It is worth mentioning that CFS was the structural material of ORA house (Figure 8) that Heriot-Watt University contributed to the Solar Decathlon Middle East (SDME) competition in 2018 where the project has been ranked the top 4 out of 15 projects in the construction and engineering innovation contest. It can be noticed from Figure 8 that the foundation was made as well from CFS.

6 Conclusion

This paper highlighted some advantages of using recycled waste in construction material to confirm the sustainability in construction. In UAE, although some recycled materials are in use in buildings (e.g. GGBS, SF), the other materials such as RA, plastic, ceramic waste are not authorized because of lack of use standards for UAE. Therefore, it is so important that the industry gets engaged with universities and research centres to do the necessary for issuing these standards.

On the other hand, the future digital construction (e.g. 3D concrete printing) requires to be sustainable by using these recycled materials.

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3D Printing Adoption in The Construction Sector

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Abstract: Cost is the main driving factor for the implementation of new technologies, and it is also the largest obstruction to their internal development. Adaptation to new ideas is often difficult to translate across all sectors of a business but once accepted, the benefits can be grossly witnessed. This paper serves to inform that, with the current status of 3D printing technology, the cost vs return is a fine line, however, the development of the technology is increasing at such an exponential rate that any business unwilling to meet the market trends, in terms of 3D printing adoption across worksites, will fail to gather the benefits on a grand scale.

Keywords: 3D Printing; Construction; ALEC; BIM; Fitout; Additive Manufacturing

1 Introduction

3D printing represents the direct manufacturing of a part or component by means of a layer-by-layer manufacturing process guided by computer-aided design. This technology offers significant advantages to various business sectors through many applications. In the construction industry, 3D printing can be utilized to print construction parts or to 'print' whole structures. Construction is well-suited to 3D printing as a great part of the data important to printing exist because of the designing process, and the industry is as of now experienced in computer-supported manufacturing. The ongoing rise of Building Information Modeling (BIM) specifically may encourage more prominent utilization of 3D printing. Construction 3D printing may permit, quicker and increasingly precise development of bespoke items just as bringing down work costs and creating less waste. It may likewise enable construction to be embraced in hazardous conditions, for example, in space [1].

2 3D Applications Within ALEC

2.1 Overview

Innovation in construction has so far occurred mainly in the early and late phases of construction – design and engineering, and operations and maintenance – rather than during the actual construction phase. However, with the incorporation of computer-aided design across construction projects and the interconnectivity between the source software and the printer software, this may soon be a thing of the past.

While the actual timeline and details are uncertain with respect to the adoption of 3D printing across the construction industry, it is said by many that it is simply a matter of time before it is a common or standard feature across the industry.

Embracing this inevitable change, **ALEC Engineering & Contracting (ALEC)** has begun the deployment of the technology across its sites in various forms from replacement parts to formworks and even detailed models to assist in the understanding of complex work packages.

ALEC is currently underway with a drive to deliver more innovative ways to complete its projects with the highest attention to detail and in the most efficient of manners. This drive has seen the introduction of an array of new technologies and adaptive procedures for everyday tasks and processes. The adoption of Building Information Modelling (BIM) has introduced a new platform on which information can be exchanged. This technology encompasses all the information about a project which contains digital descriptions for every aspect of the physical project. BIM technology allows projects to be built virtually before they are constructed physically, all in 3D space [2].

2.2 BIM in 3D Printing

As the projects are being fully analyzed in 3D digital space this allows for a direct transfer of information into a platform that allows for the printing of the information to create an exact 3D replica of the BIM model in physical space. This was the process followed for the 3D printing of the Energy Transfer Station (ETS) Room on one of the projects under the ALEC umbrella.

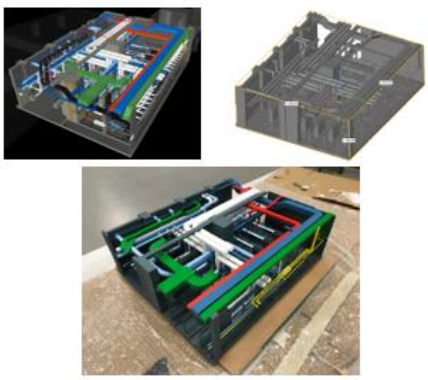

Fig. 1. BIM model vs digital 3D printing model and the final 3D printed product.

From Figure 1, it can be noted that through the integration of the 2 technologies – BIM and 3D printing –a product of great precision can be produced, despite the technical and bespoke nature of the item in question. This tool will now serve as an onsite 3D aid to deliver work packages with the highest precision and attention to detail and will further add, however small, to the advancements of 3D printing in the construction industry.

2.3 3D printing in Fitout

As the industry develops, and clients seek projects that stand out amongst the masses, architects and interior design contractors are continually challenged to deliver on complex design packages involving an array of unconventional and complex design components. In many cases, traditional manufacturing methods can deliver on the requirements of these components, but when these are bespoke in nature, then the itemized manufacturing can become a massive challenge – such challenges have been faced and overcome on a number of **ALEC** projects to date.

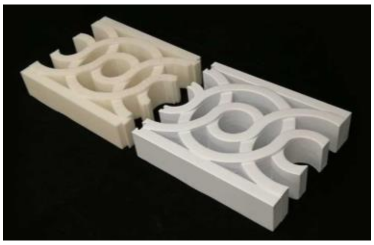

Fig. 2. Side-by-side comparison of a grill diffuser manufactured using traditional methods vs 3D printed methods.

An example of one of these would be the bespoke requirement for a set of grills and diffusers on one of **ALECs** projects. Due to the complex shapes making up the item, sourcing a "traditional" manufacturer who would be able to deliver a small number of custom grills would result in a significant increase in cost. The answer – 3D print them.

The process requires only the original part or a 3D model of it and can be printed and issued to the site within one week (item dependent). The printing process also involves optimization and customization where required. In this case, unnecessary material was removed from the final model and magnetic holds were incorporated into the design to remove the need for hard fixing.

The final product was received ahead of schedule, lighter in weight, and custom made to the needs of the site (Figure 2).

2.4 3D Digital Libraries

A fundamental advantage of 3D printing is the availability of on-demand printing. This means that should an item be required immediately, such as machine parts, for example, then the 3D model simply needs to be loaded into the software and printed ready for use in a matter of hours. This will eliminate lead time and reducing equipment downtime. In order to fully utilize these benefits, **ALEC** has chosen to digitize its small parts stocks throughout its warehouses and is adding to the comprehensive library on a constant basis.

3 Future Applications

The future of 3D printing on construction sites is becoming clearer and more unavoidable as the technology develops and matures to the needs of the sector. Bold predictions for the additive manufacturing market have been put forward for the years to come as more complex shapes and geometries are being explored on new projects in an aim to make them stand out but along with this, new methods are needed to make these shapes and structures a reality.

A forecast put forward by Smartech Publishing in 2017 shows the growth in revenue of Additive Manufacturing (AM), a 3D printing process, in the construction industry, over the period of 2017 to 2027, to be slightly over 5700%. Attributions to this growth include 3D printing of houses as well as infrastructures such as bridges and skyscrapers [3].

Figure 3 shows that, whilst the materials and hardware do grow steadily, applications and services arising from 3D printing technology dominate the expected revenue – an analysis that will result in the greater adoption of 3D printing across the construction and manufacturing sectors.

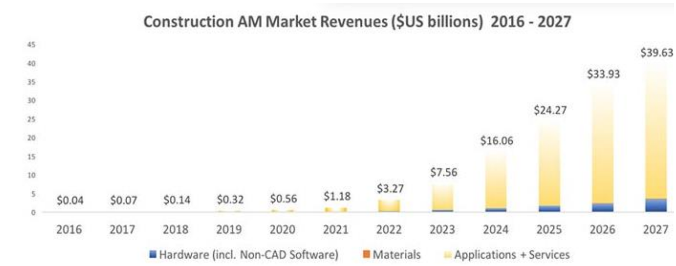

Fig. 1. Expected revenue as a result of 3D printing practices over the period of 2016 to 2027 [3].

In anticipation of the expected uptake, a significant amount of research is underway to find further avenues to explore 3D printing in structures. At the moment, load-bearing mechanisms such as pillars and columns, or structures requiring internal steel reinforcement, do not pose as viable items to be 3D printed, however, in order to match the future expectation of the technology, this would have to change and is thus under deep investigation.

4 Conclusions

His Highness Sheikh Mohammed bin Rashid Al Maktoum, Vice President and Prime Minister of UAE and Ruler of Dubai, has launched the 'Dubai 3D Printing Strategy', a unique global initiative that aims to exploit technology for the service of humanity and promote the status of the UAE and Dubai as a leading hub of 3D printing technology by the year 2030.

The Dubai 3D printing Strategy will make Dubai the worlds 3D printing hub. The strategy adopts an emerging technology that will help cut cost in many sectors, especially the medical and construction sector in Dubai. The technology will restructure economies and labour markets and redefine productivity.

The aim is that by 2025, based on Dubai Municipality's regulations, every new building in Dubai will be 25% 3D printed. The initiative was set off in 2019 starting at 2% with a gradual increase to the strategical goal seeing that 25% of Dubai's buildings to be 3D printed by 2030 – A market estimated to penetrate 300 Billion US Dollars [4].

Based on the information coming from market leaders as well as strategies aimed to include the technology across some of the world's largest construction hubs, it is clear that 3D printing is a technology that can be greatly beneficial to the construction industry and will soon be in common use across construction sites around the world.

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Agile BIM Integration and Framework

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Abstract: Agile and BIM methods are sharing similar principles to achieve successful delivery of a project. This research will discuss the way to integrate agile project management and building information modelling. Moreover, a study of agile project management enhancement to building information modelling will be discussed. This integration has not been discussed widely in construction or manufacturing industries. This research will cover this integration and will discuss the new methodology of management and technology.

