Setting up standards for high-rise construction

"Dr. Joseph Colaco epitomises both structural engineering excellence and creative collaborative effort between architect and engineer. His design innovations improved the construction of high-rise buildings, enabling them to withstand enormous forces generated on these super structures. These new designs opened an economic door for contractors, engineers, architects, and investors, providing vast amounts of real estate space on minimal plots of land. He is noted for his contributions to the designs for some of the multi-million dollar projects in the United States, Middle East and India including Chicago's 100-storey John Hancock Center, 75-storey JPMorgan Chase Tower in Houston, 169-storey Burj Khalifa Tower in Dubai (present tallest tower in the world) and The Imperial Twin Towers, Tardeo, Mumbai, India." – wikipedia.com

Here he discusses his life and work with ICJ. Excerpts:

ICJ: Dr. Colaco, give us some idea about your Mumbai background and your career's beginning as a concrete technology expert.

Dr. Colaco: I was born and raised in Byculla, Mumbai. My father was a professor at the St. Xavier's College. I went to VJTI and finished my civil engineering from the University of Mumbai. I then went to work for Shalimar Tar Products (STP) and helped them build what must have been India's first precast concrete product's factory in Bhandup, Mumbai. This was in the early 60's when not many had heard of precasting. We were tendering projects in precast. But giving in to my yearning for knowledge and the desire to learn more about precast pre-stressed concrete I kind of fell in love with concrete, and decided to go to the United States of America to pursue higher studies. I applied to different schools, got acceptance from the MIT and Stanford, but decided to join the University of Illinois because they offered me a scholarship. My father was a professor so he couldn't afford to send me abroad to a school without a scholarship.

ICJ: How was your experience at the University of Illinois?

Dr. Colaco: While completing my Masters degree in Civil engineering, I quickly found out that the Illinois was the number one university in the United States for concrete research; back in the 60's the notable work being carried out at Illinois were for reinforced concrete, and pre-stressed concrete including flat slab design. My advisor Professor Chester Paul Siess was the President of American Concrete Institute (ACI). I spent four years working with him and did my PhD under him. Working in the lab, I used to mix my own concrete, test my own samples, put all the strain gauges with my own hands. till the middle of the night. I was doing tests on the reinforced concrete joints (with column rebar splices) under high rotations to simulate movement under seismic load.

ICJ: How did you get your first major high-rise building project?

Dr. Colaco: I was two months from finishing my PhD in 1965 and was discussing my work with my advisor Professor Siess in his office when one of his past students, (ten years senior to me) called Professor Siess. On the phone was Dr. Fazlur Rahman Khan who was going to design a 100-storey tall steel building in Chicago and he was looking for an engineer to help him. When Professor Siess recommended me for the job, Dr. Khan almost declined to accept me saying that he was not looking for a concrete engineer but a steel expert. Knowing that Dr. Khan himself had done his PhD on pre-stressed concrete, it didn't take long for Professor Siess to convince Dr. Khan to hire me.

Soon after meeting Dr. Fazlur Rahman Khan, I found out that he was a genius. Dr. Khan was from Bangaladesh. All the major developments of high-rise for about twenty years were done by him.

ICJ: And then many projects followed?

Dr. Colaco: So when we finished that 100-storey tall John Hancock Center builiding in Chicago, Dr. Khan and I moved on to work on a 50 storey building in Houston called One Shell Plaza which at that time was the tallest reinforced concrete structure in the world. However, due to Houston's poor soil conditions, One Shell Plaza's foundations would be able to support only a 35-storey normal weight concrete building. To give the Shell Oil Company the tallest building possible, we decided instead to use lightweight concrete, weighing only 115 pounds/cft. This enabled the owners to build a 50-storey structure with the weight of a 35-storey one – approximately 40% more office space. It is the first all-lightweight concrete building and one of the first tube-in-tube structures ever built. At 230 m tall, it is the tallest light weight concrete building in the world. Since I majored with a concrete background, Dr. Khan put me in-charge and we got involved in everything you can think of in lightweight concrete. First of all, we had to have high strength concrete. For columns, the normal strength concrete used to be equivalent of M40. He wanted to get M60. So how to get lightweight concrete to give M60? So we did all that. We also wanted to control the modulus of elasticity, so we had modulus of elasticity tests. Shrinkage and creep tests were also carried out. Houston's soil consists of mostly sand, silt, pre-consolidated, and clay. This composition swells, shrinks, and is sensitive to variable displacements when heavy loads are applied. Tall buildings constructed directly on this soil would experience noticeable settlement. To solve this problem, we utilised a raft foundation 2.4 m thick. In those days the raft foundation was scarcely heard of in the USA. It took a total six months to do mix designs and testing and to get data for lightweight concrete. We developed a lot of the original research on lightweight concrete that today is the bible for designing lightweight concrete. That project set up the standards for such constructions.

