2030: The Structural Engineers Role in Beating Professor Beddingtons Perfect Storm Predictions

1. Zira Island, Azerbaijan

Professor John Beddington’s predictions centre upon climate change, rapid population growth and their associated complications including: food security, energy, water and resource demand, and network robustness.

How can structural engineers be prepared to address these problems, come the year 2030?

20 years is a relatively short time in terms of widespread change throughout the structural engineering industry... Forums, research and experiments, discussions, drafting and publishing of guidance, rules and design codes takes many years. The Eurocodes, for example, were first actioned in 1975 by the Commission of the European Community and they have only just, in March 2010, replaced the conflicting National codes in our design offices

However, we must also realise that 20 years also holds a very large window of opportunity for individual brilliance, such as Fazlur Khan’s revolutionary approach to tubular building stability, which gave birth to the “economical” skyscraper in Chicago when the John Hancock centre was topped out in 1968. This enabled towers to be built taller, using fewer materials than their counterparts from yesteryear

2. Fazlur Khan's revolutionary tubular bracing. Similar designs have been adopted on skyscrapers throughout the world

Here, we will examine current research and ideas within the fields of structural engineering, architecture and materials science which will have the potential to overcome the issues raised by Professor John Beddington over the next 20 years. Some of these notions are more likely than others to be comprehensively adopted across the globe within 20 years, some of which are already commercially viable yet not widespread, others are ground-breaking concepts and require years more research and funding while some are even controversial.

Certainly, all research and proposals to tackle the threat to humanity and our planet should not be discounted, no matter how radical, expensive or far-fetched they may seem in the first instance.

Improving Resource and Food Security Through Building Design.

One of Professor Beddbingtons most sobering conclusions is that humanity needs to discover a way in which to "produce 50 per cent more food and energy, together with 30 per cent more fresh water, whilst mitigating and adapting to climate change"

60% of the world's population will reside in cities and urban centres by the year 2030. Availability of land for quality farming and agriculture will reduce and the intrinsic, yet, deleterious rate of population growth, particularly in developing nations, will create a huge demand for food that we simply don't have the resources to grow or supply. Fresh water is also predicted to cease existing as a free commodity and this adds to the detrimental effects facing farming as currently 70% of the world's freshwater is used for irrigation in agriculture.

These factors evidently require a method of farming that requires less acreage and is more efficient in terms of yield and reducing the dependence of pesticides, fertilisers and, critically, irrigation.

Recent proposals to challenge traditional building use in order to solve these problems have yielded ideas such as vertical farms, Eco cities and even the emergence of "archology".

Research carried out at the University of Columbia by professor Dickson Despommier, argues that building multi-storey farms in urban centres would reduce the need for mass transportation and distribution, contain and eliminate the spread of disease, thereby eliminating the requirement for pesticides. The amount of freshwater required for irrigation will also be reduced as the crops will be grown in a closed, controlled environment and evapotranspiration will be recoverable.

Removing the requirement to transport crops from rural areas to urban centres, potentially even quashing the need to import crops from overseas, will drastically reducing the appalling "food miles" that is inherent of present day produce commerce, where food prices are inherently linked to the price of fuel

3. "Skyfarming" in a Vertical Farm

Of course there are counter arguments to this case, primarily; the fact that the most expensive square footage in the world is that situated in high rise buildings. However, if engineers can pave the way for a cost effective modular structure to be built, which offsets the cost of uneconomical irrigation, fallow acres, pesticides, fertilisers and the aforementioned transportation costs, then perhaps economists and politicians can be swayed into adopting such changes.

Vertical Farming could also raise further challenges to the structural engineer. If agricultural and small scale livestock farms do find themselves in bespoke or mixed use buildings, than the engineer must have an understanding of how the building works. New M&E equipment would have to be provided for and research into serviceability limits, load criteria and design codes would be essential for such a building.

A more realistic scenario for the early part of the next 20 years would probably be the development of prototype vertical farms, which will allow the theories to be tested, and provide an interesting tourist attraction which will help cover the cost. However, small scale agriculture built into transfer levels, roofs and south-facing facades on mixed use buildings should be expected. Integrating agriculture in this way would create a pleasant living and/or working space, whilst providing an opportunity to test the technology with real end-users. This, along with experiments using prototypes, could then lead to cheap high rise buildings being designed and build specifically for farming.