Keywords: Agile Project Management; Building Information Modelling; Project Management; Agile BIM integration

1 Introduction

Building Information Modelling (BIM) and agile integration adaptation in the construction industry had not yet identified. The integration between agile and BIM as a framework for project design, construction and operation is included in this research. Agile project management methods and techniques will integrate with BIM in order to provide a clear framework to be adopted in the construction industry. This integration will help to identify the processes in order to maximize coordination and collaboration throughout the project life cycle for data management, information distribution, customer satisfaction, welcome changes and technical excellence. Building design faces a challenge during changes adaptation and rework. Agile project management supports BIM by providing a short and fast iteration of work, improving coordination and communication, eliminating unnecessary activities, developing more beneficial engineering analysis and improving activities sequence. Agility supports BIM by increasing customer satisfaction and improving risk management (Kumar and McArthur, 2015).

2 BIM Agile enhancement

BIM as software is mainly used for design. BIM is also used for providing geometric and non-geometric information data to stakeholders, facility management, contractor, and sub-contractors, suppliers and management team. Agile project management approach and teams enable more interaction with the architectural design to provide visualization for customers. Agile supports BIM by providing clarity, simplicity, and beneficial communication, regular feedback from customers, changes adaptation and a high response to customer needs. BIM combines all the data from all stakeholders involved in the project during design, construction and operation phases. All data provided by asset management, health and safety, sustainability, maintenance, facility management, space planning and authorities are saved to be used during the project operation phase. This information needs a proper management system for coordination between BIM team and management team in order to collect, distribute, review, highlight and follow up the actions during the project lifecycle (Kumar and McArthur, 2015).

3 BIM Agile development

BIM needs a proper management system to ensure work deliverables and collaboration. Agile project management is proved as a successful management method for the past years in the manufacturing and software industry. BIM functionalities and agile principles are studied and analysed with 32 interactions (Sacks et al., 2010). Table 1 shows a matrix between 12 agile principles and 13 BIM functions. Agile principles are motivating the individual to support BIM functionalities by adding value to the integration. Table 2 shows a description of some of the integrations between agile and BIM. The following are a description of agile principles and BIM functionalities.

Agile approach is based on 12 agile principles as the following: (Nir, 2014)

1- Customer satisfaction.
2- Adopting changes.
3- Frequent delivery of products.
4- Working together.
5- Motivating individuals.
6- Face to face communications.
7- Delivering working product.
8- Sustainable development.
9- Technical Excellence.
10- Simplicity.
11- Self-Organizing teams.
12- More effective iterations.

BIM technology is providing the owners many advantages such as better quality, high performance, reduction of errors, less time and cost. Uses of BIM model by facility management and owners are helping in multiple areas. BIM supports the design, construction and operation processes throughout multiple procedures and functionalities such as (Eastman et al., 2011):

1- BIM provides client an overview of the design during earlier stages throughout 3D visualization.
2- Ability to accept changes at any stage of the project lifecycle in order to apply corrections needed.
3- BIM provides an automated generation of 2D drawings at any time for any plan or elevations. This functionality helps in reducing errors during drawings generation for all activities. BIM helps to generate drawings as soon as changes are applied.
4- BIM supports collaboration and coordination between multiple designs. Moreover, BIM provides more control over all the process of design which will lead to better improvement and implementation of value engineering and cost efficiency.
5- BIM provides accurate cost estimation and quantity surveying during early stages of the project. BIM helps to provide clear cost estimation for all parties involved during design stage in order for them to make better decision.
6- BIM helps to improve energy efficiency and sustainability of the project earlier during design stage.

Table 1. Agile BIM Matrix

Agile Principles/BIM Functionalities	Visualization	Rapid Generation of Multiple design alternatives	Reuse of model data for predictive analysis	Automated cost estimation	Maintain of information and design model integrity	Automated generation of drawings and documents	Collaboration in design and construction	Rapid generation of construction plan	Construction process simulation	4D visualization of construction schedule	Online communication of product process	Computer controlled fabrication	Integration with project partners
Satisfy customer			24						12	15			
Welcome changes						14	8	10	13	16		22	29
Frequent Deliverables		3										23	
Working together							9				19		30
Motivate Individuals													
Face to Face Conversation											20		31
Priority for working product	1							11					
Sustainable Development					6		17					25	
Technical Excellence			4			7						26	
Simplicity				5						18		27	
Self-Organizing Teams											21		32
More effective Iterations		2										28	

Table 2. Matching Integration of Agile Principles and BIM Functionalities

No.	Discussion/Description
1	Agile deliver faster products during iterations. BIM provides visualization to the teams for better understanding.
4	BIM increases technical excellence by reusing project data analysis results for future application which minimize rework.
6	BIM application of sustainable standards and environmental policies will support agile project management application for better sustainable products.
8	BIM supports agile project management to adopt changes throughout better collaboration and coordination between management team and stakeholders.
10	BIM supports agile to apply changes during project lifecycle by rapid generation of construction plans.

4 Agile BIM framework

The framework of agile and BIM is to show a clear idea of how to start a construction project within the new approach of management. This framework supports the application of changes within iteration to show for all stakeholders involved in which stage the project is. This framework links between management, design and construction stages. Agile BIM approach is not only about following the framework, but it is about how the teams behave within the framework. Meanwhile, the management of a modern project management approach, like agile, the role of the project manager is redefined as a guide and mentor. Agile team methodologies are self-organizing and motivating, the role of the project manager is to support and help the team to accomplish the task (Uikey and Suman, 2012).

This framework depends on teamwork between the owner or development team, agile team, BIM team and construction team. Agile project management and BIM framework are for customer value, to provide a product that meets customer requirements throughout continuous innovation. Agile is adapting culture based on self-organizing and self-discipline (Highsmith, 2010). According to technology development and customer demand, nowadays some products are subjected to changes on a weekly bases. BIM supports agile project management to adopt these changes and applying them to the product. In the construction industry, agile project management is capable to interfere in changes requirements during the design and construction process (Highsmith, 2010).

Customers in the construction industry prefer companies that adopt changes and satisfying all customer requirements. Construction industry clients are developing green projects for sustainability and technology to make the life of humans easier and comfortable. To apply agile project management, a study for projects' delay and cost overrun needs to be analyzed and understood. Project complexity is one of the main reasons for project failures in cost and time. The poor performance of construction projects is divided into internal and external causes (Sohi et al., 2016). External causes are weather conditions, regulations changes, market changes and unexpected conditions. These causes are out of control during the project lifecycle. Internal causes are client changes, material delivery delay, and shortage of manpower, design changes and equipment delivery (Sohi et al., 201). BIMMMIM and agile project management framework implementation rescue project quality, cost and duration from these risks. BIM supports agility to encourage and motivate individuals by providing better decision making, coordination and collaboration between stakeholders involved in the project. Agile and BIM framework needs a skilled team and proper interaction between individuals and customers in order to deliver working products in a short period of time while adapting to changes. Meanwhile, agile managers provide the ability to the individuals to self-managing tasks to reach completed activity (Highsmith, 2010).

Agility leadership needs to drive the idea of focusing on leader needs, not what developers want. Agile leadership needs to focus on adding value to the project. Agility distinguishes between the project leader and project administrators where focusing on compliance activities is project administrative not project leadership. According to agility, the customer pays for value only and anything else considers as overhead. Sometimes overhead is necessary but up to limit especially for government projects. Agility focuses on minimizing these overheads such as documentation or reports in order to save cost for the non-adding value activity. Agile BIM framework integrates agile principles and BIM functionalities to develop an alternative method of management to overcome environmental challenges.

5 Conclusion

This study developed an integrated framework that matches BIM functionalities with Agile principles to enhance a combined management approach utilizing both techniques. The benefits of this integrated framework of Agile and BIM will have an impact on managers, developers, construction executives, designers and management teams working in the construction industry.

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3D Printing Effect on the UAE Construction Industry

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Abstract: Conventional development strategies in construction are associated with quality discrepancies, time extensions, cost overruns, waste generation, poor health and safety practices, and environmental impact. Lately, the application of 3D printing technology in the built environment has been showcased as an elective development strategy improving traditional building strategies while reducing the issues related to conventional strategies. 3D printing is an advanced automated process that can produce complex shaped components by adding material layer by layer, a process known as additive manufacturing. 3D printing technology has been applied to many industries generating substantial advantages of reasonable production time, less human involvement and minimum material wastage. 3D printing offers potential benefits to the construction industry such as improved quality and structural efficiency, reduced construction waste, flexibility in architectural design, improved safety and accuracy, reduced human involvement and faster production. However, there are many concerns about its application, capability and limitations. 3D printing technology is still young and requires more research and development for application in the construction industry. This article explores the challenges and limitations of the technology alongside its benefits and its current application in the UAE construction industry.

Keywords: 3D printing; UAE construction industry; 3D printed buildings; Additive manufacturing

1 3D Printing in the UAE construction industry

The construction industry is known for its traditional low-tech practices, high amounts of material waste, high consumption of natural resources and poor environmental performances, in addition to the well-known cost, time, quality issues. Lately, this image of the industry has been changing with new strategies involving smart technologies combined with innovative approaches. 3D printing is gaining great interest in recent years due to the significant benefits it may offer to the construction industry in terms of increased customization, reduced construction time, reduced human involvement and reduced cost [1]. With 3D printing technology, building components can be printed off-site to be assembled on-site or the whole building can be constructed on-site, pouring the material progressively layer by layer. It is a technology associated with its versatility in creating complicated shapes and structures. Research shows an increase in awareness and adoption of 3D printing technology in the global construction industry [2]. There is an appetite for better ways of doing business in the construction industry in all parts of the world.

The UAE construction industry continues to be active in new private and commercial developments as well as the state-of-the-art structures. UAE is one of the pioneers in adopting 3D printing technology. The Office of the Future in Dubai, inaugurated on May 23, 2016, is the world's first fully functional, inhabited and the most advanced 3D printed building in the world. The structure denoted the beginning of another period in the UAE construction industry. The building was designed with futuristic and creative design features using the latest advanced and sustainable materials. The 3D printed house components were all printed by a giant cement printer in China. The printed components were then dispatched to Dubai. The project ultimately reduced labour costs by 50 % to 80% and construction waste by 30% to 60% [3]. It took only 17 days to print and two days to install and is considered as the catalyst for future3D printing developments in Dubai. Dubai Future Foundation (DFF) achieved a Guinness World Records title for the world's first 3D-printed commercial building in Dubai (Figure 1).

