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Structural Sustainability in the Gulf – Fact and Fiction

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Biography

Kerry Galbraith is head of the structural department for KEO International Consultants in Doha, Qatar. KEO is a full service consultancy offering A&E design, project management and construction management services and infrastructure design. With 1600 staff in the Gulf, KEO is one of the largest AE/PMCM consultancies on the region.

Kerry is currently involved in the design of several mixed use developments at The Pearl Island in Qatar - a reclaimed island with a projected population of 40,000 people - including the Abraj Quartier, Medina Centrale and Porto Arabia projects. He also provides structural review services for Qatar Foundation at Education City working with international architects including Raphael Vinloy, OMA, Legoretta Legoretta and L&O.

Prior to joining KEO, Kerry ran the Chicago office for Magnuson Klemencic Associates, a structural engineering firm. He has 20 years of international experience in the industry with projects in Chicago, Seattle, Vietnam, Kuala Lumpur, the Philippines, the Middle East and the United Kingdom. His project experience has primarily been in the design and construction of high rise buildings and complex structures including the Seattle Public Library and the William H Gates School of Law.

Kerry graduated in 1988 with a degree in Civil Engineering from the University of Auckland, New Zealand.

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Abstract

The main objective of this paper is to educate developers, designers and contractors on the role of structural design in sustainable buildings and its implication within the gulf region. Sustainable design has become a trend amongst developers within the Gulf and in many instances the developers do not understand the implication that sustainable design will have on the cost and schedule of their development. Through understanding of the philosophy sustainability and the structural design process, the structural engineer can incorporate sustainability into their design. These techniques have an impact on the schedule and cost of a project but there are basic sustainable structural design techniques available that have minimal impact. It doesn't have to be difficult; sustainability can be achieved by keeping it simple.

Keywords: Structural, Design, Gulf

Introduction

Sustainable design has become a trend amongst developers within the Gulf and in many instances the developers do not understand the implication that sustainable design will have on the cost and schedule of their development. Sustainability is often included in the design brief issued to consultants, but the level of sustainability is neglected. In these conditions it is left to the consultant to define the level of sustainability that is to be incorporated into a project. It is up to the individual disciplines to quantify the impact the degree of sustainability will have on time and cost to the project. To undertake this exercise a clear understanding of what sustainability is and its impact on design is required.

To provide clarity to this topic the following key points are reviewed:

- What is sustainability?
  - Design to have zero environmental impact.
  - Continued environment for future generations.
- Difficulties in applying sustainable structural design in the Gulf
  - Minimal local materials
  - Desalinated water
  - Extreme temperature
- Techniques that can be utilized to enhance sustainable design in the Gulf
  - Simple – design methodology that is already in use.
  - Minor – Delete un-necessary construction materials
  - Major – alternative structural systems.

Sustainability

The philosophy of sustainable design is to design for zero environmental impact and to provide for a continued natural resources for future generations. While it is not feasible for the building industry to adhere to the true meaning of sustainable design the industry can embrace the intent of sustainable design through knowledge and understanding of the implications their design will have on the environment. Sustainability is a philosophy, it is not something that is specific to a particular building. It is something that needs to be embraced within the culture in which we live and work. It is not about achieving LEED points it is about achieving a balance between the sustainable needs of the environment and the wants of the people that inhabit the environment.

During the 1970's energy crisis the catch phrase was "taking a cold shower in the dark". The catch phrase for the new millennium should be "environmentally balanced design".

To assist in understanding sustainability the following organizations provide guidance to the building design industry:

- Relevant organizations:
  - www.usgbc.org
  - www.thegbi.org
  - www.architecture2030.org
  - EPA – Environmental Protection Agency
  - ASCE Policy on Sustainability
  - ASCE SEI Sustainability Committee

Sustainable buildings are not defined simply by the materials used in construction or by the method of construction, sustainable assessment is over the life of the

building. While certain construction materials may have favorable sustainable aspects, they may be detrimental over the life of the building. To quantify life cycle assessment the design community and associated affiliates have created a series of tools. Some of these tools are available for purchase (Athena EIE), others are in-house programs developed by design consultants (SPeAR).

