fixed to observe the effectiveness of each parameter compared to the P_f value. It may be noted that the actual tolerance range that is allowed in the actual design is different from this value.

Based on experience and for the purpose of analysis the COV for the random variables are assumed as given below;

$$h_{ef} = 0.2;\ C_{a1} = 0.2;\ C_{a2} = 0.3;\ f'_c = 0.2;\ T_s = 0.1;\ \text{and}\ V=0.1$$

These parameters random variables are assumed to be normally distributed. In this study only two failure modes are considered, that is concrete breakout failure in tension and shear. Accordingly the performance function that is used in the current analysis is given below.

$$Z = R - L \qquad (6)$$

where, R is given by Eq. 1, 2, 3 and 5 respectively for breakout failure of a single anchor in tension and shear for single and group of anchors. Here L is the tension or shear load on each bolt or group of bolts. For the purpose of analysis Monte Carlo simulation is used with number of cycles, N, is limited to 1000. The probability of failure is therefore calculated using the following equation:

$$P_f = \frac{No.of\ Failures}{N} \qquad (7)$$

Analysis has been performed for all the bolts as the bolt loads and few other design parameters are different for each bolt. As expected the probability of failure varies for each bolts and the maximum probability of failure for the case study example was observed for the corner bolt number 7 and 8 (Figure 4). These two bolts are subjected to maximum tensile load and least edge distance. For the purpose of evaluating the effect of different parameters, only normalized values are presented. The probability values are normalized in such a way that, the maximum probability of failure obtained in the actual case is normalized to 1. Figure 5 presents analysis results for breakout failure in tension. It is clear from the graph that the distance from the center of bolt to the edge of concrete in one direction (C_{a1}) was the most dominant parameter.

As the tension load increases the probability of failure increases. Alignment and number of bolts affects the load on each bolt. By increasing the number anchors tension load acting on each anchor will be reduced. It is observed from the analysis that as the edge distance decreases the probability of failure increases. Therefore the designers should consider these parameters while designing and arranging the location of the steel bolt connections. The second most effective factor was the tension force acting on an anchor or group of anchors (T_s,).

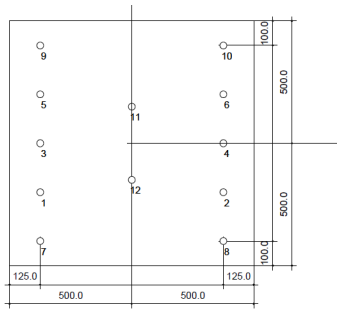

Figure 4: Geometric alignment of the bolt connections

Another important parameter is the effective bolt depth (h_{ef}). Similarly, for the group of bolts, breakout failure in tension, it has been observed that, eccentricity of loads is the only major additional parameter that is present in the case of group of bolts compared to the single bolt case. Otherwise the effect different parameters are similar to what was seen in the case of single bolt case. In the case of breakout failure due to shear, shear the most dominant factor is the distance from the center of a bolt to the edge of concrete (C_{a1}). Other parameters that influence the failure mode are the shear force acting on an bolt or group of bolts (V), and the distance from center of bolt to the edge of concrete in the direction perpendicular to C_{a1} (C_{a2}). Analysis results are graphically depicted in Figure 6.

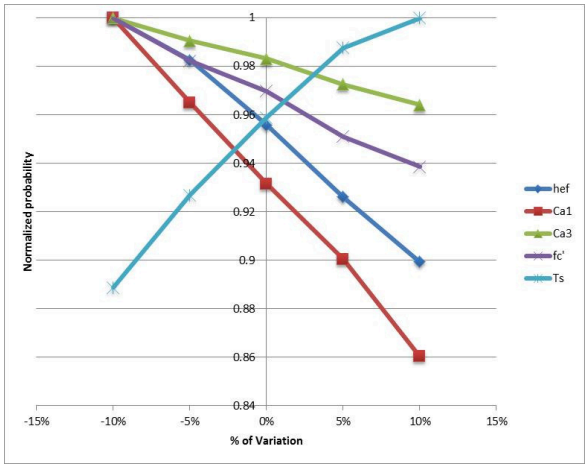

Figure 5: Effect of different parameters on probability of failure for breakout failure of single bolt

