A Life of Leisure

Istruct E Gold Medal address

Presented by Dr John Roberts

OnTuesday October 24th 2006

Introduction

It goes without saying that I regard it as a singular honour to be awarded the Institution's Gold Medal. It is not something that one ever gives a second thought to on a day-to-day basis, so to find out that one's peers and colleagues in this profession regard my work as worthy of this recognition is extremely gratifying.

In discussing the subject of this address with the President and the Chief Executive I was encouraged to do two things. Firstly, and perhaps inevitably, to reflect on the rather unusual field of work in which I have been involved for over 20 years and which in many ways epitomises the public perception (such as it is) of my career 'so far - the engineering of major theme park rides and attractions. And secondly to allow an opportunity to consider, as I did in my Presidential Year (1999-2000) the public face of engineering in general and structural engineering in particular.

Career commencement

How did it all start? How does one move imperceptibly from an undergraduate, struggling with what remains a demanding and challenging intellectual pursuit, to that semi-mythical 'experienced engineer; qualified, confident and authoritative in his or her chosen specialism? I don't know the answer to that question, other than the fact that it definitely involves observation and learning from the past; from mistakes as well as successes, and from other engineers as well as one's own personal experiences.

My career started in what must still be a very straightforward and conventional way. I went from school to University at the age of 18 without a great deal of thought or evaluation of my future career path. In my case school was one of the earliest comprehensive schools in Bristol, which was a pioneer in this new form of education.

I don't recall any form of careers advice but I think I was heavily influenced by a series of 'summer holiday' jobs on building and constructions sites. This worked in reverse - the work was long, hard and uninviting, but seemed to me at least to be extremely well paid. On each site there was an occasional, well publicised visit by 'the engineer' who was treated with a fair degree of reverence by the agent on site. I fondly imagined that this was the job For me - imagine how much the engineer would earn compared in my efforts as a labourer (this was a big mistake - it took more than 10 years before my salary reached the same level as my 12 hours a day, 7 days a week work on site).

Fig 1. Hammer head striking nail head - driven into wood block

But anyway; the choice was made and I set out for Sheffield University in the autumn of 1966. I was fortunate to be taught by a succession of lecturers in structures who both explained and enthused me, even then, to focus on structural engineering. I decided to stay on, after completion of my degree in 1969, for a 3-year PhD research project in dynamic overload of steel structures. Slightly tongue-in-cheek

I often tell people that I am one of the few PhDs who actually make use of their degrees in non-academic work, but I think that this was more by accident than by design as I will explain later.
What I actually investigated was high speed application of 'overloads' to steel struts. This is best described by two opposing facts that I think are understandable by `anyone'- and I am very keen on being able to describe what we do in our profession, even at a detailed technical level, to intelligent non-engineers. The two facts? Firstly, the well known but still surprising phenomenon of pieces of straw becoming deeply embedded in or even passing right through solid timber doors during hurricane or tornado winds. Secondly the fact that if you set up a test rig which applies a slow steady force in compression to a steel nail ready to penetrate a hardwood block, it will buckle and fail to penetrate, even though it is perfectly possible to hammer it fully home with a number of blows. In fact both steel as a material, and the buckling behaviour of a strut as a structural member are strain-rate dependant or time dependent, a valuable lesson that bears regular repetition

Staying on at university had me feeling left behind my contemporaries who had by then been working in the profession for 3 years, and since I always imagined I would be a designer (that early site work did do some good) I thought I should head straight back out into site work, to catch up and complete my practical experience as soon as possible. I worked for 2 years for what is now Alfred McAlpine plc, firstly at a brewery reconstruction and then on an urban motorway project, the M63/M56 interchange. I can't tell you how galling it is now to use this same stretch of road for my daily commute to work and to have suffered the indignity of long periods of delay and disruption as the road was upgraded due to, and I quote directly here, 'having reached the end of its useful life.'