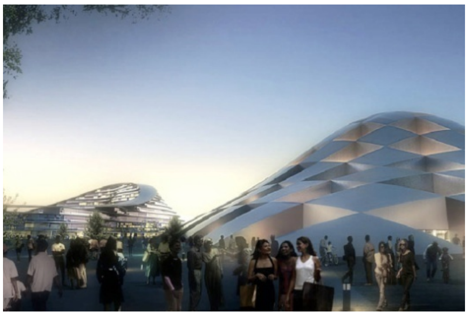
4. Vertical Farm design for Las Vegas

5. A large variety of crops can be cultivated in a so-called "sky farm"

Arcology

2030 is likely to be a key time for the upsurge in large mixed use “eco cities”, or Arcology (architecture + ecology) which aim to be at least self-sustained in terms of energy use. By 2030 we should expect that a handful of these will already be built and data will be available in order to demonstrate their levels of success.

Already, master plans exist for such developments. Zira Island in Azerbaijan (see main picture) is an offshore development on an island in the Caspian Sea in the Bay of Baku that is entirely independent of external energy resources. The 1,000,000m^2 resort and residential development consists of 7 large pyramids, which mimic 7 mountains in Azerbaijan. The island aims to be self-sustaining by using solar heat panels, photovoltaic cells, waste water and rain water collection and off shore wind turbines.



6. Zira Island Visualisation

MASDAR city in Abu Dhabi is another eco-city proposal and will be a car free and carbon neutral city, MASDAR city will become a centre for clean energy research and advance technology start-up businesses. The MASDAR headquarters will set the standard by becoming the world’s first energy positive mixed use building. That is that the building produces more energy than it uses (power stations are not deemed to be mixed use)

Structural engineers will need to familiarise themselves with the pyramidal form, which is prevalent in such master plans for large scale future developments.

Similar, more radical, schemes with pyramids that dwarf those in the Azerbaijan scheme have been mooted for Dubai and Tokyo, Such scale of structure will rely on technology that is in its infancy today. It is unlikely that the Zero Carbon Pyramid in Dubai or the, even more imaginative, Tokyo Shimizu Mega City will be realised in 20 years.

The scale of the 750,000 person Shimizu city in a pyramid vision is so vast that current materials technology cannot facilitate construction; however, the design aims to showcase what will be possible when technologies such as carbon nanotubes become commercially viable, something which is certainly attainable by 2030. Nanotubes will revolutionise engineering and will unlock new abilities for engineers with its lightweight and super strong molecular structure. Nanotubes potential is so great that it could render steel a historical building material for primary elements. Structural Engineers, especially those who are only just embarking on their careers, should pay explicit attention to this technology and the theory behind the material as it will, one day, revolutionise construction and enable structures to be built that previous generations of engineers would find hysterically impossible.

Construction Materials Production

Construction materials production is one of the worst offending industries in terms of greenhouse gas emissions in the world, concrete production being particularly guilty. Every ton of cement manufactured for the production of concrete creates approximately 1 ton of greenhouse gases. This equates to approximately 5-8% of the world’s total CO_2 human emissions. Within the next 20 years, Engineers can help to reduce this through adopting new concrete technologies that replace the traditional, carbon-belching, Portland cement. Current research of interest includes geopolymer concrete and eco-concrete made from combining pollutants with seawater.

7. Can one of the most vulnerable victims of human activity hold the key to low carbon cement? Scientist are attempting to emulate how corals produce marine cement

Geopolymers are an aluminosilicate material which has the potential to replace cement in order to minimise greenhouse gas emissions. Indeed, research at the Louisiana Technology University has demonstrated that fly-ash concrete has 90% less lifecycle greenhouse gas emissions when compared to ordinary Portland cement. The amount of acres used in which to dispose of industrial waste, where fly-ash originates, will also be reduced if fly ash is popularised. Geopolymers research is also aiming to identify processes where clay bricks and mortar can be reacted to form carbonates, which sequest carbon dioxide from the atmosphere.