Fig. 1. The World's first 3D Printed office (Dubai Future Foundation, 2020)

One of the latest developments with this strategy is the Dubai Municipality's Warsan building-first two-story 3D-printed building on the planet. The 3D-printed office building is an engineering achievement, using only three workers and one printer. Different organizations have begun grasping the technique through different coordinated efforts in an effort to meet Dubai Vision 2030 where the city plans to have one-quarter of all buildings built with 3D printing by 2030 [4].

According to Dawoud Al Hajri, Dubai Municipality director-general, “3D printing technologies in construction will increase the speed of execution and lead to the completion of buildings in a very short time. This will reduce construction costs and contribute to the development of solutions to demographic challenges by reducing the number of construction workers”. Onsite 3D printing equipment and local components are used for the construction of the Warsan building [5]. The building is now entered into the Guinness Book of World Records as the first two-story printed building [6].

Fig. 2. Dubai Municipality Warsan building (1st image source: The National, November 2019, 2nd image source: Dubai Media Office)

Recently EMAAR, one of the major developers in UAE, has introduced their plans on Dubai’s first 3D printed home. Emaar aims to provide customers a unique opportunity, allowing them to "design, download and print" homes. They believe that 3D Printing enables developers to deliver homes faster and reduce construction waste [7].

2 Benefits versus Challenges and Critical factors for wider use

For every new concept, there are challenges as well as benefits. 3D printing concept comes with various merits such as fast delivery of projects, improved health and safety, reduction of construction waste and increased efficiency. The construction industry is one of the significant contributors to most countries' GDP. Hence performance in that sector is very critical to the countries’ economies. The Construction sector contributes about 6.4 % to Dubai’s GDP [8].

3D printing is generally a known concept to the UAE construction industry practitioners. However, the technology has not yet found inroads in the line of work of the construction practitioners. In other words, it is not a concept that forms part of their day-to-day tasks. Currently, it is prominent in a few projects, however, to meet the vision of having one-quarter of all buildings built with 3D printing by 2030, the UAE construction industry needs to increase their efforts to find ways of implementing the technology effectively, efficiently and strategically.

An industry survey [9] identified that for effective application of 3D printing technologies in the UAE construction industry, critical factors to be considered are time, cost, structural integrity, safety, and combination of the system components. Another important factor underlined is stakeholder involvement and acceptance of 3D printing as feasible construction technology. According to the findings of the interviews with the industry practitioners conducted by Marowa [9] 3D application benefits include high quality and fast production of building units resulting in high productivity and shortened project delivery time with minimized construction waste. If these benefits are leveraged, there may be multiple benefits, such as an improvement in social welfare due to affordable high quality and sustainable housing with lower rental charges based on lower construction costs.

The survey showed that some of the challenges face organizations in implementing 3D printing are: high costs related to buying and setting up the machines, lack of sufficient knowledge on the technology, lack of skillset in the construction organizations and lack of sufficient research and development on the technology and sustainable printing materials. Clearly, research and development are considered costly and time-consuming by traditionalists, distancing them from the potential gains of new smart technologies and innovation in the construction sector. Most of the interviewees agreed that this is a revolutionary technology long needed, however, they need to see it practically in full swing in order to consider implementing in their businesses. Some of the respondents agreed that; 3D printing is still in an experimental phase implemented in commercial projects. Respondents see a need for extensive research and development involving time and high costs. Additionally, clients choose for more traditional and well-known technologies which, in their opinion, are quicker to implement. This is mostly due to resistance to change and fear of the unknown that almost all new technologies faces [9].

3 Conclusion and Recommendations

While 3D printing in construction has immense potential, its novelty gives challenges. Many challenges can be met by investing in research and development to enhance the technology, sharing knowledge and development of the skillset required. For this purpose, research and development teams should be set up to explore opportunities and limitations. A strategic approach is essential for the effective application of technology in the construction industry. The construction industry needs to raise awareness of the potential use of smart technologies and acquire the required skillset. The UAE Governments' vision and leading role in embracing the 3D printing technology and their support for the private sector through incentives, development of codes and specifications are critical in the effective implementation of the technology.

It was suggested to have more exhibition of prototypes related to 3D printing. Also, there was a need for more research and development which could create more standard products that can easily be implemented into the project streams.

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Technology Impact on Physical Site Performance in Construction Industry

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Abstract: In this paper, few major technologies which are impacting and improving the construction industry performance and cast the concentration on more control and feasibility of physical site progress are discussed.

Keywords: Health and Safety; Smart Reporting; Augmented Reality; Virtual Reality; Reality Capturing; 4D and 5D Progress monitoring; Radio-Frequency Identification; Machine Learning.

1 Introduction

The construction industry innovation has always been weak in terms of the amount of money and effort spent on research and development (R&D) comparing to the other industries. However, the scope of innovation in the construction industry is broad and applies to every aspect from buildings, products, material, process, methods of construction and business operations. As a result, in the last decade there has been witnessed a leap in construction innovation that related to the disruptive technological advancement. This has become an important feature to evaluate a construction company**.**

As announced by the government of the UAE, the country is striving to become the most innovative country by 2021. The construction sector; as one of the main industries; has been progressing towards the digital transformation and fast-paced efficient construction. As a result, more requirements have been raised by the government and the clients leading to increase in the construction innovation and creativity.

Technological developments have always driven construction forward, hence today we can build stronger, taller, complicated and more energy efficient structures. Technology has made construction sites safer and workers more efficient. It has allowed us to increase productivity, improve collaboration, and tackle more complex projects.

New technologies in construction are being developed at a rapid speed. Currently construction sites across the world are adopting new technologies such as connected equipment and tools, drones, robots, augmented and virtual reality (AR/VR), 3D printed buildings, smart dashboards, blockchain etc.

Few major technologies which are impacting and improving the construction industry performance and cast the concentration on more control and feasibility of physical site progress are described below.

2 Smart Reporting

Smart reporting tools ensure executive management and all project stakeholders have access to the vast amount of effective data within the click of a button. Dashboards are visualization tools which make it easier to analyze the information at hand. This ensures timely actions from all concerned parties and increases the accountability of the project teams and business stakeholders, but most importantly ensures timely mitigation measures can be taken to enhance operations.

2.1 Health and Safety

ASGC Construction has been an industry leader in creating smart dashboards for facilitating Health and Safety. They have created consolidated and individual project-based dashboards highlighting the fatalities, injuries, lost time incidents, manhours, time to the hospital, number of incidents by type and other key parameters as highlighted in figure 1.

Through this dashboard, anyone can filter the number and type of accidents by clicking any body part of the human illustrated in Figure 1. This provides real-time access to safety managers' senior management to access information about the projects.

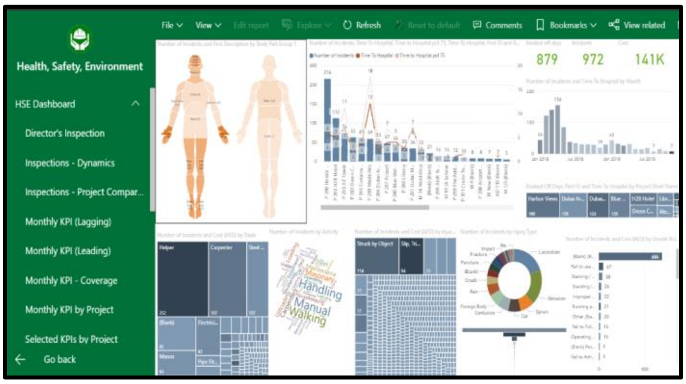

Fig. 1. ASGC HSE Dashboard

2.2 Operations Management

Project or organization-based dashboards provide key actionable information. The dashboards depict information like project name, contractual data, key milestones, project progress data, project time remaining, commercial data, procurement data, cash flow, HSE statistics, QA/QC data, areas of concern and other key parameters. The dashboards also include site progress pictures to facilitate the data being captured.

This ensures that senior management and project managers can access site information remotely at any given point of time.

3 Augmented Reality (AR) & Virtual Reality (VR) in the Health and Safety

Adoption of technology is impacting a lot of areas in the construction industry and one area which is garnering a lot of attention is improving safety as construction is considered one of the most Insafe industries across the globe as workers are exposed to a wide variety of hazards and face a great risk of a work-related fatality.

According to International Labor Organization estimates, approximately 6,400 people die from occupational accidents or illnesses and 860,000 people are injured on the job every day. The main cause of fatal accidents in workplaces in most of the developed world is falling from height – from scaffolding, ladders, ropes, or access platforms. Workers' safety is of utmost importance to any construction company and technological solutions are enabling companies to train and empower their laborers to prevent accidents and reduce serious injuries and fatalities.

Virtual and Augmented Reality can be utilized for site safety training as it would facilitate in providing exposure, training and educating the labor on how to work in challenging environments like working at height or confined spaces by creating a safe and controlled environment.

Augmented reality can be utilized to create an interactive site safety training game which is engaging and facilitates site safety to the labors.

Workers would be allowed to walk in a specific area of a construction site, they would need to select their Personal Protection Equipment (PPE) and would have a safety checklist according to their trade (i.e. helper, carpenter, steel fixer, mason etc.), they will be provided with either/or scenarios of potential safety issues to themselves or others on the site, at the end the report would be generated for each labor. The detailed report for each labor would be submitted to the safety managers and officers and would be followed potential action i.e. further training or fit to work on the project.

VR can also be utilized to perform psychometric analysis on construction labors, and it would help in reducing the number of suicides on construction projects.

Through the utilization of AR and VR, the risks of Health and Safety hazards on construction sites can be significantly reduced.