The Leadership in Energy and Environmental Design (LEED) Green Building Rating system by the US Green Building Council has become the benchmark for the design, construction and operation of green buildings.

While design consultants can incorporate sustainability into their designs it is the developer and the planning authorities who have the greatest control over the degree of sustainability incorporated into a project. It is the developer who decides to reclaim land when there is available space else where. It is the planning authority that defines the height and density of construction.

Gulf Environment

The Arabian Peninsula is a harsh environment. Temperatures range between 7deg C (45F) and 47deg C (117F). For 6 months of the year the average maximum temperature does not get below 35degC (95F). The average annual rainfall in Dubai is 92.9mm. For 6 months of the year the average rainfall in Dubai is 2.5 mm (DMS). There is no natural potable water supply to meet the demands of the population. Apart from the oil and gas there are minimal natural resources.

The construction industry requires a regular supply of labor, materials and construction equipment. Importing labor has a significant impact on sustainable construction. New housing has to be built to accommodate the labor. There is an increase in demand on local infrastructure. Transportation has to be provided both locally and internationally back to country of origin. There is a ripple affect on importing labor which has an extensive impact on the environment.

Key aspects of the construction industry which have high environmental impact are as follows:

- Limited useable natural water source. Desalinated water has high energy requirement. Concrete which has a high water content is the major structural component of the majority of the projects under construction in the Gulf.
- No timber resources. Timber used in form work has to be imported.
- Harsh temperature – high energy air-conditioning requirement.
- Limited locally available human resource.
- Limited locally available construction equipment.

For sustainable design structural engineers in the Gulf should be aware of the source and the method of production of the materials used in the construction of a building. Key aspects of consideration are: natural resource use; transportation of materials, recyclable materials, energy consumption and pollution.

The Gulf is often seen as a region devoid of many of the natural resources required in the construction of building structures. Even though there are aspects of the Gulf construction industry which have high environmental impact, there are other aspects which are favorable in terms of sustainability.

Concrete consists of 4 main ingredients, water, cement, sand and aggregate. Water is locally available but is desalinated. While in some countries concrete batching plants recycle the water they use for cleaning, in the Gulf they don't. This could be rectified at minimal cost if the regulatory authorities made it a mandatory requirement. Cement is produced locally but the raw materials are imported. In the current market demand exceeds supply so cement has to be imported to supplement local supply. In some of the Gulf States the supply of cement is regulated by the Government which imposes a tax on imported cement. With the exception of Bahrain sand is sourced from within the country. The aggregate for the region is sourced from the mountains at the north end of UAE and Oman.

The steel used in the manufacturing of reinforcement used in concrete structures is milled locally. Iron ore is imported into the region which is milled into billets. In the Emirates the billets are provided to the reinforcing steel companies which have re-rolling facilities to produce the reinforcement steel. In Qatar reinforcing steel is provided by the Government controlled Qatar Steel Company (QSC). This is an integrated facility which mills and rolls it's own reinforcing steel eliminating the transportation requirement that is experienced in UAE. 65% of the reinforcing steel used by QSC is used in Qatar the remainder is exported to the Emirates.

Fill material used in the construction industry in the Gulf is sourced locally. Quarry's in each country produce large aggregate material which is mixed with locally available fine aggregates to give the required grading profiles.

Asphalt used in the construction of roads is batched within each country. The Gabbro aggregate used is quarried from the mountains in northern UAE and Oman. The oil by-products used are locally available.

Even though steel is milled locally for the production of reinforcing steel there is insufficient steel produced to meet the demand of structural steel. Structural steel rolled shapes are imported into the region. For larger projects the structural steel is often fabricated

in the country were the structural steel sub contractor is based, reducing the requirement for imported labor.

Even though it may appear that the region is devoid of natural resources used in construction some of the materials used are sourced locally which meet the transportation requirements of sustainable design. The region has the available natural resource to produce the energy required for the production of steel and the drying of cement.

