Admixtures for Tall Structures

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Tall buildings or skyscrapers are constructed for several reasons. One reason being the creation of a status symbol, for example, the Burj Khalifa, the world’s tallest building which was constructed to symbolize Dubai as a world city. Other more obvious reasons for the presence of such structures would be part and parcel in the construction of central business districts in cities and also urbanization of populations. Urbanization is taking place at a faster rate in India than most places in the world. Urbanization in India was mainly caused after independence, due to adoption of a mixed system of economy by the country which gave rise to the development of private sector. Population residing in urban areas in India, according to 1901 census was 11.4%. This count increased to 28.53% according to 2001 census, and crossing 30% as per 2011 census, standing at 31.16%. According to a survey by UN State of the World Population report in 2007, by 2030, 40.76% of country’s population is expected to reside in urban areas. As per World Bank, India, along with China, Indonesia, Nigeria and the United States, will lead the world’s urban population surge by 2050.

Mumbai saw large-scale rural-urban migration in the 21st century. Mumbai accommodates 12.5 million people, and is the largest metropolis by population in India, followed by Delhi with 11 million inhabitants. Witnessing the fastest rate of urbanization in the world, as per 2011 census, Delhi’s population rose by 4.1%, Mumbai’s by 3.1% and Kolkata’s by 2% as per 2011 census compared to 2001 census. Estimated population, at the current rate of growth, by year 2015 of Mumbai stands at 25 million, Delhi and Kolkata at 16 million each, Bangalore and Hyderabad at 10 million.

Hence with urbanization increasing at such a fast pace, especially so in a developing economy such as India, pressure on available land. This answers why construction companies in India are looking vertical space, kick-starting the trend of high-rise buildings dotting the country scape.

Builders and architects are concentrating on building skyscrapers primarily because they are convenient. It allows them to create a lot of real estate on a relatively small ground area. Until the 1900’s, the world of tall buildings was dominated by the North American continent and the United States in particular. In 1990, 80% of the world’s tallest 100 buildings were located in North America. Two decades later, these numbers have fallen to 35%. This trend is the result of a dramatic and continuing increase in tall building construction in both Asia and the Middle East. The construction of the Petronas Twin Towers in Kuala Lumpur built to a height of 452 m, Taipei 101 standing at 508 m and now the Burj Khalifa in Dubai at 828 m which stands 773 metres higher, or 15 times taller, than the world’s first “tall building”, the Home Insurance Building completed in Chicago in 1885, are a testimony to this fact.

There’s been an increasing trend toward construction of structural concrete super-tall buildings for several good reasons discussed in the following section of the paper. Whilst using such concretes, one needs to pay greater attention not only to aspects such as the mix design but also to its performance with respect to handling, pumping, placing, finishing and curing.

Structural Material

For many years, steel was the material of choice for the tall building, a fact displayed in the first 12 world’s tallest buildings. Currently, composite, concrete and mixed-structure construction is much more prevalent in tall structures. Only 24% of the world’s current 100 tallest structures contain a purely steel structural system, down from 57% in 1990.

Reinforced concrete provides twice the dampening effect compared to steel, reducing forces on super-tall buildings due to wind and the cost of construction. Concrete buildings are quiet and structural concrete is naturally fire resistant. Modern formwork systems for horizontal and vertical castings greatly increase productivity and improvements in concrete pumping equipment and techniques, make easy and fast delivery of concrete possible.

Advancements in concrete technology because of newly developed materials such as chemical admixtures have assisted in improving the properties of concrete, including strength and modulus of elasticity (E) making high-rise construction more attractive. Self-Compacting Concrete is increasing in use too, mainly due to the utilization of admixtures classified as Viscosity Modifying Agents (VMA) and Viscosity Enhancing Agents (VEA) and the availability of more economical fines or fillers.
Chemical Admixtures

Super-tall construction requires that the concrete to be economical and yet deliver high performance characteristics. High performance characteristics being properties such as high strength, low water/binder ratio, flowable for extended periods at ambient temperatures fluctuations from say 10 deg. C to 50 deg. C and most of all, pumpable to heights in excess of 600 m.

