PRACTICE

The Challenges of Running a Structural Engineering Practice

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Ms. Sheth is a Member of Bureau of Indian Standards (BIS) Committee for Earthquake Codes (CED 39), BIS Committee for Special Structures (CED 38) and Cyclone Resistant Structures Sectional Committee (CED 57). She is Principal Author and Co-ordinator for BIS Sub-Committee for Drafting of Tall Buildings Code for India for (BIS) Special Structures Sectional Committee (CED 38). She has been on numerous World Bank post-disaster reconnaissance teams, including for the Great West Japan earthquake, Great Sumatra earthquake amongst others.

In the present essay, Alpa Sheth brings out her rich experience of engineering practice and deep involvement with teaching of Structures to the students of architecture and civil engineering in various capacities to provide unique insights on the state of structural engineering education and practice in India and how that impacts not just the relationship between architects and engineers but the production of buildings itself.

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Is an Engineer Just a Technician?

A well known architect while bargaining with his structural engineer on his quoted fees is rumoured to have impatiently said to him, "Look, I don't know what this fuss is all about. I've placed all the columns and beams and sized them too; all you have to do is put reinforcement bars in them." That pretty much summarizes the relationship of the architect-engineer, especially in India, over the past few decades. An engineer is often (mis)taken as a technician or he is constantly treated as such until one day he begins to believe he is indeed one and slowly ceases to apply himself innovatively on a project. His attitude is that of abject surrender and servitude, taking the path of least resistance. He feels increasingly trapped in a dry, insipid profession which offers neither the thrills of ingenuity nor the moolah to bribe your creative conscience into silence.

It wasn't always so. One can recount examples of outstanding engineers who dared to experiment, make mistakes and tell the world about their mistakes and how they went about rectifying them. An immediate example that comes to mind-is that of the Millennium Bridge. Before it was inaugurated in the year 2000, the bridge was the subject of much acclamatory discussion due to its sleekness and unique form. The media could not write enough about the greatness of its architect Norman Foster and his other stellar works. No one knew who the structural engineer was. However, after the footbridge was opened to pedestrian traffic, it began vibrating alarmingly. The architect washed his hands off the bridge, shrugging it off as the responsibility of the structural engineering consultant, Arup. The little known tailpiece is that not only did Arup study this very odd resonance induced vibration, they fixed it at their own cost! (Which went into millions of pounds).

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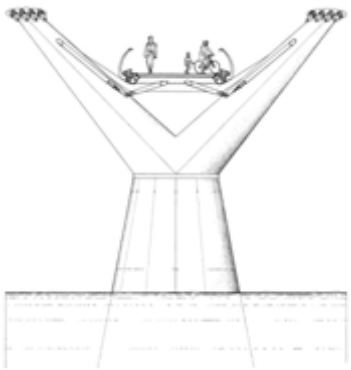
Another example is that of Le Messurier and the tale of the Citicorp Center building in New York. An engineering student questioned Le Messurier on his design which got him thinking and he realized that the joints were indeed not strong enough for a particular wind load condition. This design flaw, if discovered, could have caused him expensive litigation, professional disgrace and possible bankruptcy. On the other hand there was little chance that anyone would ever find out about the design flaw if the extreme wind load condition did not ever happen in the life span of the building (it hasn't, until date). At one time, Le Messurier is said to have even contemplated suicide but better sense prevailed and he confided with the architect; they opened up to the client and came up with a rectification plan to strengthen all 200 of the bolted joints in the building by welding plates onto them. His honesty was much appreciated and while the retrofit cost the client $ 8 million, Le Messurier contributed just 2 million dollars that was his insurance cover.

Both the above examples are illustrative of the fact that engineering is indeed not a "technician's" job. There are ways that a structure could behave which are not easily apparent - and that makes engineering an exciting journey of discovery. A lesser architect



The Millennium Bridge, London- the only pedestrian bridge in the city, structural design by Arup.
[Sources: https://commons.wikimedia.org/wiki/File:London_Millennium_Bridge2.jpg,
http://www.fosterandpartners.com/projects/millennium-bridge/]

than Hugh Stubbins, Jr. (architect of Citicorp Center) would have shown no interest in understanding the problem and would have asked the structural engineer to shut up and sit tight than confess to the client and risk litigation and loss of face.

