Quality Means Durability and Not Strength Alone! *Smart Concrete*

By: *Dr Jackie Voo Yen Lei*

INTRODUCTION

CONCRETE, what is it? What was/is its role in the past, present and future? In general, the "non-engineering" personnel would understand concrete as one type of building materials that simply a mixture of cement, water and aggregate. The accuracy of this definition is neither right nor wrong, because for most under-developed and developing countries; like Malaysia, the understanding on the composition of concrete is nothing more than simply the mixture of cement, water and aggregate; whereas for developed countries, the understanding on the composition of concrete is far beyond merely these three components.

For less than a century, the evolution of concrete technology has gone through a drastic change after the Second World War. Modern concrete is becoming a very sophisticated composite as it constitutes the marriage of ground clinker and calcium sulphate (i.e. cement), mineral or amorphous products which have yet to penetrate into the local market; organic polymers, which were engineered using highly technical processes to accommodate specific tasks, and occasionally accompanied by discrete synthetic/organic/steel fibers to exhibit properties that are too ambitious to make dreams come true.

Let's refer to the CEMBUREAU to see what the statistics have got to say about the world cement production in the past, present and future. According to CEMBUREAU, the total world production of cement in the 1900 was about 10 million tonnes, whereas in 1998 the production was 1.6 billion tonnes and the latest reported figure showed 1.87 billion tonne of cement produced in 2003. It was predicted that the global cement consumption will increase to about 3 billion tonnes by 2020 (refer to Figure 1).

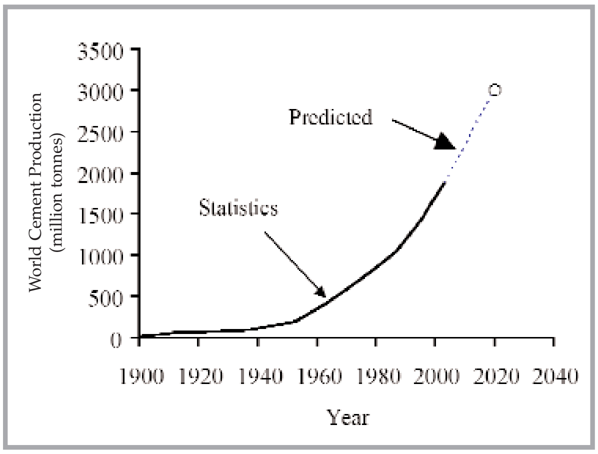

Figure 1 – World cement production, according to CEMBUREAU

It is evident that concrete has become the most widely used man-made material in the world, and it is second only to water as the world's most heavily consumed substances.

Sociologist have taught us that urbanisation will make a society wealthier and thus, directly raise the standard of living through the development of the city and consequently result in a great demand for infrastructures; and thus increase the consumption of cement-concrete.

So, with this drastic increase of cement-concrete production for the next few decades, should the Malaysia concrete industry stick to the 20-30 MPa scenarios, or should it evolve with the contemporary technology? Assuming the industry is willing to move with the times, the next question will be: is the current cement industry or concrete technology of Malaysia ready to face such trends and can the industry cope with the changes?

It must be kept in mind that the development of concrete will result in more choices of concrete in the "menu" with specific property, application and characteristic to cater to specific circumstances. Also, this drastic change will result in the recruitment of more specialised personnel, active input from professors/researchers of local universities, the import of knowledge and the re-evaluation of current design codes and construction methodology.

PAST & PRESENT

For a long time, the Malaysia concrete industry has produced so-called "*universal concrete*", which is good enough for universal circumstances and which compressive strength is usually between 20-30 MPa (which is locally known as grade 20 or grade 30).

Strictly speaking, the design of a concrete structure is done by experienced or qualified structural engineers. Unfortunately, very often, what the current structural engineers understand about concrete is the material's 28 days compressive strength and who know very little about the paramount importance of concrete durability. It has no doubt that the knowledge of 28 days compressive strength of a concrete is the fundamental parameter to demonstrate a calculation that will allow the construction of a structure that is safe, but, the issue on whether the concrete will keep its mechanical properties during the whole designed life span remains lack of proper justification.

For instance, many examples show that concrete which have a sufficient 28 days compressive strength loses most of their functionality due to the structures facing environmental agitation that has not been adequately conceived in the design.

The use of concrete of a higher strength (40-50 MPa) began to be specified for columns in high rise building. This type of concrete was first known as the high strength concrete (HSC) during the 1950's. Over the years, the name of these high strength concrete has been changed to high performance concrete (HPC) because these concretes have more characteristics than simply as a high strength cementitious composite.

In general, high performance concrete is when the well-known "*universal concrete*" is upgraded with additional supplements such as the more commonly used fly ash and superplasticiser. Besides in the enhancement of its megapascal, HPC has a much lower porosity and consequently makes it a more durable material that perform better under extreme conditions such as aggressive environments and chemical attacks.

HPC is becoming more popular, especially in the field of high rise building, off-shore structure, oil platform, bridge and precast industry. In 1998, the highest building in the world is a concrete high rise building built in Malaysia – the Petronas Towers, which uses HPC that has a compressive strength of 60 MPa. Other examples where HPC has been actively used is in precast line manufacturing, such as Hume Industries (M) Berhad and OKA Concrete Industries Sdn. Bhd.

It has been realised very recently that HPC is more ecologically friendly than "universal concrete" because the HPC can support a given structural load with less cement. Moreover the life cycle of HPC is estimated to be two to three times higher than that of usual concrete.