Sustainable Structural Design Techniques

Sustainable structural design can be achieved through a variety of techniques. An understanding of these techniques and their impact on construction time and cost can provide the skills an engineer needs to incorporate sustainability into their designs. As the majority of labor, plant and materials are imported into the Gulf, the design techniques not only affect the local environment but also impact other countries.

Some of these techniques designers are already incorporating through good design methodology without realizing it. Sustainable design techniques can be categorized in levels of cost impact and are identified as follows:

1. Techniques that are already being incorporated into structural design.
    - Designing buildings with regular framing results in re-use of form work systems on each floor in multi-story buildings.
    - Use of pulverized fly ash (PFA) as cement replacement.
    - Take out excessive reinforcing
        - Smart detailing can reduce reinforcing by 10% - 15%
    - Use of Steel in lieu of wood for shoring of formwork. Lifecycle re-use
    - Post tensioning
        - Reduced concrete volume
        - Reduced reinforcing quantity
    - Flat slabs design – less formworks
    - Use of diaphragm walls as both temporary and permanent for basement wall design.
    - Reuse of excavated material for fill material.
    - Use of locally available coarse and fine aggregates in the batching of concrete and asphalt.

2. Minimal impact.
    - Use exposed concrete finishes – no render less sand / cement / water / labor / energy requirements.
    - Use of precast – potentially re-useable material. Hollow Core Slabs have long span capacity and require less concrete and less formwork. There is a transportation cost but if the pre-cast supplier has their own batching plant at their yard then the difference in transportation requirements between pre-cast and cast in place is negligible.
    - Minimize screed depth when designing hollow core slabs.
    - Detail structural elements in increments of the length which the material is fabricated. This minimizes material waste.
    - Detail components so easier to take apart for reuse
        - Bolted steel connections
        - Screw sheet rock to framing
        - Easy to put together is easy to take apart

3. Moderate impact.
    - Minimize the use of materials which have a high energy demand in their production. i.e. concrete masonry block walls, render. Historically masonry block work has been used in the region for the construction of internal partition walls. Alternative light weight partitions are now available in the region and should be considered.
    - Use of cellular steel beams in steel buildings. Cellular beams weigh 35% to 50% less than wide flange beams capable of carrying the same loads with the same span. (Gibney 2007)

4. Difficult:
    - Use of alternate materials. Concrete has a high energy demand relative to other building products. 95% of the energy used in producing concrete is consumed in the processing of cement. Water used in batching concrete is desalinated which has a high energy demand. Structural steel has 97% recycled content. However in the current market structural steel demand exceeds supply of recycled material. In the past 10 years American steel makers have reduced the energy required to make one ton of steel by 28 percent (AISC). New technology in the manufacturing of structural steel is resulting in higher steel strengths which results in less material used. The price of alternative materials is market driven. In recent years there has been a 20% premium of structural steel versus concrete construction within the Gulf. Prices fluctuate on a regular basis affected by supply, demand and high inflation within the region
    - Use of alternate structural systems to minimize materials used. By increasing the number of columns the structural spans are reduced which in turn reduces the structural materials used. This can impact the functionality of the space and affect the marketability of the project.
    - Don’t build.

At the onset of a project a matrix can be created to identify potential sustainable features that can be incorporated into the project. These can be quantified in terms of cost and time which will assist developers in deciding which to incorporate into their project.

	Easy	***Moderate***	***Difficult***
Designer			
Construction			
Owner			

In association with this matrix a life cycle assessment can be undertaken to determine the optimal structural system, steel versus concrete. Even though structural steel may be appear to be the more sustainable option during construction, given the high temperatures in the region, over the life the building concrete may be preferable due to its greater thermal inertia.

Conclusion

Sustainability is a philosophy which should be incorporated into design of every building. Through understanding the environmental impact of the structural systems and materials used it is possible to incorporate sustainability into structural design. Each environment is different and has its own limitations. The sustainable design approach utilized in one country may not be applicable to other countries. Sustainable design techniques do not have to be difficult. Structural engineers are already using sustainable design techniques, they just may not realize it.

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