4 Virtual Design & Construction (VDC) and Reality Capturing

During the construction execution stage, multiple technologies can be implemented to facilitate project planning, monitoring and controlling (e.g. 4D & 5D simulations, animated videos and simulations, virtual and augmented reality and gaming engine utilization for construction and pre-construction stages). For large and specific organizations within the industry, VR & AR can aid in project management, remote inspections, sales, and design management.

4.1 4D and 5D Progress monitoring

The 4D model adds another feature to BIM, i.e. visualization of a project timeline. 4D progress monitoring has a significant role in project planning, as it includes important data like the start and end dates of every component and their criticality. The 4D model helps the project team get minute details as it visualizes the assembling of a building over time.

The 5D is the visual analysis of Project progress where the budget is compared to the value of the work achieved overtime.

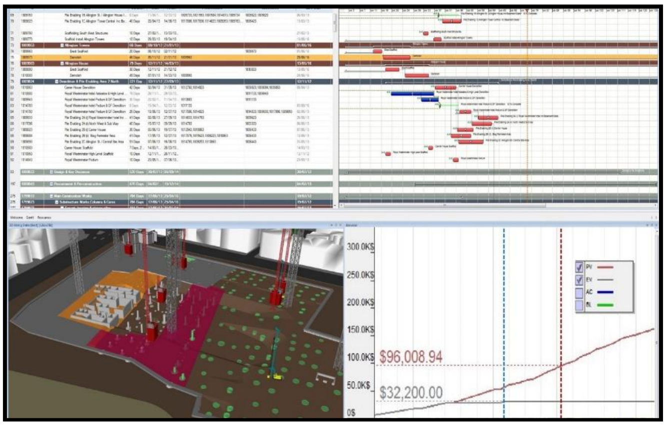

Fig. 2. 4D and 5D Progress Monitoring

4.2 Reality Capturing

"Visual reporting" - The reports generated by the new tools used to capture project progress including Drones, Time Lapse & 360 cameras.

These tools ensure live access to different project stakeholders to timely updates as well as area-specific visual material that aids in discussions, meetings, planning the workloads and decision-making and mitigation of risks.

Tools include Drone surveying during structural and façade works, 360 project walk-through tours during post-skeleton works and project time-lapse.

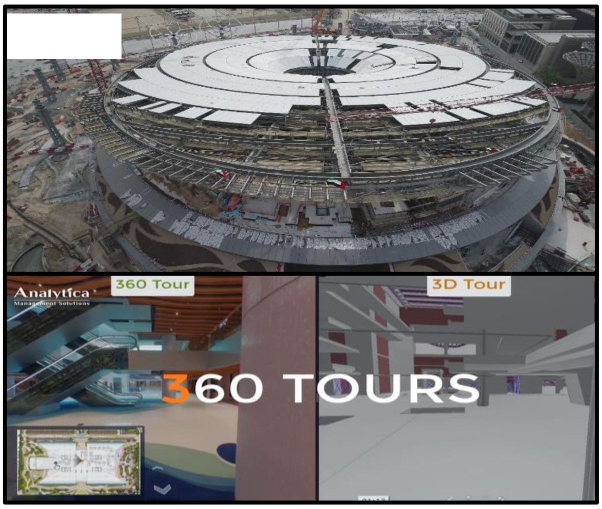

Fig. 3. Reality Capturing

5 Radio-Frequency Identification (RFID) technology

RFID is increasingly being used on construction projects to increase efficiencies, manage assets and improve safety.

5.1 Productivity

RFID helps to visualize worksite operations, quantify labor productivity, track workforce activity and automates worksite attendance. RFID tags are installed on labor helmets which are linked to the organization's HRMS, each construction project is divided into productive and non-productive zones, movement of each labor is tracked on the project through installed gateways across the site (refer to Figure 4). Consolidated customizable reports are generated and live dashboard is available for quick monitoring.

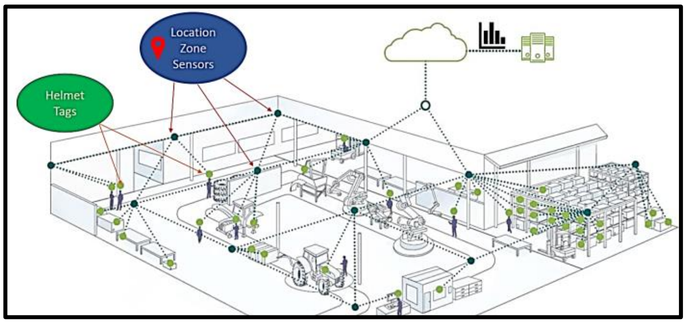

Fig. 4. RFID Network.

5.2 Health & Safety

Protecting workers in construction sites often brings a greater challenge than protecting workers in other sectors. Installation of RFID tags on labor helmet helps in improving site safety in a proactive approach such as:

Table 1. RFID Health & Safety

Mitigate Risk Effectively	**Improve Evacuation Measures**	**Expedite Emergency Response**	**Track Safety Incidents**
Monitor skills, qualification s and clearances for every zone to keep on-site workers safe	Alert all workers onsite simultaneousl y when emergency situations arise	Detect falls, slips, trips, and head impacts automaticall y	Resolve all hazardou s incidents or near misses as they happen

6 Machine Learning

The construction industry is adopting IT technologies like machine learning to optimize the scheduling of construction projects.

Machine learning is helping construction companies by predicting the outcomes of construction projects to help them understand complexity and risk.

The process of machine learning is explained as follows:

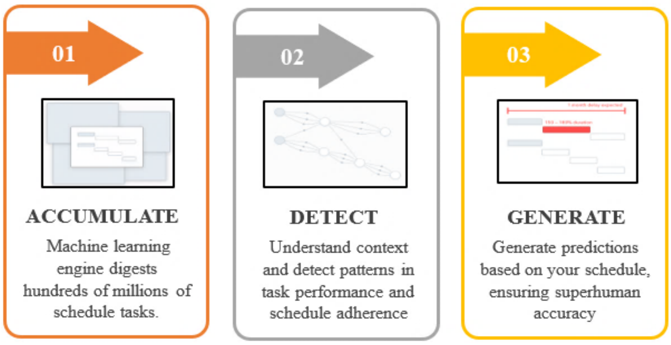

Fig. 5. Machine Learning Process.

Construction firms that continue to refuse to innovate are going to die. They have to realize the benefits and adopting technology. The way forward is that construction companies should asses the technologies available and adjust their processes, operations and business models accordingly.

7 Conclusion

Smart technologies in construction are vital especially with the current pandemic impact of COVID-19 as the world is moving fast towards the aspects of the fourth industrial revolution and GIG economy of being smarter and feasible promoting the culture of distance learning, remote working and part-time hire.

Smart solutions for Monitoring& Controlling physical site operations along with algorithms and mathematical models utilizing big data will be vital in terms of preventive maintenance, personal safety and future foresight.

Additionally, the financial impact of the current global situation which we personally call the 3rd world war (WW3) will force all industries to be more agile with fewer expenses which logically means more investment on R&D for more development and feasible improvement.

Technology for Health and Safety in Construction

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***Abstract*:** This paper reports on a field study that was conducted to investigate the Health and Safety challenges faced today on construction sites in the U.A.E. It provides a brief review of hazards, then lists the challenges faced by Health and Safety officers with practical experience in local construction companies. It then identifies a number of technologies and how these may be deployed to address some of those challenges.

Keywords: Construction; Health and Safety; Technology

1 Introduction

The construction industry faces many challenges in an ongoing quest to improve Health and Safety. Fatality rates in the construction sector are about six times higher when compared with other industries [1]. This is due to the very nature of construction projects where each project has its own specific characteristics, a workplace where a large number of people collaborate to carry out tasks often in a high-risk work environment and involving the use of various tools and equipment. Any failure in operation or human error can have grave consequences. This problem is compounded by constant changes in the job site environment and weather conditions, the involvement of multiple contractors, an unskilled labour force and the diversity of work-related activities. Regionally you can add to that the verbal communication challenge where people on the construction site are native speakers of different languages. The severity of the situation in developing countries is well-documented and there is an urgent need for further research to better understand the issues [2].

Over the years, best practice procedures, rules and regulations evolved, and countries have enacted various laws for ensuring a benchmark in the sector. Nowadays, it is accepted that the safety of workers and structures is an important factor in determining the success of a project. But despite all these efforts, the construction industry still reports far too many accidents and construction workers suffer grave consequences as a result.

Construction sites have been very slow adopters of innovative information and communication technologies to improve Health and Safety on construction sites, with little investment in solutions tailored to those needs. This paper reports on the challenges faced as reported by Health and Safety officers with practical experience in local construction companies. It also identifies a number of technologies and how they may be deployed to address some of those challenges.

2 Health and Safety in Construction

2.1 The Study

Construction in the U.A.E is a flourishing sector and Health and Safety on construction sites gained visibility and importance in recent years by all parties involved. This paper presents the findings of a field study carried out as part of an MSc student project at Heriot-Watt University Dubai. Safety Officers at four construction companies operating locally took part and the aim was to understand the challenges faced in Health and Safety on construction sites and investigate opportunities provided by various technologies to address those.

The meetings were held in January and February 2019. The first one was at Al Nabooda Construction Group which is one of the leading construction companies in the UAE specializing in infrastructure development projects. The second one was at GDM Interiors specializing in Construction and Design and has been operating in the UAE for forty years. The third one was at Jazeera Emirates Power, a contractor focusing on extra-high voltage substations and power plants. The last one was at Consolidated Contractors Company (CCC), a contractor engaged in building, transport, infrastructure, and pipeline projects.