To meet these challenges posed by various stakeholders including engineers, contractors and ready mixed concrete producers for the construction of such super-tall structures, BASF embarked on an intensive R&D project. The aim of the project was obviously to develop & deliver products capable of meeting the demands and needs necessary for the manufacture of such high performance concrete even in harsh environments. The R&D work resulted in an innovative concept being developed. This new concept is termed Total Performance Control (TPC). TPC concept ensures that the stakeholders achieve a concrete that is of the same high quality as originally specified; starting from production at the batching plant, to the delivery and application into place and followed by its hardening process. TPC is the state-of-the art technology that provides improved short and long term performances of concrete by controlling the two distinct features essential for high-quality concrete: extended workability and low water/binder ratio. These features are the key to the success of such an admixture system.

The key element of the Total Performance Control is the Glenium SKY superplasticiser. Glenium SKY is an innovative superplasticiser based on second-generation polycarboxylate ether (PCE) polymers. It is derived directly from the TCP concept and is specially engineered to provide high water reduction and slump retention for ready mix concrete simultaneously. As compared with other PCE superplasticisers, it is possible to obtain a high quality concrete mix with accelerated strength development and extended workability without delayed setting characteristics. Glenium SKY is made using nanotechnology. A nanometer is a millionth of a millimeter – the dimension of molecules and polymeric chains. In-house expertise in nanotechnology allows BASF to control the chemical and physical behavior of polymers and their interactions with cement by augmenting chain length, side chain length and density, and electrical charges as well as free functional groups. For the first time, nanotechnology allows local requirements and conditions to be better met.

Self-Compacting Concrete produced using the TPC concept provides a concrete mix with exceptional placing characteristics, accelerated cement hydration for high early strength development and quality concrete. The addition of a Viscosity Modifying Agent (VMA) to Self-Compacting Concrete with Glenium SKY superplasticiser enhances the robustness of the mix by providing excellent cohesion and anti-segregation properties. Robustness of a mix is desirable, especially when such mixes are expected to perform under high pump pressures and also flow for long horizontal distances and remain stable when dropped from heights into structural members such as columns and beams.

Mechanism of Action

The dispersion effect of superplasticisers is based on the adsorption of molecules on cement particles, imparting a negative charge that causes electrostatic repulsion and steric hindrance between them and, therefore dispersion. The hydration, and particularly the ettringite formation, works against the superplasticiser. Already adsorbed molecules are covered by the ettringite lawn, thus are ineffective. The particular configuration of the Glenium SKY molecules allows its delayed adsorption onto the cement particles and disperses them efficiently over a long period of time.

The molecular structure is essential for the early development of strength. With superplasticisers based on conventional polycarboxylate ether, the molecules cover the entire surface of the cement grain and build a barrier against contact with water. Therefore, the hydration process takes place slowly. The Glenium SKY molecules, on the other hand, leave sufficient room on the cement surface to allow a rapid hydration reaction, resulting in high early strength development.

A schematic representation of the mechanism of action of a normal PCE superplasticiser versus Glenium SKY is given below.

Application

Burj Dubai, called Burj Khalifa since its opening, is the tallest building in the world by a large margin. Concrete admixtures from BASF have made a substantial contribution to its construction. The world’s tallest construction, reaching up 828 metres into the Dubai sky with the number of floors reported at 189, was opened on 4 January, 2010. Both, the second largest construction, the 610-metre Canton TV Tower in Guangzhou, China, and the second largest “house”, the 509-metre Taipei Financial Center in Taiwan, pale in comparison with these
80MPa – which is roughly equal to the pressure the total weight of a small car would exert on a big toe. The high strength also provides the concrete structure with a long service life and ensures the sustainable usage of the building.

Conclusion

Concrete with specialized & tailored admixture systems utilizing nanotechnology & unique polymer science can deliver the following benefits to stakeholders of tall structures:
- Ensuring a constant high-quality concrete even at a low water/binder ratio
- Providing concrete with extended workability at high temperatures, without delayed strength development
- Guaranteeing a concrete that meets the original specification from the fresh to the hardened stage
- Offering a single, versatile admixture system for many types of applications and conditions

References

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