Fig 2. Paterson Laboratories, Christie Hospital, Manchester

Finally, then, at the age of 26 in 1974 I arrived at a design office, Bertram Done & Partners, in central Manchester. This was a real baptism of fire small, locally-based practices which nevertheless worked across a wide range of public, commercial and industrial projects certainty provided a fast-track introduction to real structural engineering practice. My very first project was an in situ-post-tensioned concrete transfer structure which carried a new three-storey building over an existing underground 'laboratory' which could not be disturbed, and this involved the use of curved post-tensioning ducts; calculations were, of course, only by simple hand methods. It was duly tendered and built, all in a remarkably short space of time. The reason it sticks in my mind is simple - within about a year from starting work in this design office I decided to sit the 'Part 3' exam, and you can guess what the structural concrete question was - yes, a three-story structure spanning over an opening where no foundations were to be placed. Even the dimensions of the project were almost identical I am pleased to say that I therefore passed our exam at the first attempt.

Rides and theme parks

Working on rides and theme park projects is clearly a rather unusual occupation and like many major steps taken in life this one happened completely by accident and in an unplanned manner I had by now joined the large design office at Allott & Lomax in Manchester- 250-strong and heavily engaged in a programme of work on power stations, and for the nuclear industry which was headquartered close by in Risley, near Warrington.

In 1985 I had just become a director of Allott & Lomax, and one of my colleagues had met by chance a director of Blackpool Pleasure Beach (BPB) whilst on holiday A new scheme of independent inspections by engineers had been introduced by the Health & Safety Executive, and BPB was searching for a consulting engineer to do this work for them. I arranged to meet the owners (the Thompson family) and the Director of Engineering, and decided (some would say uncharacteristically) that honesty was the best policy with respect to our previous experience on rides. In fact I had never even been to a theme park or fairground, and had no knowledge of rides at all. Against the odds we were engaged by BPB initially to carry out annual

Fig 3. General view of Blackpool Pleasure Beach

thorough examinations' of their 130 plus rides and attractions at Blackpool, as well as at their other theme parks at Southport and (now closed) Morecambe. Fortunately we were given a lot of assistance and encouragement by the staff at these facilities and in return we brought to them our perspective of engineering from other types of buildings and projects, as well as a multi-discipline strength in mechanical, electrical and control systems, and in formal risk and safety engineering techniques. They remain our clients to this day. and in the close-knit world of theme parks there is a significant interchange of ideas and people, so that work for other clients soon followed.

Our first venture into the design of rides (as opposed to inspection) happened in 1987, simultaneously at BPB and at a new client Alton Towers, who had approached us after a recommendation from BPB. At BPB we designed the foundations and station structure for a project scheduled to open in 1988, a 'toboggan ride' call The Avalanche. Meanwhile at Alton Towers we carried out a more significant project, designing in an incredibly short time frame the entire track, superstructure and foundations for a 3.2km long monorail system that in fact linked a new car parking area to the entrance to the park. The trains had been purchased by Alton Towers from EXPO 86 in Vancouver and were already en-route by container ship from Canada to the UK. In a period of 16 weeks we designed, tendered and supervised the construction of a continuously welded box-girder track carried above ground on steel columns, with pad foundations. The 820t steelwork contract was competitively tendered and let within the first 2 weeks, so as you can imagine the state of the design was not as 'complete' at the start of construction as one would normally have preferred. But the opening date was sacrosanct and we have learnt how to deal with clients for whom completion dates are more important than anything else. For the Alton Towers monorail we needed to do a complete temperature change analysis (after all, the external exposed steel track formed a continuous loop 3200m long) and we had agreed with Alton Towers that this would not be completed until the construction on site was well underway. When we did complete this work after the project had been opened to the public - we realised that we would have to alter the design at 12 locations to cater for the forces induced into the structure by extremely cold weather. We planned to make these changes after the park closed in early November for the season, but in fact a severe frost in late-October that year caused damage to the holding-down bolts at the 'worst' three of the l2 locations predicted We were, in a perverse way, quite `pleased' that this had happened; it is nut often that one is provided with such a graphic demonstration that one's calculations are correct! The strengthening was duly completed and the monorail system has performed well ever since. It remains the only major monorail operating in the UK and I believe it has by now carried around 50M passengers in the 18 years since it opened'.