I remember a case of a mall in Ahmedabad that our office was peer reviewing[1] on Jan 24, 2001. I told the structural engineer that he hadn't designed and detailed for earthquakes and the building could suffer significant damage in a seismic event at which he guffawed loudly. "Whoever has heard of designing buildings for earthquakes in Ahmedabad? There's never been an earthquake in Ahmedabad". The architect agreed with him. And then the Bhuj earthquake happened four days later on 26th January causing cracks developed in exactly the same places as we had predicted. But at least the building survived. 130 other buildings collapsed in the earthquake with epicenter over 200 km away. Not a single structural designer was punished. The only engineers that went to jail were from the Ahmedabad Municipal Corporation. A very well-known architect of Ahmedabad went so far as to tell me that 130 building collapses in the city did not even add up to a collapse rate of 0.1% and it was a conspiracy to show Gujarat in bad light by highlighting the collapsed structures rather than celebrating that 99.9% buildings survived. More than 800 people dead were just statistics or collateral damage.

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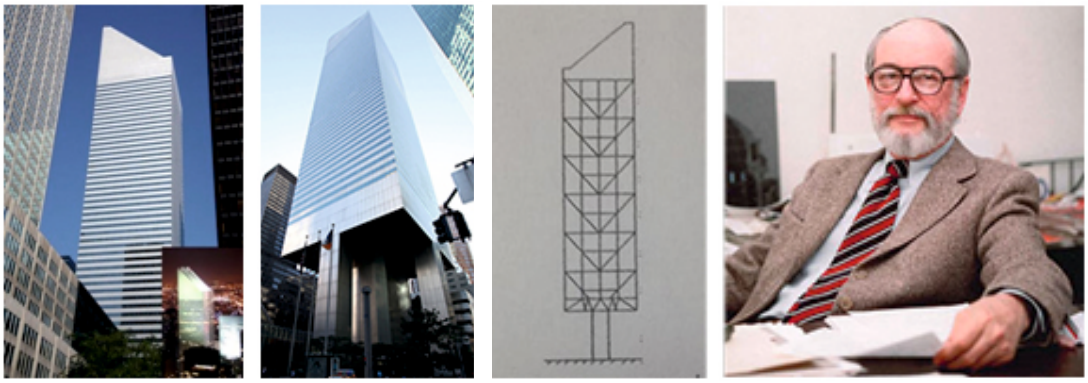
Reluctance in Engaging a Good Engineer

To understand the complex relationship of architects and engineers in India (I must confess it is only a tad better elsewhere), one needs to dwell deeper into the Indian psyche. Indians are gamblers by nature. Despite over 120,000 fatalities in road accidents across the country, it is still not possible to get drivers of two wheelers to wear a helmet or of four wheelers to tie a seat belt. Accidents happen to



The Citicorp Centre at New York City (1970), schematic structural frame and its structural engineer William Le Messurier.
[Source: http://therealdeal.com/2014/04/17/how-student-saved-citicorp-center-from-potential-collapse/]

other people. There is no perception of risk. Likewise, architects do not see merit in getting buildings designed from a good structural engineer who has the skill set and would be investing adequate resources when a building designed by a poor structural engineer charging one third the fees (and thus investing matching resources) appears to stand up just as well. The undisputable fact is - not too many unstable or unsafe buildings collapse.

Engineers and Architects Learn Differently

Increasingly, structures courses are dumbed down in architecture schools across the world. The few exceptions are those architecture programmes which are housed in engineering-centric institutes such as IITs and NITs (in India). As a result, the discerning skills of an architect to judge a good structural engineer from a bad are not well developed and it is only when things go horribly wrong that they scurry for trouble-shooting to a more able engineer. At other times, the best structural engineer is the cheapest and most pliable one.

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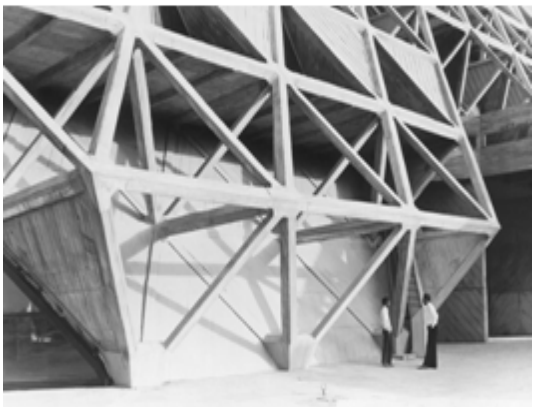
A young woman engineer at my office lamented the difference in teaching methods in architecture and engineering colleges. She graduated giving just one presentation in the first year and one during her final year. She was never required to open her mouth otherwise. Most of her classmates entered engineering college without the ability to string a sentence in English. So do some architecture students. The difference is that engineering students graduate with a degree still unable to form an English sentence. The architecture student on the other hand, having been subject to all kinds of stress tests where she is made to explain and defend her work- during juries, presentations, projects and so on, comes out quite an articulate and confident professional.