ICJ: Wasn't that period one of the most professionally satisfying periods of your life?

Dr. Colaco: Yes, it was. Houston was a 'concrete' town. So we did a lot of major work in concrete and I started dabbling with concrete and how to build better, faster and more economically with concrete, drawing on some of my own Indian experiences. For example, in America, flat beam construction was common. The beams and joists were kept at the same depth. However, the forces or moments and shears are the highest at the columns and less in the middle so we came up with the idea of a haunched girder system. We used that in high rise buildings making construction economical. Then, we started playing with the flat-slab and came up with tapered drop panel system. And then we did two-way banded pre-stressed post-tensioned, flat slabs. We did a lot of innovative work on concrete to make building construction more economical.

ICJ: When did high strength concrete tall building happen?

Dr. Colaco: In the 80s, we gradually started migrating to high strength concrete. We kept on going to higher concrete strengths. To date, we have done arguably the tallest concrete building in the United States. It is a 300-m tall building in Chicago. It is called Two Prudential Plaza. It has fairly high strength concrete equivalent of about M80 concrete. We had tests on modulus of elasticity and thermal analysis of exposed concrete, and shrinkage and creep analyses that were done by my colleagues.

Dr. Khan started the shrinkage/creep analysis with an engineer named Mark Fintel (from the Portland Cement Association) and then my colleague Srinivasa 'Hal' Iyengar did the follow-up. They and I have defined how to design tall buildings for shrinkage and creep. All the basic advances in concrete for tall buildings design came out of University of Illinois; that's where I went to school working under Professor Siess. Dr. Fazlur Rahman Khan, Srinivasa 'Hal' Iyengar's and I made a lot of advances between 1960 and 1985 . If you look at all the design standards that are being used today, they all came from the work during those twenty five years.

ICJ: When did you become active again in India?

Dr. Colaco: In the mid 90's I started getting involved again in Mumbai. The first work was the Imperial Towers at Tardeo. Before that I was involved in the Burj Khalifa 800-m tall in Dubai. We did the peer review and value engineering of that project. After Imperial Towers several tall building projects started and since then I have been doing tall buildings in India.

ICJ : How was your initial experience working with Indian project owners?

Dr. Colaco: I will tell you a funny anecdote. I wouldn't tell you the project owner's name though. An Architect from Mumbai wanted me to help him with a 40-storey building project. So he told the project owner that he

knows a good engineer and his name is Joe Colaco. Since my name did not sound familiar to this Owner, he thought the architect was trying to get a white man for the project. So he told the architect "No...no.. no we don't want a 'Gora' (meaning a white man) . When the architect explained that I am not a 'Gora', the Owner looked at me in disbelief and asked me about my background. When he came to know that I was born and brought up in Byculla, Mumbai with an ancestry from Goa, the matter got settled. But the manner and spontaneity of the conversation in Hindi was so funny that I cannot help but recall it as my "gora" moment.

ICJ: How is the market for tall buildings?

Dr. Colaco: The market for tall buildings in America is very slow. Tall building constructions right now are in China the most, India is probably the second and Saudi Arabia is the third. In India, several projects in important cities are making the country a "happening" place. For example, we are involved in over 20 buildings in Mumbai. We are working on the tallest building in Kolkata right now on Chowringhee Road, four or five projects in Bangalore, six projects in Kochi , four projects in Gurgaon a suburb of Delhi including the tallest building in Gurgaon.

"In America we do one storey in four or five days and here in India it takes two or three weeks"

ICJ: And you coordinate all that from Texas?

Dr. Colaco: We have an office here in Vadodara with 40 people working there and we have a bigger office in Texas. I keep going back and forth.

ICJ: What scope of work do you accept for your involvement?

Dr. Colaco: I am a structural engineer by training and experience. But what happened when I was getting involved in the Imperial Towers, Tardeo contract with a well known construction contractors, was that the architect contacted me to find out how a building can be built faster. In America we do one storey in four or five days and here in India it takes two or three weeks. So these people said "tell us about it". So the contractor wanted to know about new construction techniques. So we started by telling them about new shuttering systems. In those days Mivan, Meva, Doka and Peri were just heard of. We were already using Mivan and Doka in those days. I talked to them about pumping of concrete, placement booms and these sorts of things. They hadn't used any of these systems. They had read about these developments in magazines. So they started expanding my scope. Instead of just helping with the structure, they expanded my scope to include should I say concrete technology. I think that is the best way to describe it. So we started talking about high strength concrete, pumping of concrete etc. in addition to peer-review and value engineering.