Fig 4. Avalanche (Toboggan Coaster)

Roller coaster designs

Our work at BPB in particular, and at other theme parks in general, allowed us to inspect and observe the performance of a range of roller coaster rides. Roller coasters have always represented the 'peak' of passenger carrying rides and have done so for well over l00 years since the 'modern roller coaster and 'modern' theme park both saw the light of day in America. BPB had a large number of coasters, including five historic timber coasters dating back to the early 1920s. Without exception these had been designed and manufac-

Fig 5. Silver Ride Monorail, Alton Towers

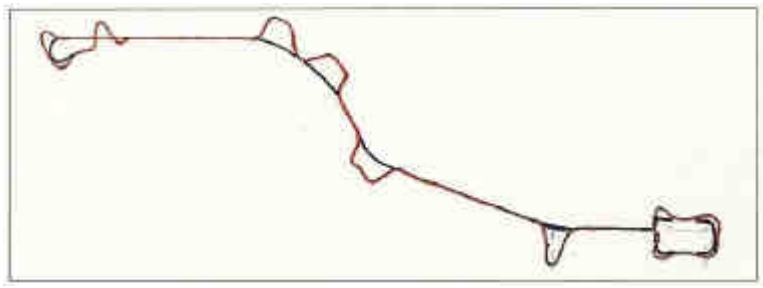

Fig 6. Monorail - Temperature movements

tured in the US, and then shipped to the UK and erected on site by American engineers and contractors. It was (and still is) a very specialised niche market, almost exclusively served by turn-key suppliers who design, fabricate and erect the entire project.

In 1992 we started working with BPB on its largest ever ride project, the world's tallest (and therefor the world's fastest) roller coaster now called The Pepsi Max Big One. Whilst the designer (and contractor) for the ride itself was the famous firm of Arrow Dynamics Inc. of Salt Lake City, Utah, it was agreed that we would design all of the 'non-standard' sections of the supporting steel structure, and the very considerable subs structure and foundations. Arrow designed the track itself, the standardised sections of the supporting structure, and of course all of the trains and their mechanical, electrical and control requirements. However we had by then developed sufficient expertise in the dynamic design of coaster tracks to be able to assist, by way of an independent dynamic analysis, with evaluating and where necessary improving the Arrow design. Our formal role however was limited to the design of the foundations and the 'special' sections of the track support structure, and then to co-ordinate the overall steel work/ superstructure design .This then allowed UK contractors and suppliers to build much of the project, and in the end about 50% of the £12M total cost of the ride (in 1994 prices) was spent here in the UK. Looking back on this project and with the benefit of hindsight, we should have taken a stronger line with respect to some concerns we had about the dynamic performance of the ride relating to the track geometry But we had no track record (so to speak) of the design of coaster tracks and therefore we were not confident enough to challenge the established designers, who had a world wide reputation in their own field of specialisation.

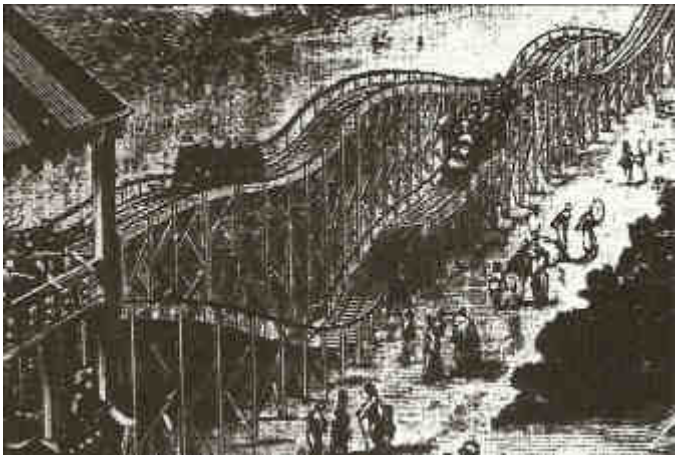

Fig 7. Coney Island 1884

The project opened to great acclaim in 1994 and has proved enormously popular ever since, typically carrying over 4M passengers per year Our concerns over the design proved to be wed-founded, however and within a year of the opening we had re-designed two sections of the track to improve the running performance of the trains. This experience, coupled with the feedback from instrumentation that was fitted onto the train seats and gave a real-time record of accelerations and velocities (to compare with the design values), persuaded us that we were perfectly capable of designing the key part of a roller coaster i.e. the ride track profile and the associated ride dynamics. Following on from this we later amended the track profile (to improve the ride performance) on two more steel coasters, the Black Hole at Alton