2.2 Overview of Hazards

The construction industry is quite diverse and has grown at exponential speed in the last decade with activities ranging from small domestic projects to major infrastructure projects. Construction workers are exposed to specific hazards that are grouped into four categories: Physical, Chemical, Biological and Ergonomic. Noise, vibration and extreme temperature are some of the physical hazards that could cause hearing loss, loss of sensitivity, stress, breathing disorder, muscle cramps, dehydration and unconsciousness. Chemical hazards can exist in many forms like dust, fumes, liquids and gases which may enter the body through inhalation, ingestion, absorption and injection. The effects on the worker range from developing a headache or a skin allergy to serious lung disease, collapse and even death. Biological hazards include infection from bacteria, viruses and other toxins. If neglected the consequences could result in a mild allergic reaction to a more serious medical condition resulting in death. Ergonomic hazards are most frequently encountered in construction and constitute the major causes of injuries and death [3]. Injuries can occur as a consequence of heavy lifting, lifting not in accordance with accepted standards, using poorly maintained or inappropriate tools and prolonged hand-intensive work. Musculoskeletal disorder is the most common condition resulting from ergonomics hazards. These hazards and the icons representing them are summarized in Figure 1. The use of icons to warn of the hazard is important as signs are useful in reminding workers of hazards and they can also bridge the language barrier.

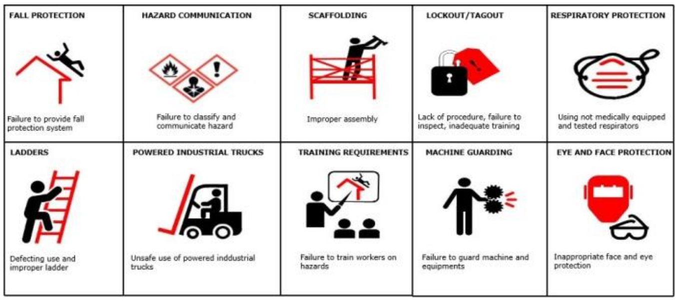

Fig. 1. Icons used in Health and Safety to warn of hazards [5]

2.3 Identified Challenges

The following is a set of challenges as reported to the researcher during the investigation. Construction firms normally follow the standard practice of risk assessment based on identifying specific hazards that are associated with an activity which in turn may create various levels of risk that need to be controlled by putting measures in place. Risk assessments have to be set up and managed by people with relevant knowledge and responsibilities. Safety control measures are mostly manual in nature and require workers to strictly follow the safety practices, in another word, workers are responsible for their own safety. And this itself represents a big challenge as workers may not follow the safety measures out of negligence or ignorance. The key safety challenges reported by the safety officers are listed as follows:

- ✓ Lack of live monitoring of the site conditions.
- ✓ Training the workers and communicating with them in a language understandable to them.
- ✓ Access to training materials and videos as and when required.
- ✓ Survey of the site conditions within a time limit to identify hazards before starting the activity.
- ✓ Controlling unauthorized vehicle access to the site.
- ✓ Live detection of site temperature, air quality, proximity, noise or any other hazards.
- ✓ Real-time check-up of workers' health condition including measurement of heartbeat, fatigue, body temperature so alerts of problems can be fed back to the affected worker.
- ✓ Communication between workers and immediate alert notification to a central control room in case of emergency.
- ✓ Communication in areas where there is no cellular network coverage.

3 Technology Solutions

The adoption of technology signifies a major shift in the way construction companies operate today and represents a new frontier in ensuring safety. Massive amounts of data about site safety conditions can be captured and processed automatically in real-time compared to the traditional practice of a safety engineer manually overseeing the site. Technology makes it possible to interconnect the site with a central control location to monitor the day-to-day activities which can further help identify, analyze and control the risks using the collected data. Technology empowers and drives companies to take better decisions in terms of Health and Safety, and organizations are realizing that to remain competitive in their market, they need to leverage both data and technologies [4]. To address the Health and Safety challenges, technologies that could be used to address challenges are listed below. Many technologies have been around for some time, with Drones and the Internet of Things (IOT) being the most recent additions with the most potential.

Closed Circuit Television (CCTV): Provides live monitoring and recording of site conditions. advancement of technology has added more features like 2-way communication, motion and intrusion detection, emergency alerts and detection of fire, temperature, water and smoke.

Automatic Number-Plate Recognition (ANPR) and Biometric Access Control (BAC) Systems: ANPR and BAC systems can help in restricting unauthorized entry of the vehicles and workers. This is an automated process for entry and exit of the vehicles and workers and it helps in live tracking of vehicles and workers who are currently on site.

Drones: It is necessary to identify hazards on site before or during working hours as site conditions may change rapidly. It has until recently been impossible for safety engineers to take a survey of large sites, tall buildings and any other areas that are difficult to access within the time allocated and as a result hazards get unnoticed leading to accidents. Drones help to inspect the high-risk areas, track workers and site conditions, and so safety plans can be updated as and when needed.

IOT enabled wearables: Specialized advanced wearables fitted with a range of sensors can help monitor site conditions, identify hazards and accidents, provide immediate assistance in case of emergency, detect proximity, dehydration, fatigue, heartbeat, gas exposure, heat stress, fall detection, improper use of personal protective equipment and track the location of workers.

2-way radio: Communicating with workers at remote sites with no cellular network is a big challenge and leads to delay in communicating and attending to the accidents. 2-way radio does not depend on the cellular network and can communicate with other devices up to 10 kilometers away.

Construction Safety Requirement	Impact
CCTV, Drones	
Live monitoring of the site conditions	Identify hazards, prevent accidents
Instant language translator, video conferencing	
Training the workers and communicating with them in lanaguage understandable to them	Training in a language understandable to everyone, overcome language barriers with text-text, text-speech and speech-speech translation
Video Conferencing	
Access to training materials and videos as required	Access anywhere, Data stream in the form of training videos and Text.
Drones	
Survey of site conditions within a time limit to identify hazards before starting the activity	Survey of large sites, tall buildings and other dangerous zones very quickly
ANPR, BAC	
Control of unauthorized access	Prevent unauthorized vehicles and workers entering into dangerous zones unintentionally or otherwise
Sensors	
Live detection of site temperature, air quality, proximity, noise and any other hazards	Sensors that can be fitted into CCTV, wearables to identify hazards
Sensors, Apps, IOT-enabled wearables	
Realtime check-up of worker's health to capture heartbeat, fatigue, body temperature with feedback to alert the worker and any other party	Detect proximity, dehydration, fatigue, heartbeat, gas exposure, fall and improper PPE use
Cellular network, 2-way radio, mesh network	
Communication among workers with immediate alert notification to the control room in case of emergency	Intercom using mobile, radio and mesh network
2-way radio	
Reliable communication	Uninterrupted communication among workers and emergency team in the areas where there is no cellular network

Instant Language Translation: Construction sites in the region often involve a work force from different parts of the world who speak different languages and training and communicating in a language understandable to everyone remains a big challenge. A language translating device is very useful as it can help to overcome the language barrier by providing features such as text-to-text, text-to-speech and speech-to-speech conversion.

Table 1 summarizes the technologies with the impact they can have of the various challenges in Health and Safety.

Table 1. Summary of available technologies and their impact on Health and Safety requirements

4 Conclusion

Research into novel approaches that use recent advances in a range of technologies to address challenges in the construction sector is still emerging. The potential for improving Health and Safety and managing the processes around it is considerable and can have real impact. This slow progress may be partly due to limited understanding of what technology can offer, but also due to the lack of regulation. It may also be the reluctance of investing in solutions that are yet to be tried and tested. In a world where technology seems to have disrupted many sectors, the construction sector is bound to start catching up very soon and simple, affordable and user-friendly tools are within reach.

Acknowledgements

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Modular Construction and Health and Safety (HSE) Concerns

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***Abstract*:** The construction industry is one of the oldest industries in the world. It is a very risky industry and very slowly changing compared to other types of industries like IT hardware or car manufacturing. In fact, it has not been changed since the Romans and it's time for it to change.

Modular Construction is the perfect implementation of offsite manufacturing in construction and design for the manufacturing approach. Such construction methodology has been going on for decades in the world and recently started in the MENA region particularly in GCC.

This paper addresses the HSE concerns in the construction industry and suggests Modular Construction as one of the solutions to control construction fatalities by transferring the majority of site activities to controlled, low rise activities in the manufacturing facilities.

Keywords: *Modular Construction; Offsite manufacturing; Health and Safety; Precast Concrete.*

1 Introduction, A clip of history

Since the early seventies of the last century and after the official formation of the United Arab Emirates, the construction industry was one of the most active industries in the area driven by the economic growth and the governmental policies of the GCC countries in general and UAE in particular.

The need for real estate in all the economic sectors albeit industrial, residential, tourism and retail pushed driven the boost in the construction industry.

The city of Dubai is world widely known as the most rapidly grown city that witnessed a tremendous spread over 40km length along its coast in less than 50 years by which the old Deira city joined Jebel Ali to form the current Dubai.

Fig. 1. Dubai growth over 29 years in photos.

Such large speed in construction could happen by increasing the construction workforce and adopting new technologies and construction methodologies in construction such as post-tension, precast, modular façade and offsite manufacturing systems in general.

2 Offsite Manufacturing growth in UAE

The heavy demand for fast track construction methodologies grew up slowly compared to the speed of construction during the first two decades since UAE was established and the conventional methodologies were dominant and the speed requirement was achieved by increasing the workforce at the site thanks to the low pay rates.

Although the first precast clad tower was built in Dubai in 1978, it took the market thirty years to adopt precast as a construction option whereby precast implementation was very shy till the late 1990s and number of manufacturers did not exceed ten.

Entering the 21st century was accompanied by further demand on construction supported by the growing economy and the real estate escalated demand. As a result, a faster construction system became extremely important and precast started being considered as a good option together with other systems that use conventional workforce in more productive manners such as post-tension systems for slabs and road bridges.

The first decade of the 21st century was the golden era of the precast industry in UAE whereby it gradually proved itself to be more reliable and more precast factories were established to follow the increasing demand. Gradually, full structural implementation of precast in high rise buildings is noticed and many landmarks were built in a very short time.

Pre-modularized façade elements were also adopted increasing the use of off-site manufacturing concepts in addition to precast. Offsite manufacturing demonstrated its capability to balance between time and cost.