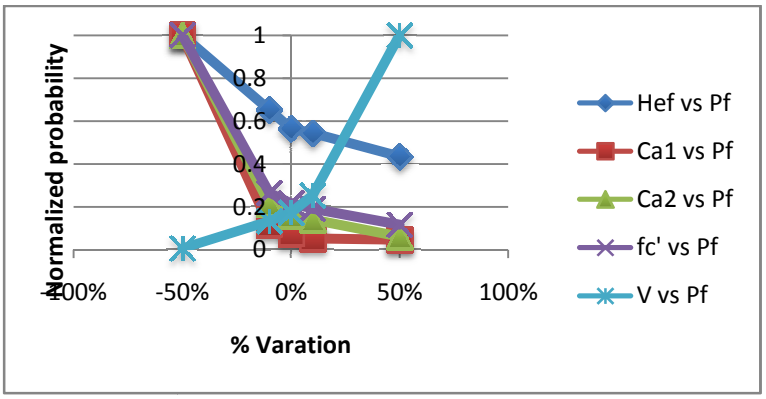

Figure 6: Effect of different parameters on probability of failure for breakout failure of single bolt

Conclusion

In the present work an attempt has been made to examine the effect of various parameter on the probability of failure in steel to concrete bolt connections. Concrete breakout failure in tension and shear failure modes are considered for the present study. It is observed from the analysis that edge distance and embedment depth of bolts are two major parameters that affect the reliability index for the concrete breakout failure in tension. Similarly, edge distance is a major factor that affects the breakout failure mode in shear the major factor that affect is the edge distance. Hence the tolerance range for these two parameters needs to be carefully arrived and controlled while implementing a steel to concrete bolt connection. A case study example from an ongoing project has been presented with normalized load values. Further work need to be done in order to understand the effect of inclination of bolts on the probability of failure.

Acknowledgement

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Risk Management in China: Applying International Best Practice to Foreign-Invested Projects

Geoffrey Mills[1]

Abstract

Chinese contractors operating overseas have experienced difficulties in adjusting to the international environment. This in fact mirrors earlier international experience of western firms entering new markets – so, as with much in life, the main lessons have already been learned by our predecessors and the challenge is to pass them on to the next generation. One of the key differences in moving from a relatively mature and well regulated construction environment, as China is, to a range of different and largely immature markets is the need to become much more aware of risks that in the home market to a large degree are covered by an established legal, regulatory and operating environment.

To understand the differences it is first necessary to understand the characteristics of the home market and in China there are many features of the system that effectively provide a safety net to contractors who fail to perform.

This paper describes how the operating environment in China in many respects provides a poor grounding for Chinese contractors moving overseas and hence how important it is for such firms to adopt a rigorous approach to risk management as will be covered by other papers.

Text

I am writing this from the perspective of a consulting engineer and with a lifetime in consulting engineering.

Thucydides, in his History of the Peloponnesian War, had lived through a period of some decades of turmoil when the fledging Greek states were trying to find a peaceful solution to their coexistence. Every attempt at a peaceful solution failed and he concluded that it was in our nature that the future of mankind would be

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warfare. The quest for a risk free construction environment may be similarly challenging but that does not, of course, mean that we should not continue to strive for improvement.

Thucydides further realised that in his short but nonetheless eventful life he had seen more than he could assimilate and so he felt that his history needed to be not just (and indeed not even) an assessment of the turmoil that he had witnessed but a factual record of events which might allow some future historians to make more sense of it.

Having passed normal retirement age just before writing this paper I feel that my more effective contribution is not to repeat the good advice that we have all heard so many times in the past and that is now enshrined in eminent publications and even (from 2009) an ISO Standard but to share my own experience of mistakes – my own and those of which I have had first-hand experience.

I will loosely collect them together under some common headings which I note conveniently gives me a Ten Commandments of circumstances to avoid, or more likely to watch for as they inevitably occur again in the future. Unfortunately libel laws and common courtesy mean that a number of my best examples have had to be left out to. So in no particular order:

1. Innovation

There is so much published on this crucial topic but to the best of my knowledge there is still no agreed definition. My own preference is "anything that the team involved has not done before." Given that as a safe rule "every innovation fails" and that as a construction industry we cannot build prototypes without great risk, then attempting something new should be generally be avoided. In many cases, strengthening the team can solve the problem but if the team is new to a task it will probably fail.

Let me take, for example, some very large dockside cranes. Costs were trimmed as part of an overall "value engineering" exercise and one saving was associated with an automatic anchoring system, which would be used in storm conditions. This was replaced with a manually operated pin system involving a steel dowel that could be twisted to release and then lowered into one of a number of a restraint holes in the jetty deck. This assumed that the meteorological warning of a storm would be sufficient to allow the crane driver time to move the crane to one of the anchor locations and then exit the cab to drop the anchor into position. In the event, that assumption was false – and two cranes ended up in the river!