Fig 8. Big Dipper - Blackpool Pleasure Beach

Fig 9. Big One - Blackpool Pleasure Beach

Fig 10. Big One - Blackpool Pleasure Beach

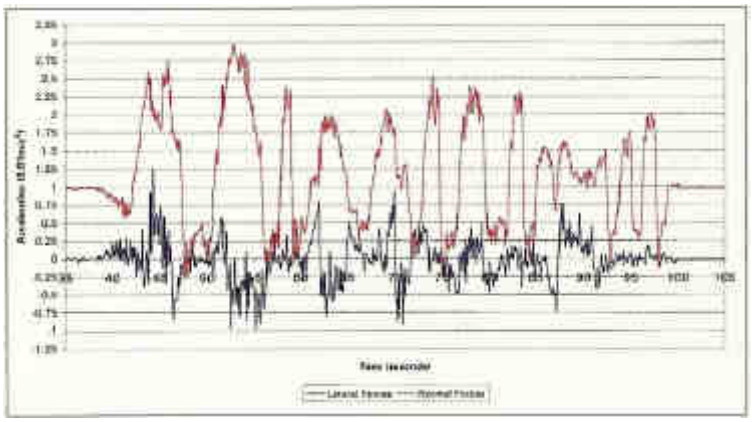

Fig 11. Dynamic performance graph

with the results from these tests, and using a traditional and basic figure-of-eight layout we duly designed the entire track and support structure and Gulliver's duly constructed it themselves, following a 'pattern book' of details we had prepared They also had the cars made using a traditional design in use on numerous other rides. We were very anxious on the big day when, for the first time, a car was dispatched from the top of the lift hill for the first circuit of the track. I had known from published accounts that timber coasters needed to be 'run-in' before they performed properly. Indeed there was

Towers and the Vampire at Chessington World of Adventures. It is actually much more difficult to splice in a short section of new track into the middle of an existing ride and handle the transitions between old and new geometry than it is to design a
whole new ride profile from scratch, so these three projects taken together served as a very useful proving ground for our dynamic design capabilities for ride projects.

Modern timber coasters

The opportunity to put these new skills fully into practice came, rather unexpectedly, on a Traditional timber roller coaster. Since the late 1980s there has been a resurgence of interest in timber coasters. These rides have a timber track as well as a timber supporting structure and have a lineage directly traceable back to the classic American coasters of the 1920s and 1930s, and before that back to the first-ever purpose-designed coaster built on the beach at Coney Island, New York, in 1884. In the 1980s the designers and builders of timber coasters were still all American. In 1996 we heard through the theme park grapevine that the owner of a number of small family orientated theme parks branded as Gullivers wanted to build his own timber coaster, but he was not able to agree terms with any of the established specialist companies, who all wished to provide him with a turnkey completed project. Once again luck played its part, and in a phone call with him I offered to design a simple timber coaster for him to build himself. This was exactly what he wanted and so the project was underway Of course we then got cold feet, and I arranged for some loading tests to be carried out at Bolton Institute to establish exactly how the traditional form of construction of the track - multiple layers of boards laminated together with nailing but no glue performed in practice. Armed

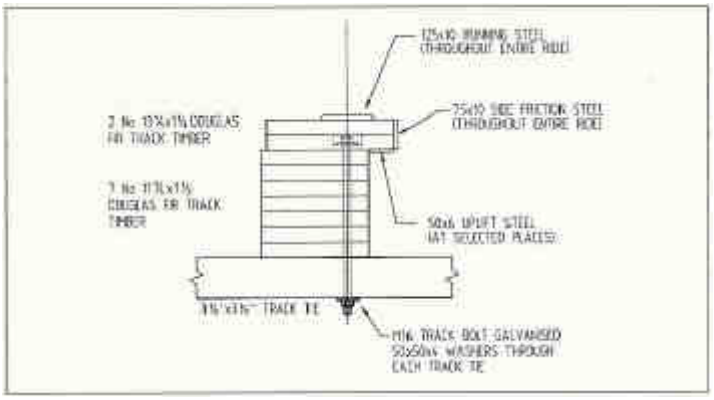

Fig 12. Timber track construction (section)

anecdotal evidence of it sometimes taking a few weeks of pulling and pushing cars around the track, by hand, before they had bedded-in sufficiently to complete a circuit under their own gravity-induced energy from release at the top of the lift hill. In spite of this it still came as a big worry when I took a phone call from the owner that first day, telling me that our design 'must be incorrect' as the car had failed to climb even the next hill on the track, never mind complete the circuit and return safely to the station! Needless to say it was just a bedding-in problem and within a day or two the ride was performing exactly to plan and has now done so for almost 10 years.