3 From precast to Modular Construction

By the time the consultants adopted offsite manufacturing in their design using precast and modularized items like façade and amenities pods, the market witnessed another move towards lesser manpower utilization across the country responding to the government initiative to control the population of imported manpower. This brings modular construction as a solution since it reduces manpower through enhanced productivity and the best quality provided thanks to the controlled factory environment and better working surroundings.

This shift is easy to reach due to the similarity between precast and Modular Construction whereas the two systems are similar in offsite manufacturing principle, precast and modular construction are based on repetition, precast elements can be easily utilized in modular systems as they are the raw material for modular assembly and both systems rely heavily on design and engineering outputs.

4 Modular Design Vs. Modular construction

Modular design is a way of design that utilizes repeated modules and unit layouts with fixed dimensions replicated through the concerned building.

This works for any type of construction and it is essential for offsite manufacturing, but it is not Modular Construction in the full meaning.

Modular Construction goes further than geometrical control of the design to the construction away from the site which needs the building to be divided into smaller components (the modules) and such units are independently built or manufactured off-site.

5 Why Modular Construction, any challenges?

Modular construction is the right implementation of the off-site manufacturing concepts by bringing the majority of site activities to the factory then ship the finished modules to the site for installation, final testing and commissioning and handing over.

The main attributes to modular construction are:

- Fast track construction
- Early Delivery, Faster Return on Investment (ROI)
- Improved and consistent Quality
- RELOCATABLE and Scalable, On Demand
- Optimal use of Resources
- Enhanced HSE environment
- Optimal use of Capital.

Modular Construction has its own challenges as well as its advantages. Those challenges are Structural safety and design sensitivity for handling and logistics, the system's agility and ability to respond to architectural design requirements, the need for excessive coordination before starting production, the early selection and approval of materials by the client, logistics, transportation and hauling.

6 Health and safety in construction

Construction work is one of the most hazardous jobs that include road construction, tunnels, retail, simple housing and high-rise skyscrapers. Work in such industry includes very risky and dangerous activities whereby workers are subject to injuries and harmful incidences that lead to fatalities at high rates.

Fatalities are generally caused by falls, entrapment between objects, being exposed to gases or toxic material and electrocutions.

6.1 International statistics

The awareness of HSE in construction across the world grew up by time following the complexity volume of construction whereas the number of studies about this subject is generally low compared to other subjects of the industry.

According to a study conducted in 2017 by the National Institute of Occupational Safety and Health [1] that surveyed articles and papers on occupational health and safety among 32 specialized journals, the number rose up from 2 papers between 1930 and 1970 to 129 in the period between 2001 and 2010. This reflects a growth in attention towards this subject, but it also reflects how far this important subject is forgotten.

A study by Wikipedia [2] reveals scary numbers of fatality rates of the construction industry in the world varied from 99 annually per 100,000 workers in Europe to 1.62 in UK.

The study also reveals that 31% of the work fatalities in USA are attributed to the construction industry and that construction sites annual fatalities in South Africa hit 150 per 100,000 workers.

Table 1. Construction fatality rates in several countries [2].

Company/Region	Fatalities (per annum per 100,000 workers)	Year
Australia	6.2	2018
Canada	8.7	2008
Europe	99	2012
France	2.64	2012
Finland	5.9	2008
Germany	5	2008
Ireland	9.8	2013
India	10	2008
Norway	3.3	2008
Sweden	5.8	2008
Switzerland	4.2	2008
United Kingdom	1.62	2015

6.2 HSE statistics in UAE

UAE has been leading the construction industry in MENA region for the last three decades with remarkable spread and variety of construction types topped by Khalifa tower landmark, the highest building in the world. With this variety and challenges, the construction work became more risky and dangerous especially with working at heights.

A study conducted in 2009 by Peter Barss and a group of medical doctors [3] on Occupational Injury in UAE found that while the fatality rate in UAE is 27 per 100,000 workers, 23% of fatalities in Abu Dhabi are caused by injuries. Such a large number is significantly alarming when Brass et al. [3] compared it with the cancer fatality rate (12/100,000).

The study also found that 51% of the fatalities are caused by external causes with 61% of them are due to Heights of falls (Figure 2).

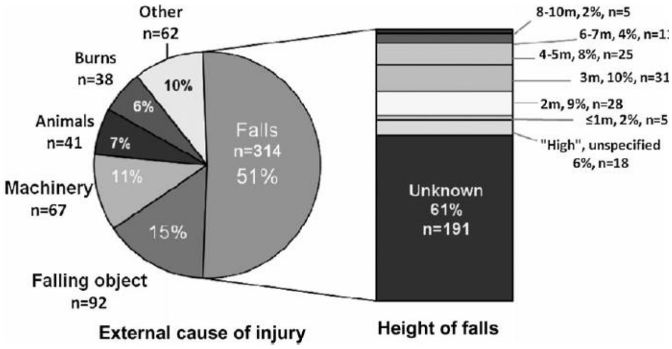

Fig. 2. Work related injuries [3].

The study reflected how HSE at the site is significantly important in the work at height.

7 Modular Construction and HSE:

The main advantage of modular construction is the enhancement in health and safety whereby the majority of the construction activities (could reach 90%) are brought to the production yard where the highest work activities would be at one floor high (4meter max.) and the environment is more controllable in terms of waste control, dust generation, lose material and unintended activities.

Referring to the study of Barss et. al. [3], modular construction eliminates hazards of 61% of the external causes of injuries being the work at height, in addition, eliminating the various hazards corresponding to 90% of the construction activities compared to the conventional construction methods.

A report by McKinsey & Company [4] on modular construction refers to modular construction as the future of construction due to its high productivity rates. Higher productivity leads to lesser manpower per activity and, consequently, lesser exposure to construction hazards and better healthy environment.

Reports by modular construction companies in UAE show very low rate of incidences and null fatalities whereby the Lost Time Incident or injury (LTI) rate, calculated through the number of lost time incidents occurring in a workplace per one million man-hours worked, of modular construction is far below the industry average in the UAE being 0.2. One example provided by DuBox modular construction company is illustrated in Figure 3.

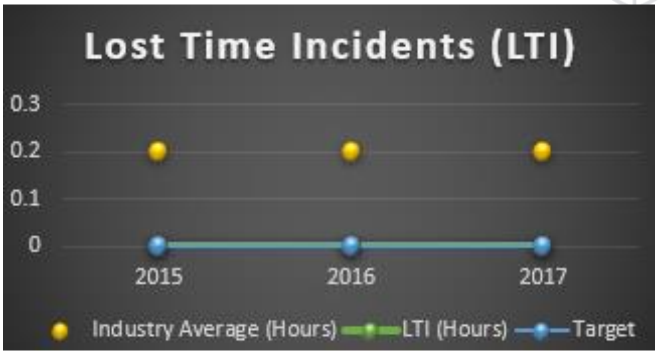

Fig. 3. LTI chart (Curtsey, Dubox).

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The Role of Safety Culture Across Industries

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Abstract: Following the progress in high-risk industries, workplace safety has gained great attention not only academically but also publicly. Safety culture and safety leadership have been recognized as key factors driving this progress. A number of organizations have adopted safety culture assessments in their safety management systems in order to evaluate the state of safety, as well as to identify the weaknesses and strengths regarding their safety culture. Organizations also train their leaders to have a positive impact on safety. Pioneer work on safety culture was conducted in hazardous industries such as aviation, manufacturing, military and nuclear power. Theoretical developments emphasize organizational and leader commitment to safety as one of the key aspects of safety culture, which illustrates the close connection between the concepts of safety culture and safety leadership. This paper brings an overview for understanding the state of safety culture within a workplace. It concluded that the assessment of the employee to leaders' commitment to safety at different levels of the organization plays a crucial role in the safety culture spreads.

Keywords: *Safety culture; workplace safety; injury rate; safety behaviour, safety leadership.*

1 Introduction

Following the Chernobyl disaster in 1986, concern over hazardous industries attracted wider attention for safety research in order to improve the understanding of human error and human performance. Although earlier research mostly focused on individual factors as sources of error vulnerability, organizational factors such as safety culture were identified as the main cause for major accidents (Neal et al., 2000; Borys et al., 2009). In line with the theoretical developments emphasizing an organizational commitment to safety as one of the key factors of safety culture, a number of organizations adopted safety culture assessments in their safety management systems in order to evaluate the state of safety, as well as to identify the weaknesses and strengths regarding their safety culture.

The accident causation theories in high-risk industries progressed via the technical period, human error, social-technical and finally the organizational culture period where the interaction between the human performance and the environment was acknowledged (see Wiegmann et al., 2004). Pioneer work on safety culture was conducted in hazardous industries such as aviation, manufacturing, military and nuclear power.

2 What is safety culture?

One of the most widely cited definitions of safety culture is provided by the International Atomic Energy Agency (IAEA)following the Chernobyl disaster: "The product of individual and group values, attitudes, perceptions, competencies and patterns of behavior that determine the commitment to, and the style and proficiency of, an organization's health and safety management. Organizations with a positive safety culture are characterized by communications founded on mutual trust, by shared perceptions of the importance of safety and by confidence in the efficacy of preventive measures" (ACSNI, 1993, P.23). However, in a workplace safety investigation in a manufacturing company, Zohar (1980) introduced the term "safety climate" as "reflects employees' perceptions about the relative importance of safe conduct in their occupational behavior" (p.96). Since then, the definitions of both safety culture and safety climate have been subject to numerous theoretical discussions and the terms often used interchangeably. For example, Clarke's (2006a) meta-analysis showed that when compared to safety attitudes and dispositions, safety perceptions had more predictive value in relation to work accidents.

In the organizational literature, the concept of culture is generally taken to mean something less tractable and more complex than climate. Schein (1990) proposed that climate is only a surface manifestation of culture and that culture manifests itself in deeper levels of unconscious assumptions. Similarly, Cox and Cox (1996) linked culture to personality, which is generally more widespread and stable, and climate to mood, that subject to short-term changes. Again, this was also reflected in the assessment of safety culture. For example, Denison (1996) argued that compared to safety climate – a snapshot – of the current safety culture (Mearns et al., 1997), in order to assess safety culture, qualitative methods should be preferred as surveys cannot fully represent the underlying safety culture.