In Malaysia, the acceptance of HPC is nevertheless relatively slow, but it is progressing steadily and it will continue to progress because personally, I think it is about time for the designers and developers to receive a wake up call, to acknowledge that the value added concrete is not merely in its serviceable long-life, but also its socio-economic sustainability. Quality means durable, not just strength alone!

FUTURE

For decades, concrete is the fruit of a simple technology; and today it is mastered by the essence of "pure science". The emergence of scanning electron microscope (SEM) and other advanced instrumentation have progressively improved the philosophy of concrete microstructure behaviour up to the nano-scale. As the industry moves into the era of computing technology and incorporating the essence of complex laws of physics, chemistry and thermodynamics; it will result in a rapid progression in the science of admixture, particularly for concrete and optimisation on the rheology of binders. No more guess work! No more trial and error!

The binders of tomorrow will contain less and less conventional ground clinker and will feature increasingly complicated mineral products with the aim to make more durable concrete rather than simply megapascal gainer. Some of the most widely used binders are fly ash, blast furnace slag and silica fume. Today, fly ash is a relatively common material that can be obtained from many local suppliers whereas silica fumes are still in it's infant stage.

Interesting development on chemical admixture of tomorrow will be more and more specific in its application. Today, concrete admixture: superplasticiser, air entrainer agents, anti wash-out admixtures, waterproofing material, etc, have become the most important recipe to make stronger and more durable concrete. For instance, some promising superplasticisers are able to maintain slump levels for at least 1-2 hours and gives a minimum slump of 200 mm. Another example is concrete with water/binder ratios as low as 0.12, which can be achieved without deteriorating its workability.

According to Professor P. C. Aïtcin (2000), who is one of the earlier researchers in the development of ultra high-performance concrete: the concrete of the future will be ecologically sound, and it will increasingly embrace greener environmental philosophies. He stated that contractors and designers must understand that the modern concrete will have lower water/binder ratio and more durability is needed. Contractors and designers have to realise that what matters is not the cost of 1 m^3 of concrete but rather the cost of 1 MPa or 1 year of life cycle of a structure. Once this concept is understood, the construction industry will start to move forward.

In the mid 1990's, French researchers, Richard and Cheyrezy (1994, 1995) developed an ultra-high strength high-performance concrete known as reactive powder concrete (RPC) which has a compressive strength over 200 MPa. When this concrete is confined in a thin-walled stainless steel tube, the triaxial effect will augment the concrete to reach a compressive strength of up to 375 MPa. By replacing the sand with fine metallic powder, the compressive strength increases to 800 MPa, which is stronger than BHP-Billiton structural steel.

The fiber reinforced RPC is a unique material (some people termed it as the *smart concrete*) with possibilities for use in a wide range of structural and non-structural applications due to its superior strength, high durability and enhanced ductility. Enormous benefits have been reported for the application of RPC, such as the fiber reinforced RPC used in the prestressed girders without any conventional stirrup in the web regions which serves as highway traffic-bridges or pedestrian bridges (Voo, 2004). The beauty of this technology is a smaller, lighter and improved durable member. In terms of construction and management effort, the construction time and labour costs may also be decreased significantly.

When RPC was first announced in the mid 1990's during the construction of the world's first RPC structure, the Sherbrooke pedestrian bridge in Canada, the cost of 1 m^3 of RPC shocked many engineers who still compares to the cost of 1 m^3 of the universal concrete and HPC. 1 m^3 of RPC was approximately RM 3,500, which is at least 20 times more expensive than conventional concrete. The continuation on the development and optimisation of RPC has made it currently possible to produce similar kinds of RPC at a cost of RM 1,500 and I believe in the near future similar types of RPC can be produced for RM 1,000-1,200. In some applications when durability and compressive strength are key factors, reactive powder concrete can compete with structural steel that cost over RM20,000/m^3.

To date, many landmarks have been mounted world-wide using this newly developed technology, such as the Sherbrooke Footbridge in Canada (1997), Cattenom Cooling Tower in France (1998), Seonyu Footbridge in South Korea (2002), Sakata Mirai Footbridge in Japan (2002), Shawnessy Light Rail Train Station in Canada (2003), Yamagata Footbridge in Japan (2004), Shepherds Gully Creek Bridge in Australia (2004) and Bridge of Futur in USA (2005).

Although many past and on-going studies, conferences and workshops have been conducted internationally, and yet, the demand of RPC as durable building material has yet to be established in Malaysia.

The implication of RPC is to provide more architectural opportunity and innovative space to future engineers, architects and even builders in the industry. Very often, structural designers are limited by the Codes on what "*universal concrete*" can and cannot do. The versatility of RPC provide the modern architects with nearly infinite potential to create structures with perfect finishes, or even unlimited complex shapes that are light without sacrificing its durability and ductility. Perhaps, it's time to think outside the square!

I believe that the critical barriers which prevent the rapid introduction of these *smart concretes* into the Malaysian market are the lack of enabling technologies or stakeholders to support the cost-effective commercial production, industry liabilities and institutional barrier.

CONCLUSION

Sooner or later the designers of tomorrow's concrete will realise that the design and placement of concrete cannot depend solely on material strength alone. Instead, the concept of "durability" should be the key factor for the success of sustainable development. I feel that if local experts are able to find some semi-industrial applications which makes RPC more competitive, it will lead to more affordable contracts implementing this type of promising material in the concrete technology of tomorrow. By all means, the evolution of tomorrow's concrete technology should proceed forward with the objective to provide a greener and ecologically sound environment for our future generations. ■

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