ICJ: You are delivering a talk at the CTBUH Conference, Shanghai, China next month. What are you presenting there?

Dr. Colaco: I am presenting the Palais Royale project of Mumbai, since it has the most up-to-date concrete technology. The Owner had his own lab on site. We did all our tests right here. We actually made M90 concrete. We designed using M80 on this one, but we made M90 just to check. We did temperature checks on concrete, did strength tests on reinforcing and on concrete cubes and so on. So there has been a lot of good testing and that and the engineering is what we are going to talk about in Shanghai. Our presentation (Mr. Girish Dravid and me) will show how to develop quality control systems for high rise concrete buildings underlining the point that even emerging economies like India can use advances in concrete design and construction. So it's an interesting challenge. One of the things you ought to know is that earlier there used to be an interesting division of construction technique. There was a feeling that once you got above forty floors you needed to change from concrete to steel construction for a lot of reasons; steel was faster, it was light in weight, columns were smaller and so on and so forth. Thanks to people like Dr . Khan and little bit to myself, we started pushing concrete technology a little bit higher using higher strength concrete. By introducing new shuttering systems or slip forming cores or jump forming cores, using Mivan or Meva and pumping concrete, we have overcome that height barrier. Now with 800-m tall Burj Khalifa, there is no question of steel being the only option.

ICJ : Concrete tall buildings are economical. Is it a myth or a reality?

Dr. Colaco: I will tell you one anecdote to answer this question. I was doing a forty-six storey building in New York City. It's called One Park Avenue and on the first

day I walked into a meeting and the contractor said, "Dr. Colaco, you are from Texas. Here in New York, we build only in steel." In America there is a split; you come to the south you get more concrete and you go to the north you get more steel. So we designed the entire building in steel and we were about 75% of the way through the design, when I got a phone call from the Owner. This was his first major job. He said, "Dr. Colaco, I don't know what's going on but you need to come to New York immediately, drop everything else." It was a Sunday. So I got on a plane and went to New York. I went to his home and met at his kitchen table. He said "there is a concrete sub-contractor who walked into my office on Friday and said that he will build the project faster if I did it in concrete and will give me $2 million back." The owner was asking me if this was believable. I am a very cautious fellow when it comes to money, because I was born poor. So I said "why don't we test it. I will do a preliminary design in concrete establish the sizes, quantities and all that. Then you tell him to sign a contract giving completion time and savings." He agreed and the sub-contractor signed. The Owner took all of the steel drawings and threw them in the garbage. We started all over again in concrete. That concrete sub-contractor was building one floor in two half days right through the New York winter. Each floor measured 2200 sq m. And when he finished he gave the owner $2 million. The advances in speed and strength of concrete have progressed much faster than the advances in steel. Now the limit of 40 storeys is no longer there. People are building taller and taller and when the 800-m tall Burj Khalifa is almost all concrete. Every tall office building that has been done since 1995, except for the Burj Khalifa has been 'composite', means steel and concrete used together for the vertical elements. There are no pure steel buildings that tall anyway. That's how fast the concrete builds. So it is very heart warming. The quality control is getting much better. We finished a 75-storey/300-m. tall building in Houston with 19 m. excavation. It is called the J. P. Morgan Chase or Texas Commerce Plaza using high strength concrete composite construction in 29 months.

ICJ: Is constructing with concrete difficult? Can someone who has never done a tall building before do a good job?

Dr. Colaco: The world famous architect in New York Architect I. M Pei who has done substantial buildings all around the world called me one day and said that he wanted my help with a project he was doing in Singapore (right next to an old colonial hotel called Raffles), they were going to do a sixty-storey tall building. They had signed a contract with a Korean contractor called Sanyongg to do the building. Since I had worked on these advances in concrete tall building, Mr. Pei wanted me to instruct Sanyongg engineers on how to do a tall building in concrete. They had never done a tall concrete building construction before. So we had about twelve Koreans in my office with video cameras and all that. Incidentally I am also a Professor at the University of Houston. So I started on the board and drawing diagrams with cameras rolling. When I finished, they thanked me and they left. Six months later I was in Singapore. I called the I. M. Pei Architect wanting to take a look at their project. It was the best concrete I had ever seen in my life. They had put 'super-plasticizer' or high water reducing agents in the mix. You couldn't find even a blow-hole, the concrete was as smooth as you could get. I called the architect again to tell him not to cover the concrete because of the excellent surface. It did not happen as the Owner had his own commercial reason to cover the concrete with marble This was a 60-storey building done in Singapore in the 1980's and was one of finest jobs. The information technology today is sending information around the world with lightning speed. Any advancement made anywhere in the world spreads quickly and within a few years everybody else knows. It ensures that concrete knowledge flows to the whole industry all around the world, which is very heart warming.

■