Sometimes it is possible to construct a prototype and this was the case for a specially designed fleet of rough terrain tipping vehicles. The risk of falling over

sideways was identified and so a bespoke, extra-long axles set was specified. To test this, the prototype was taken to an established vehicle test centre. The prototype passed the test. A field trial was then run with the prototype, fortunately, where it was found that it was quite stable laterally but the entire vehicle tipped over backwards when the tipping mechanism was operate.

Over the past 20 years, many of China's teams of engineers have been responsible for significant projects on which they had no prior direct experience. We should recognise their achievement.

2. Unrealistic Programme

There is a saying in Quality Assurance: "there is never enough time to get it right first time but always time to do it again when it fails." Too frequently, investors do not want to put in the time at the outset to ensure that the job is likely to go smoothly.

An extreme case – ignoring good advice, an investor commenced work on a development in China without the necessary permissions in order to save time. A year later the company was made to dig up what it had started and to reapply for a license. The China board was sacked.

More commonly, an investor will underestimate the time needed to complete all the pre-contract activities, including his own review and development tasks, and so either the contract proceeds with the risk of avoidable later variations and extensions of time, or the contract start is postponed for a longer period than would have been needed if adequate time had been planned in from the outset.

It needs a very persuasive consultant to convince an investor that he should probably slow down, or take alternative action to achieve the programme more reliably if time really is "of the essence." In any case, whose place is it to determine the correct business decision?

To have an educated discussion on that subject requires the investor to value the benefit of time. This is required not in the somewhat cruder way normally used to assess the limits of delay damages but a real assessment of the value (or cost) to the business of beating, meeting or failing to meet the programme. In most cases, that time will vary depending on when any delay might be known, since contingency options close down the closer one gets to completion.

Some investors, in my experience, will fail to make that assessment but still exert strong – albeit uninformed – pressure to finish on time. In the event of a possible delay, the informed investor will be ready to discuss acceleration and know what it might be worth spending to achieve that. The lesser informed will threaten

action and may have the apparent contract powers to do so, but will nevertheless suffer the delay and so any redress becomes a financial one which is rarely adequate compensation – although without knowing the value of time, how can that be assessed?

3. Unrealistic Budget

It was reported that when Churchill and Eisenhower first asked the head of the Royal Engineers when he expected to complete construction of the Mulberry Harbours (for the Allied invasion of France), he responded "By 1953, or thereabouts."

When they explained their need to have it in place by 1944 – some nine years sooner than he anticipated – he reportedly retorted, "You can have it cheap, quick or clever – any two, but not all three."

It may be an exaggeration to say "there are no technical problems on projects, only financial ones" but it contains more than a germ of truth.

Assuming a reasonable degree of design and procurement competence, then the final balance of quality, price and programme represents a block of rubber in which two sides can be squeezed at the expense of the other but to reduce the total volume is a much greater challenge.

Budgets should – like cigarettes – be presented in packets with a health warning, since until the project is quite well advanced there needs to be significant contingencies, well beyond the level that most investors will want to hear.

4. Failure of Legal Remedy

This is a significant problem in China and in many other parts of the world. Indeed my neighbour in Oxford runs a group in one of the Oxford colleges researching how countries work where the law does not. The law in England is imperfect and the law in China is imperfect – but each has their own imperfect characteristics.

A recent out-of-court settlement in the UK, which was close to the insured limit of the (large) consulting firm concerned, was totally used to pay legal fees with no damages being awarded to either side. The law had completely failed as a remedy and both parties decided to wrap matters up as they were merely feeding the major law firms. The total legal fees of the two parties were greatly in excess of the settlement.

China has some problems with the legal system that I cannot write about, but some of the problems I have experienced (and can write about) are:

- In over 300 contracts not one of our clients (western investors) has ever tested the courts or an arbitral tribunal – although one is about to as I write. Western investors, as a breed, settle. That means that in so many areas there are no clear legal precedents. My company has initiated some court/arbitral actions and been generally satisfied with the process (even where we lost!) and we have been involved as expert witnesses but recourse to the law is very much the exception even though the costs of an action in China are low in comparison to western jurisdictions.
- Defaulting contractors in China cannot be removed from a project and a replacement brought in without a formal judgement, which generally takes more time than is available and hence leads to negotiation.
- Local provincial authorities often act outside of the national laws but given that there is no available enforcement mechanism, investors just have to live with those aberrations.
- The application of the law favours the labour force and that can be manipulated to the disadvantage of the investors – by (for example) the courts requiring the investor to pay workers directly who have not been paid by their contractor or sub-contractor employers.