Fig 13. Antelope Coaster - Gullivers World

The next project we designed was a quantum leap, from the small and simple family coaster at Gulliver's World in Warrington to a European record-breaking fast-and-furious timber coaster at Tusenfryd in Oslo, Norway. We had written speculatively, after the completion of the Gulliver's coaster to all the large European theme parks to let them know we could now design timber coasters! Our letter (translated by us into Norwegian) landed at Tusenfryd at exactly the time they were at the early stages of considering a new large timber coaster. I went to Oslo to meet them, and a key Factor was that - in order to take up an offer of sponsorship from the Norwegian timber exporters association - the ride had to be designed and built using locally sourced timber No problem, one would imagine, except all the specialist turnkey companies were based in the US and they always used Southern Yellow Pine, (grown in Florida and Georgia) for the timber structure, and often Douglas Fir (mainly sourced from British Columbia, Canada) for the track. They had workshop facilities in the States, where they cut and prefabricated the timber prior to shipping it, world wide, to the site for assembly They were 'unwilling' to change to using Norwegian timber and fabricating the structure in Norway. Our ride in Warrington had, however, been built using Scandinavian softwood, so we had no problem in agreeing to design the project using Norwegian timber. We were duly appointed and carried out the design on a 'blank sheet of paper basis', selecting a route, the 3D geometry and thereby the dynamic performance on the basis of extensive evaluation with the client of their (and our) favourite coasters elsewhere in the world. We thus worked differently from the turnkey suppliers, in that we were only carrying out the design and when this was agreed (on the basis of predicted ride performance) with the client, then we would obtain quotations to Fabricate, erect and commission the ride.

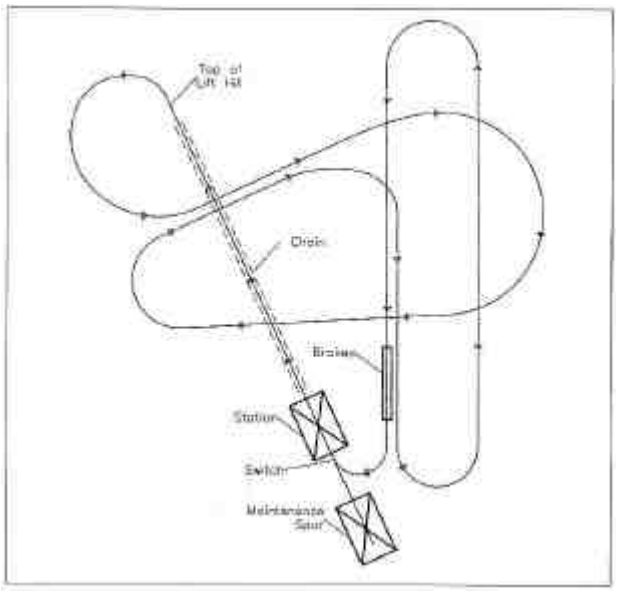

Fig 14. Thunder Coaster - Tusenfryd Track Plan

Fig 15. Thunder Coaster - Tusenfryd

At this stage a major problem arose, because no Norwegian supplier had built a timber coaster (indeed there were no timber coasters in Norway, and only one in the whole of Scandinavia) and therefore no-one was willing to quote a fixed price to build our fully completed design. Tusenfryd was forced, in the end, to accept an offer from an established coaster manufacturer who did build to our design but regrettably used Yellow Southern Pine and Douglas Fir sourced from - you guessed North America, and then they prefabricated all the timber in the USA as well. As can be imagined, the Norwegian timber industry was none too happy

Fig 16. Ferris Wheel - Columbian Exposition, Chicago 1893

about this (the sponsorship offer was withdrawn). I did get invited back a year after the opening to give a talk on the project at a meeting of the timber exporter's association and I have to say they were surprisingly polite and pleasant to me!.