8. Moss Landing Power Station, California. Where Celtra are running their pilot scheme

Calera are a small technology firm based in California. They have developed a carbon capture method of producing cement, which mimics that of coral producing marine cement by capturing the magnesium and calcium in seawater and using it to form carbonates at “normal” temperatures and pressures. Traditional Portland cement production requires heating limestone and other ingredients to temperatures in the region of 1500˚C. Calera’s method involves pumping pollutants through seawater at lower temperatures, whereby CO_2 that would otherwise be released into the atmosphere is reacted to form carbonic acid, which is readily turned into carbonates. Calera’s pilot scheme uses 370˚C gas flues from a natural gas power plant, which contain 30,000 parts CO_2 in 1,000,000. By bubbling the pollutant gas through seawater, over 90% of the CO2 can be used to make carbonates.

The potential for this method is great as other industries' waste gases contain much greater CO2 content (coal, for instance) and the reacted seawater, with the magnesium and calcium removed, is much more attractive to desalination plants. Eco cement of this nature can be used in a concrete mix on its own accord, or it can be used as a supplement in order to reduce the content of OPC. Research is still at an early stage, but promising results are being achieved. It is yet to be determined if enough marine cement can be produced to sustain the construction industry without the use of OPC, but the carbon capture of the pollutants is worth the research alone.

Conclusion

The challenge for structural engineers today is to anticipate what will happen in the future, in terms of how clients' requirements will change as they, in turn, react to global economic, political, social and technological changes and growth.

To be successful and well prepared for the future, engineers must have awareness of what is taking place in related fields such as materials science so that they can be on the cutting edge of their industry. Steel and concrete will not be the bread and butter of construction forever, huge sums of money are being invested into the benefits of composite materials and carbon nanotubes and while these may take years to appear we also need to address current issues before any saving grace arrives.

Engineers must ensure that our current infrastructure networks are robust. Only last year did we witness the effects that climate change can have on our bridges in the north of England, and how essential they are in proving post disaster aid. We should ensure that bridges and critical buildings such as hospitals are able to remain functional after a disaster, especially in developing countries where large population masses are concentrated in at risk areas where robust building practices do not exist. Climate change is thought to be responsible for a number of high profile natural disasters in recent years.

9. Bridge in Cumbria Decimated by Flooding

20 years is a small amount of time in construction, notwithstanding the time between project handover and the feasibility studies. In this sense, the structural engineer can start today by employing the simplest of feats: Curtailment.

All too often, structural engineers specify the steel required for maximum bending in (say) a concrete transfer beam, and apply it across its full length, rather than in zones of maximum bending. Utilising curtailment rules and designing reinforcement economically will save valuable resources and the energy used in which to manufacture and transport materials. The same applies for steel design where heavier than required sections appear on construction drawings Engineers should also strive to be involved with the design team early on so that the building can make use of nature, by providing atriums or thermal mass, and reduce reliance on M&E equipment. Even developing building strategies early on can design out the need for specialist equipment that is often prescribed as an afterthought.

For widespread revolutionary changes to occur, such as archological developments, zero carbon cities and rural farming being replaced by high rise vertical farms, years or research and developments in associated technologies are still required. Facilitating the construction of these challenging master plans will be at the forefront of structural engineering over the coming years. As technologies develop, we will witness the beginning and continual evolution of such schemes by traversing the learning curves that travel with the research. Certainly, increasing populations, urban growth and shortages in food, water and resources will drive changes to generic engineering design briefs. Engineers, therefore, must be fully prepared to deliver a good quality solution with the technology at their disposal.

References:
Fig 1 – Zira Island, Bjarke (Ingles Group)
Fig 2 –John Hancock Centre, Chicago. (Yahoo/flickr)
Fig 3 – Skyfarm (www.inhabit.com)
Fig 4 – Las Vegas Vertical Farm (Chris Jacobs)
Fig 5 –Chicago vertical farm- (Blake Kurasek)
Fig 6 – Zira Island, Bjarke (Ingles Group)
Fig 7 – Coral – (Yahoo/Flickr)
Fig 8 –Moss Landing Power Plant (DYNEGY)

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