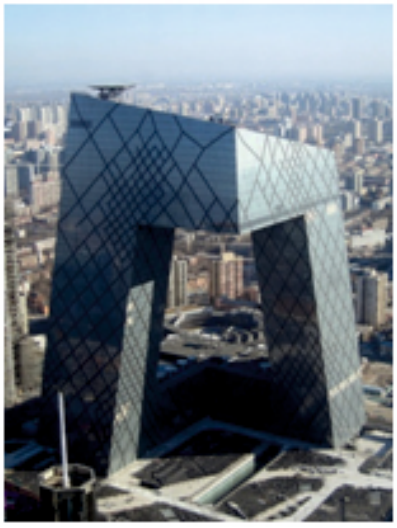
The Hall of Nations at Pragati Maidan, Delhi (1972)- a space frame in reinforced concrete with a clear span of 78m, structural design by Mahendra Raj.
[Source: http://www.mrc.co.in/sd_2.html]

For a long time, Asperger's Syndrome (a mild form of autism where people have difficulty responding to the body language, facial expressions, and tone of voice of others) was called 'The Engineer's Disease'. Engineering is a vocation which holds the potential of letting you work quietly and unobtrusively without too much interaction with the outside world. Information technology which ironically "connects" the world is one of the best refuge for the super-smart but reclusive, socially awkward engineers. Peter Thiel, founder of Paypal once said "I think society is both something that's very real and very powerful, but on the whole quite problematic. In Silicon Valley, many of the more successful entrepreneurs seem to be suffering from a mild form of Asperger's where it's like you're missing the imitation, socialization gene. Asperger's happens to be a plus for innovation and creating great companies."

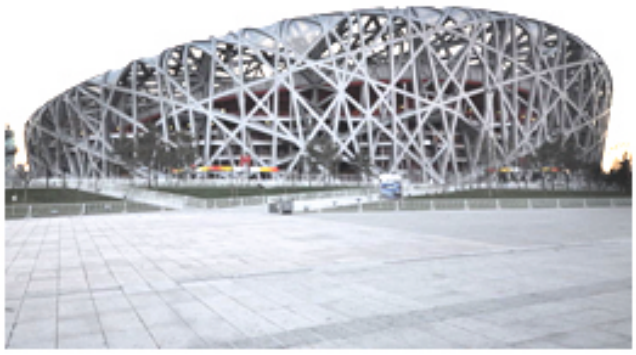
Uneven Relationship between Architects and Engineers

Structural Engineering too needs to be seen through the prism of the inherent reclusive nature of its practitioners. When a structural engineer sees a structure, he sees it the way a doctor would see his patient- underneath the façade of paint and polish, is the throbbing of the pulse and the pressure in the blood flowing through the veins- or the stress and strain in each bar of reinforcement and block of concrete. For a true engineer that is what it is all about – understand the seemingly inanimate but highly complex nature of building materials and building elements and put them together to make something unique. So while the rest of the community is more absorbed about how a structure "looks" the structural engineer cuts through the extraneous layers and is more into how it "behaves".

Time and again, the engineer is unable to convey what is important for the building stability, safety and serviceability and what constitutes good behavior. His solutions always



The CCTV Headquarters, Beijing
Source: https://en.wikiarquitectura.com



The Bird's Nest Stadium, Beijing
Source: https://commons.wikimedia.org/

Examples of "bizarre architecture" in China that uses brilliance in structural engineering to make possible undesirable buildings

seem boring, droll and uninteresting not because they are so but because he is a poor communicator. The architect switches off midway and dismisses the poor engineer with a "do as I say". The engineer needs to learn a few important skills- sketching, model-making and language skills if he is to interact one-on-one with the architect. Engineers who possess good communication skills and are competent are increasingly choosing not to work under architects. They prefer working directly with clients – fees are better and faster to come by and there is professional independence which allows them to work with engineering integrity. So, in today's times, the real estate industry ironically attracts the best structural engineers. Complex international museums and a few other similarly one-off complex structures may attract good structural engineers. Increasingly, even institutional buildings in India are also victims of mediocre engineering thanks to poor fees and a constrictive environment in which engineers have to operate for such projects.

Structurally engaging buildings are those where the architect allows the structural engineer to take centre stage. The Hall of Nations at Pragati Maidan in Delhi is one such structure where the creative synergy between the architect and the engineer elevates the building to the level of an icon. Here, the role of Mahendra Raj, the structural designer is well acknowledged in creating a masterpiece of structural design. Santiago Calatrava's work abounds in such examples of creative synergy between architecture and engineering.