5. Overstretch

This can apply nationally, corporately and individually although individual overwork is a symptom of a corporate failure.

Nationally, I recall the struggle in the early days of our motorway programme, in my first holiday job working on one of Britain's new motorways. The team I was assigned to had a bridge collapse during construction with some fatalities. From no experience of motorway building at all, the UK construction industry had to mobilise to build a network and in the first decade in particular there was a national skills shortage. The leadership of that programme included engineers who had been responsible for the Mulberry Harbours and they resorted to widespread standardisation which allowed the programme to continue with reduced risk but of course stifled innovation.

That is indeed a challenge for the next generation – building safely and sustainably requires a solution to the innovation challenge. I saw evidence of a similar challenge faced by the Chinese government in a national schools building programme following the end of the Cultural Revolution where many schools were built but not to consistent standards. One collapsed in the Sichuan Earthquake in 2008 for which there was much criticism of shoddy workmanship –

but the message was lost that even in the most remote regions, China had been investing in new schools with a programme of a scale that experience would have shown would lead to some risk.

6. Fraud

The old cartographers had a nice convention for illustrating areas that were either uncharted or known to be dangerous and illustrated their maps with sea monsters and other supernatural hazards where the simple advice was just to "beware entering here." We have no such convention but this is a most challenging area. I have a colleague, an expatriate Christian, who is married to a Chinese wife and who wanted his son to go first to Chinese school to learn Chinese language and culture and then for secondary education to move to an expatriate school of his father's nationality. A couple of years before it was time to switch he said that he was making the transition and I asked why. He said that his son was unhappy as his culture and beliefs were so different to his young friends. My colleague told me "Of course I know that Chinese parents love their children as much as any other parent so I was interested to find why they were teaching a different set of attitudes, so I spoke to some of them." He learned that his son's friend's parents believed that their children would be growing up in a very difficult world and in order to survive they had to have the tools to deal with all forms of behaviour. Hence better to ground them in the teachings (for example) of Sun Tzu and his "Rules of War" than leave them without the capability to deal with the challenges that they would have to face in the future, whether they wished to or not. My friend moved his son and continued to reinforce his Christian beliefs.

7. Culture

Some aspects of this are covered in the discussion on fraud but the cultural issues are much deeper and affect every aspect of professional life. To a very large degree my own professional career has been based on a long established British indentureship system.

Following the Cultural Revolution, China lost sight of much of its cultural heritage so the current generation of engineers is having to find its own cultural foundation. The Western model has, understandably, lost much of its earlier credibility in recent years. China's current President is so concerned about the need to re-establish China's traditional culture and values that he has made that endeavour a hallmark of his Presidency with the support, for example, of the Qunshu 360 (www.mchunghua.org).

For all the mistakes that I have made and seen I was brought up in an environment in which safety (in the broadest sense) was given the highest priority and the

British consulting firms produced engineers who were dedicated to looking after their clients and the public. There were exceptions of course but they were exceptions.

Since the Cultural Revolution, China has had a tremendous challenge in rebuilding its economy and developing a reliable construction industry both nationally and, latterly, internationally.

Emphasis has been given to initiative and the rewards available for success have exceeded the sanctions for failure. The spirit has been "he who makes no mistakes makes nothing" and indeed amongst the outstanding successes evident to any China visitor there have been a few spectacular failures.

China's own construction profession recognises the need to mature and hence the international risk assessment programme that was initiated in 2010 jointly by the Chinese construction industry and the Institution of Civil Engineers and that (at the time of writing) is due to be concluded early in 2014.

One of the important aspects of culture in relation to risk is what society judges to be acceptable, since a level of risk control that stifles development is likely to be considered counterproductive.

8. Genuine Undiscovered Mistake

People are fallible and will remain so. I have been reasonably successful through my career but I think of myself as a "70% man." I realised at university that from an early age, through school and latterly at university, I averaged around 70%. Indeed I graduated with upper second class honours, so maintaining my 70% consistency. It was at university that I first asked myself how, in professional practise, I could regularly and reliably achieve 100%, which surely I would need to do if the projects on which I worked were not to fail.

I subsequently learned of safety factors, of layer of protection analysis (LOPA) and of the legal and commercial foundation of the profession being based on not being negligent. The law does not expect me to be superior to my peers and recognises the inevitability of error. The law, in that respect, recognises reality. No business will succeed if the business plan involves no taking of risk and no structure will ever be built that is risk free.

I strongly believe that the best foundation for society for the future will be to continue to develop professions in which the commercial risk is at the negligent level, since we need to work constructively with our clients to help them achieve