3 How safety culture can help us predict workplace safety?

In their influential work, Zohar and Luria (2005) argued that since the policies and procedures are set at the organizational level, they cannot capture every aspect of the practice, and therefore the discrepancy between established policies and the execution of these policies and procedures is unavoidable. In this respect, while safety behaviours are primarily determined by supervisory practices, the top management commitment to safety would have a limited effect on worker behaviours. He further (Zohar, 2005) differentiated the effect of safety climate between routine and non- routine tasks and underlined the crucial role of supervisory practices especially for the non-routine tasks, when speed is valued over safety with consistent feedback, this might lead to the employee perceptions of lower levels of safety climate. On the other hand, when the task is routine and highly formalized (with specific and rigid procedures), the supervisory discretion is suggested not to have the same effect on climate perceptions since there would be less discrepancy at execution level when compared to non-routine and less formalized tasks.

A number of different safety-related outcomes have been adopted in the industry such as accident and injury rates and safety behaviours of the workers. However, while some measured these accidents and injuries via archival records or self-report measures, others used self-report measures. Similarly, safety behaviour data were either collected with self-report items or observations. Such discrepancies across studies confused the predictions.

4 What does literature say about safety behaviours?

The relationship between safety culture and safety behaviours were assessed via observations or self-report measures. In a study with production workers, a group-level safety climate was found to predict observed safety behaviours measured prospectively (Zohar & Luria, 2005). Similarly, in a heavy manufacturing company, Johnson (2007) reported the links between individual-level safety climate and observed future safety behaviours.

When measured through self-report items using safety participation, compliance, unsafe behaviours, and co-workers' safety behaviours, in a study on flight attendants (Kao et al., 2009), positive associations were found between the management's commitment to safety and safety participation, but not for compliance. Similarly, safety climate was also linked to unsafe behaviours of Italian blue-collar workers (Cavazza & Serpe, 2009). Clarke (2006c) although found an association between safety climate and unsafe behaviours in the UK manufacturing sector, no such link was observed for the accident history. In another study in the US (Seo, 2005), safety climate was shown to be the best predictor of unsafe behaviours compared to perceived risk, barriers, hazard level and work pressure.

Considering the definition of safety-related behaviours, one of the most frequently adopted conceptualizations was based on Neal, et al. (2000) work. They identified two components of safety behaviours of workers as safety compliance and participation. Safety compliance was defined as behaviours rooted in workers' rule obedience whereas safety participation was related to engaging in activities to promote safety in an organization rather than just following the written safety rules (Clarke, 2006b).

5 Safety culture-accident and injury rates

In the literature, a more positive safety climate was shown to be related to fewer experienced injuries and organizations with a lower level of safety climate had a significantly higher level of under-reporting rates (Probst et al., 2008). In a military sample, a group-level safety climate was found to predict future injury rates. Although a number of studies reported direct links between safety climate and injury/accident rates (Zohar & Luria, 2004), previous research indicates safety climate as a more distal predictor of safety-related worker injuries. In a cross-sectional retrospective survey study, on a sample of pilots, flight officers, and other aircrews in US Navy, while, a positive association was reported for minor and intermediate accidents and future safety climate perceptions, no such effect of major accidents was found (Desai et al., 2006).

Compared to objective data obtained from archival records, injury rates were also assessed through self-report items. For example, safety perceptions were related to worker injuries experienced in the last 6 months (Zacharatos et al., 2005). Huang, et al. (2006) also collected injury history (in the last 6 months) data with a self-report single item measure from a number of industrial settings (transportation, service, construction and manufacturing) in the US and reported indirect links between safety climate and self-reported injury experience.

Similarly, in healthcare, Gimeno et al. (2005) showed that lower levels of safety climate at the individual level coupled with lower rates of safety compliance were related to past worker injuries. While a direct effect of safety climate on back injuries was found, no such effect was reported for needle-stick injuries (Mark et al., 2007).

6 Conclusion

Based on the safety literature from the industry, it appears that utilizing two complementary methods rather than a single approach (Battles & Lilford, 2003; Cox & Cheyne, 2000) is advisable to understand the state of safety culture within a workplace. For example, similar to the approach used in the air traffic management (see Eurocontrol, Kirwan, 2008; Mearns, 2013), as part of a larger quantitative study on 1,866 healthcare workers in Scotland (Agnew et al., 2013), a workshop was designed to provide feedback to the healthcare management and provide opportunities to discuss the areas of strength and improvement in addition to future recommendations (Agnew & Flin, 2014).

Overall, previous work identified management commitment to safety as the most common theme measured in safety culture literature (Flin et al., 2000). Similarly, the majority of the work cited above demonstrated the crucial role of supervisory/managerial practices and the commitment to safety in order to maintain and improve safety by assessing the employee perceptions of leaders' commitment to safety at different levels of the organization (Hofmann & Morgeson, 2004).

* For more detail and discussion on the topic please see **Agnew, C.** & Fruhen L. (2019). On the role of safety culture and safety leadership on safety related outcomes in *Increasing occupational health and safety in workplaces: Research and practice*, Edward Elgar, UK.

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Past Events and Contributions by CESC

25 September 2019 | CESC launch

Speakers: Andrew Jackson (HM Consul General, Dubai and the Northern Emirates), Professor Ammar Kaka (Provost, Heriot-Watt University Dubai, CESC Director), Dr Olisanwendu Ogwuda (Centre Manager), Dr Roger Griffiths (Business Development Manager, Heriot-Watt University)

Summary: Public announcement of the launch of the Centre of Excellence in Smart Construction (CESC) at Heriot-Watt-Dubai campus and its partnership with 4 major companies: **ALEC, ASGC, Jacobs, and Mott McDonald**. Targeted at providing a creative environment for collaboration between multidisciplinary research teams, industry and the UAE government to solve challenges facing the construction sector, CESC to undertake internationally recognized research and industry engagement, aim to be a hub for stakeholder engagement as well as be a model for collaborative research and business discussions. Speaking on the occasion, Professor Ammar Kaka, Provost of Heriot-Watt University Dubai said, "As one of the leading universities with a campus in the UAE, we offer world-class research expertise. At the same time, we work hard to share this expertise and lead and participate extensively in knowledge transfer activities which helps local businesses to improve their competitiveness and productivity. Our newly launched Centre of Excellence in Smart Construction is an excellent example of this, and we hope to help the construction industry overcome key business challenges as well as prepare the next generation of qualified construction professionals."

For more details: https://www.hw.ac.uk/uk/research/facilities/centres/smart-construction.htm

23 to 24 September 2019 | BIM Middle East 2019 Conference & Expo, Dubai

Speaker: Professor Ammar Kaka (Provost, Heriot-Watt University Dubai, CESC Director)

Presentation title: Developing talent and BIM Managers for the construction sector.

Summary: An all-encompassing senior level 2-day conference program packed with presentations covering government policy, initiatives, standards, case study applications, BIM adoption and implementation strategies, industry collaboration, BIM / GIS integration, design strategies, legal and contracting practices... and more. It's your opportunity to discover all the latest developments in Building Information Modelling, from project concept and design, project management, to post construction asset management! It also included separate half-day workshop hosted by British Standards Institution focusing on the new ISO 19650 Standard for BIM published this year.

Professor Kaka's presentation covered skills shortages, role of a BIM manager, role Higher Education, innovation, industry challenges, rethinking construction, need for digitisation, talent requirement, CESC facilitator for change (e.g. project).

Event link: https://bimmiddleeast.com/

24 to 25 September 2019 | 2nd Construction Technology Forum

Speaker: Shameel Muhammed (Assistant Professor, Heriot-Watt University)

Presentation title: Robotic construction, Digital Construction & Future Earthen Shells.

Summary: The construction industry is on the cusp of new era. Building greener, faster, smarter and getting more from existing assets. The Construction Technology Forum 2019 brings together leaders from around the globe to discuss real technology use-cases that design, build and maintain projects better.

Event link: http://www.constructiontechnologyforum.com/

16 October 2019 | Ruwais opportunities

Speakers: Dr Olisanwendu Ogwuda (CESC Manager), Dr Roger Griffiths (Business Development Manager, Heriot-Watt University).

Presentation title: Industry-Academia Collaboration: Centre of Excellence in Smart Construction at Heriot-Watt University.

Summary: A cross sector event in Abu Dhabi on to hear about ADNOC's expansion plans for Ruwais. These plans involve both expansion of the petrochemical plant and a doubling in the size of the city, plus the addition of amenities that would mean people would live there with their families rather than just using it as a base Sunday to Thursday and the family remaining in Abu Dhabi. Construction will be a key sector for the city expansion and possibly a good test base for some of CESC research themes and collaboration with the companies bidding for the contracts.

The presentation was about the Centre of Excellence in Smart Construction (CESC), which has recently been launched at Heriot-Watt University. CESC has been established to address the global challenges facing the construction sector, to engage stakeholders (government, private sector and academia) to make a step change in the sector, and to prepare the next generation of construction professionals.

Event link: https://www.uaeukbc.org/en/events/ruwais-opportunities/

17 October 2019 | Emirates Green Building Council (EGBC) Sustainability Awards

Attendees: Dr Olisanwendu Ogwuda (CESC Manager), Dr Roger Griffiths (Business Development Manager, Heriot-Watt University)

Summary: The 2019 MENA Green Building Awards recognised organisations in the region for their innovative and outstanding sustainable building principles and practices. The MENA Green Building Awards have become one of the largest gatherings of industry professionals and researchers who are focused on promoting sustainable built environments.

For more details: https://emiratesgbc.org/wp-content/uploads/2019/10/191017-Awards-Brief-2019-Final.pdf

21 October 2019 | Emirates Green Building Council (EGBC) Sustainability Awards

Summary: Dr Olisanwendu Ogwuda (CESC Manager) talked to Ashley Williams (Editor at Construction Week magazine) about Heriot-Watt University partnerships with ALEC, ASGC, Jacobs, and Mott Donald for CESC.