On the other hand, a brilliant engineering firm like Arup is the international favourite of architects who like to build structurally

undesirable buildings. The CCTV headquarters in Beijing by Rem Koolhaas is one such example. The “Bird's Nest Stadium” was another unreasonable project designed by architects Herzog De Meuron for the excessive (and unnecessary) steel used- “bird-brained” would describe the design succinctly. Both these structures in Beijing triggered an offensive against “bizarre architecture” by the Chinese politburo.[2] So while Arup's engineering skills are laudable, their inability to sometimes make an architect appreciate “rational” structural design is unfortunate.

There are two extremes scenarios- engineers either relegated as technicians to add steel bars in a building or called upon to marshal their talents to make possible bizarre juggleries of architectural forms.

Issues in Prevailing System of Educating Engineers

The first choice of most engineering students is not civil engineering. It is usually information technology, followed by electrical, mechanical and at the bottom of the rung is civil engineering. The reason is as mentioned before- the other fields are more abstract and need lesser social interaction with the world – which is anathema for most engineers. They also command more money. So when a student enters the portals of a civil engineering college, he has already made his first compromise. After which, the next four years of college are a systematic attempt to disengage him from his love of the core field of engineering. It would seem that the world plots against the poor lad- uninspiring and disinterested teachers, insipid teaching methods, endless amounts of time invested in seemingly outdated tools and technology which a student is hard pressed to make sense of or comprehend its applications. The situation has been compounded by two phenomena. On one side is the plethora of civil engineering colleges that have mushroomed across the country, with unqualified faculty and poor infrastructure. The entry bar for joining a civil engineering college has been lowered so much in the past decade that anyone can now become a civil engineer, irrespective of whether you possess the acumen or the aptitude to pursue the field. There is tremendous pressure on colleges to graduate a student, whether he deserves it or not, just to keep the inflow coming and the juggernaut rolling. On the other side is the pressure on the top engineering colleges like the IITs to spew out more “well-rounded” graduates- which is another way of saying that while the student may get a civil engineering degree, there is more than an 80% probability that he will not be pursuing the field, so we equip him with skills to switch to information technology or financial engineering. We will soon have civil engineering students from the IITs who graduate with just one core course each in analysis and design against seven to eight courses in earlier times.

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In practice, we are already seeing this happen with the summer interns. Every so often there are media reports that over 80% of graduating engineers are not employable. One may debate

about the exact number, but it is true that most graduates other than from the top 5% colleges do not know their fundamentals well. As a result, many structural engineering practices have a qualifying exam which tests applicants on their engineering basics, without recourse to even a calculator. The pass rate on our qualifying exam is less than 5% and this includes IIT graduates too. I doubt it is any better in other structural engineering firms.

Challenges of Running an Engineering Practice

In such an ecosystem, it is a challenge to run a viable practice. If profit is the motive, one can surely find more lucrative and less stressful alternatives. A young structural designer running a 25 plus persons practice informed me that his operating cost was Rs. 8 per square feet while he was able to command only Rs. 4 per square feet. Never before I had heard operating costs being spoken of in terms of Rs./sq. ft. "How do you survive?", I asked. "I am a builder on the side so that subsidizes my expenses". I'm not sure that he was not being hyperbolic, but his angst seemed genuine. The problem with running a practice is that you are riding a tiger and can never dismount. The only option is to sell the practice, if you can find a buyer. So I do think it is difficult to sustain an engineering practice in today's stressed environment but if you are not greedy and do not take projects at ridiculously low prices, run a lean and supple practice with smart young engineers you will probably do alright.

You could perhaps enjoy running a practice (or so I tell myself) if you look at it as a learning centre or training school where you are teaching engineering to young graduates. The aim must be simple- to energize and inspire them into curiosity- how do structures behave and how do we make them behave the way we would like them to? How can we innovate and learn from how structures in nature behave? How much do we really know about materials behavior? How about we do this instead of that? How do you use the new fancy tools available for analysis to push the frontiers of our understanding rather than use them as black box substitutes for our thinking brains? It is about putting the fun back into design, of digging deeper. Surely, the other aim is to deliver quality work to clients – that's what keeps a practice afloat. And in the end, projects are the means to do what you love most- Exploring. It has never made any sense to me to see the practice as a "production centre" or a "profit centre". You have to do work that you feel good about and you have to be convinced of what you do. If you do sensible work, money usually follows, enough to sustain an uncompromised practice. ■

Notes

[1] Peer Review is a quality assurance process in structural engineering wherein a fellow structural engineer or academic will review another's design and drawings for it's appropriateness and general conformance to relevant building codes. Such a Peer Review is sometimes mandated by a local body's building bye laws for specified type of structures or may be a special requirement of a client. Peer Review may in some cases also include value engineering of a project.

[2] http://www.telegraph.co.uk/news/worldnews/asia/china/11249874/China-to-declare-war-on-bizarre-architecture.html