For more details: https://www.constructionweekonline.com/259911-podcast-heriot-watt-university

23 October 2019 | The 5th annual Construction Summit ME

Summary: Rise of emerging technologies within the construction industry with more data-driven workflows and information exchange means that stakeholders are connected now more than ever – such major shifts in the industry demands a more constructible workflow. The Construction Summit Middle East returned with a mandate to explore construction work processes and technology that go beyond BIM, and more into constructability. Expert speakers and panellists bring into focus the progression in practices, technology. They discuss how to incorporate a constructible workflow, addressing the Regions contractors, consultants, and developers, to take the next technological leap.

Dr Olisanwendu Ogwuda (CESC Manager) was a moderator on panel discussion (Joint Q&A surrounding mega-projects including Expo 2020 and Saudi Vision 2030):

- ✓ Mega-sites becoming a blueprint for smart cities
- ✓ Digitalised infrastructure: meeting sustainability, comfort, safety and security targets
- ✓ Collecting, monitoring, correlating and analysing data from sites, and visualizing it to allow real-time monitoring and control of infrastructure

Panellists:

- ✓ Juan Tena Florez (Regional Digital Design Manager, KEO Design Division)
- ✓ David Glennon (Digital Delivery Director, The Red Sea Development Company)
- ✓ Tim Shelton (Digital Transformation & Innovation Lead, Arcadis International Limited)
- ✓ Saqib Rizwan (Vice President (Major Projects - Capital Projects & Infrastructure), McKinsey & Company)

For more details:

https://www.theconstructionsummit.com/

https://www.youtube.com/watch?v=Us9xrUuLgNQ&t=3s

4-5 November 2019 | 7th International Conference for Sustainable Construction Materials by Dubai Municipality

Speakers:

Dr Olisanwendu Ogwuda (CESC Manager): CESC and opportunities for industry-academia collaboration.

Dr Yasemin Nielsen (Director of EngD Construction program, Heriot-Watt University): How to Prepare for Disruption-AI in Construction.

Posters:

Dr Mustafa Batikha (Associate Director of Research-Dubai, Heriot-Watt University): Using recycled coarse aggregate and ceramic waste available in UAE to produce sustainable concrete.

Dr Hassam Chaudhry (Director of Architectural Engineering Program, Heriot-Watt University): Increasing Clean Energy Generation using Diffuser Augmented Wind Turbines (DAWT) for Urban Cities

Event link: https://www.cbnme.com/news/sustainable-construction-materials-conference-to-showcase-ai-technologies/

19 November 2019 — Construction of future: Innovation and responsibility- Bentley event

Speakers: Dr Olisanwendu Ogwuda (CESC Manager)

Presentation title: Centre of Excellence in Smart Construction (Industry-Academia collaboration)

Summary: In this event, speakers from industry and academic institutions discuss the changing future for the construction industry and what is being done to address and develop a unified way forward for the next generation of engineers. Dr Ogwuda' s presentation introduced the drivers and challenges facing the construction industry, followed by the need for CESC (industry-academia collaboration) to address the needs of the industry. CESC strategic objectives, research capability and completed/ongoing projects and CESC members were also presented.

12 January 2020 — CESC strategy workshop

Summary: The construction industry has an opportunity to progress towards whole life cycle smart construction, to engage in more sustainability, health, safety and well-being practices and to develop the talent required for the next generation of construction professionals. To address these challenges, this CESC strategy workshop was held to bring together academic colleagues from Heriot-Watt University and colleagues from CESC industry partners. The thematic workshop was facilitated by introductory scoping presentations (local/international context), followed by breakout group brainstorming sessions and, finally, feedback and open discussions.

14-15 January 2020 — Workshop- Transiting the Construction Industry to A Zero-Net Carbon Future

Summary: The construction industry has a significant role in the transition to a zero-net carbon future. From the embodied energy associated with the extraction of raw materials, manufacturing processes and transportation of building fabrics to the operational energy demand of the built environment, the industry can influence 38% of global carbon emissions from cradle to grave. Two half-day workshops brought a small group of industry and academic leaders together from the UK and UAE to 1) assess current practice and strategy of the sector and 2) identify the sectoral challenges and opportunities to have a real impact on the sector's carbon emissions. A full range of factors including social, economic and technological were discussed to give a full picture of the challenges. The workshop was facilitated by research experts at HWU (UK and Dubai) and culminated in a White Paper that identifies the pathway to reduce the barriers to decarbonisation across the sector and to support its transition to a zero-net carbon future.

20 May 2020 | Centre of Excellence in Smart Construction (CESC) – Partners briefing on Circular Economy

Speakers: Professor Gabi Medero

Presentation title: Centre of Excellence in Smart Construction (CESC) - Partners briefing on Circular Economy: k- briq technology.

Summary: As part of the ongoing partnership between your CESC industry partners and CESC (Heriot-Watt University), a 30-minute online presentation and Q&A session was held with our UK colleague, Professor Gabi Medero. (https://researchportal.hw.ac.uk/en/persons/gabriela-m-medero). Professor Medero is the lead researcher on the k-briq technology (https://www.hw.ac.uk/uk/research/bites/eco-friendly-bricks.htm) which constitutes 90% recycled construction and demolition waste and requires one tenth of the energy to manufacture compared to traditional bricks. The technology has received positive press reviews in relation to moving towards a circular economy in the UK.

The 30-minute session was an opportunity to get an insight into the technology and explore potential industry partnership collaboration opportunities for rolling out the technology in the UAE.

18 May-30 June 2020 | ALEC prototype villa

Speakers: Dr Olisanwendu Ogwuda (CESC Manager), Dr Roger Griffiths (Business Development Manager, Heriot-Watt University).

Presentation title: Multi-disciplinary project: ALEC Prototype Villa

Summary: ALEC are developing a full-size prototype villa based on the dimensions of eight, 40' shipping containers. They are keen to extend the collaboration with Heriot Watt University across a number of new projects across HWU Schools and Campuses. This is a blank canvas for ideas to engage students and staff in a real-world project, a live client and a physical prototype. Schools in Dubai are currently in dialogue regarding BIM, procurement processes, digital twins, solar, energy, net zero carbon, AI, etc. This opportunity is also a way for the Centre of Excellence in Smart Construction (CESC) to have multi-disciplinary engagement beyond and for (some) staff to align their own research and student projects with CESC. CESC members are not just about 'bricks and mortar' but about energy, procurement, finance, artificial intelligence, well-being and so much more. Contributions have been made to the multi-disciplinary framework from various Schools on current or future activities that could be aligned to this prototype villa with ALEC Construction.

3 June 2020 | Microsoft Energy Core – AI Centre of excellence for Energy: Launch event and industry panel discussion

Speaker: Professor Sebastian Geiger

Co-ordination from Heriot Watt: Mudassar Nazeer

Presentation title: Panel Discussion on Sustainability- Energy Efficiency: What are the top ways digital tools can boost efficiency in the Energy Sector? And how quickly?

Summary: Digital transformation in the energy industry could create benefits worth approximately $640bn for wider Society. This includes $170bn of savings for customers, $10bn in productivity improvements, $30bn in reduced Water usage and $430bn from lowering emissions, according to a study by WEF and Accenture a few years ago. Environmental benefits include reducing CO2-equivalent emissions by 1,300mn tonnes, saving 800mn gallons of water, and avoiding oil spills equivalent to approximately 230,000 barrels. The United Nations supported this notion overall in 2019 stating that digital tools, including those to track resource consumption, could help the world to reduce its water and energy use by 15% and more than 1.3bn megawatts respectively by 2030.

Upcoming Events

19-21 October 2020	BIM Middle East 2020 Conference & Expo

For more details: https://www.bimmiddleeast.com/

26-27 October 2020	BuildIT Middle East 2020

For more details: https://www.terrapinn.com/exhibition/buildit-middle-east/index.stm

14-16 December 2021	CIB International Conference on Smart Built Environment

Chair: Dr Taha Elhag (Associate Professor, Heriot-Watt University)

Co-Chair: Professor Mohammed Dulaimi (Director of CIB MENA)

Summary: The Centre of Excellence in Smart Construction, Heriot-Watt University and the CIB TG96 along with several CIB Commissions are organizing an international conference on smart built environment at Heriot-Watt University, Dubai Campus. The conference theme, Accelerating Innovation to Deliver Smart Built Environment.

For more details: https://www.hw.ac.uk/dubai/events/cib-international-conference-on-smart-built.htm

News

Latest Ranking of Heriot-Watt University

Heriot-Watt University's Dubai Campus is classified as a 5-star university for the second year by **the Knowledge and Human Development Authority (KHDA)** in Dubai. Moreover, the classification brings Heriot-Watt as the first university among British universities in Dubai with classification points of 834 out of 1000. https://www.khda.gov.ae/en/highereducationclassification. It is worth mentioning that Heriot-Watt's Dubai campus has been crowned 'Best University' at the first-ever **Forbes Middle East Higher Education Awards** in 2019. https://www.hw.ac.uk/news/articles/2019/heriot-watt-s-dubai-campus-named-best-in.htm.

Heriot-Watt University is ranked first in the UK for Building by **The Complete University Guide 2021**. https://www.hw.ac.uk/study/why/our-rankings.htm

New Director for the Centre of Excellence in Smart Construction (CESC)

The Centre of Excellence in Smart Construction (CESC) is going to appoint Dr. Anas Bataw as a new director.

Dr. Bataw has Contributed to the research and development of government strategies and standards in AEC innovations and Smart Cities. In addition, he has a proven track record in academia and industry contributing to smart cities and Industry 4.0. in the UK, Singapore, UAE, Malaysia, KSA, Qatar and India. With strong leadership skills in identifying, developing, building cases and implementing innovations and smart city initiatives that are responsive to the needs of rapidly growing organizations and industries.

Dr. Bataw will start his new role on September 2, 2020.