London Eye

In our long association with theme parks we learnt a universal truth Ferris Wheels never pay their way. They act as a beacon or signpost to a park, but ride numbers are always very low and they are rarely a popular attraction.

So how did the London Eye change everyone's perception of 'Wheels' and become one of the most popular tourist attractions in the UK (if not the world) and a fantastic icon for London at the same time? The story has been told and retold enough times already for me only to add here some particular comments about our involvement and to look to the future.The London Eye had three key selling points - location, location, location - as well as an emphasis on design quality that has totally transformed everyone's view of Wheels. Location first. The London Eye is an Observation Wheel and there is something amazing to see-a close bird's eye view of London that unfolds in front of you as the wheel rotates. For some reason that is difficult to articulate this is much more impressive than the sudden vista you get from emerging at high level in a tall building and looking down, typically in one direction at a time.

Fig 17 London Eye (© Nick Wood)

Our involvement started shortly after the project was conceived by Marks Barfield Architects, without a client and therefore without a fee paying commission. Initially, we were appointed to provide an independent certifier role for the ride itself, this being a requirement of the updated version of the HSE Scheme to which I referred at the start of this paper But when the project started in earnest in mid-1998, with a construction management/design-and-build work package method of procurement, then our involvement inevitably widened to cover a number of other roles, such as advice the various designers, interface design issues, and an overall commission for approving and signing-off the construction and the contract payments as well as the design itself.

The London Eye had a fixed and immovable deadline - it was, after all, a Millennium project (albeit one with 100% private funding and none of the complications of government/grant approvals that came with public finances) and 31 December 1999 could not be delayed. As we all know, the three aspects of any project - time, cost and quality - are mutually
interdependent and it is simply not possible to achieve tight demands in all three at the same time. Here we unashamedly concentrated on time and quality, and as a result the budget costs were considerably exceeded.

Fig 18. London Eye - raising the wheel (© Nick Wood)

Fig 19. London Eye - 31 December 1999 (©Nick Wood)

The project was, however, sufficiently complete to be rotating as a centrepiece of the main London celebrations for the Millennium evening with fireworks, laser shows and other events along the banks of the River Thames. The project then opened to the public in early February 2000 and has already carried more than 20M passengers. Jacobs Babtie is fortunate to have been retained as engineering and safety advisors to the operating company since the opening, giving us the opportunity to remain closely involved with monitoring performance, assessing alterations and upgrades and a range of other activities. Recently the initial set-up ownership and finances for the project have been amended, with 'Tussauds Group now holding 100% of the equity. This change has coincided with the completion of the first 5 years of operations and further upgrades and improvements are now being actively planned as the London Eye enters the next phase of its (hopefully) long and profitable life.

Many other cities have been very keen to replicate the success of the Eye, and since 2000 we have been involved in proposals, feasibility studies or detailed discussions for observation wheels in Shanghai, Beijing, Nanjing, Singapore, New York and Las Vegas, amongst many others.

Of these only Singapore is underway (without our involvement) and none have been completed. Observation wheels of the scale and quality of the London Eye remain complex projects to finance and operate, as well as being technically very challenging. As ever, the exact location within a city is a critical issue. Placing the London Eye even a few hundred metres away from the current location, for example, could, in my opinion, have had a dramatic effect on the project as a whole.

Future ride projects

It is the nature of major ride projects that many of the owners/promoters are reluctant to publicise them at the early stages of project definition and design. We are working on several new ride projects which fall into this category!

One scheme that is, however, now in the public domain, is a new generation viewing tower at the site of 'the derelict West Pier in Brighton, This is a product of the same team that took the London Eye design through to fruition, so Jacobs Babtie and Marks Barfield are working together again on this project. A tower nearly 200m high, and with a structural diameter of only 3.5m, will allow a torus-shaped capsule, encircling the tower to rise smoothly and slowly to a viewing height of approximately 150m. Of' course - as always with theme park devices viewing towers do already exist, but this design will transform the perception of a standard off-the-shelf viewing tower in just the same way that the London Eye transformed the perception of existing wheels. A key feature is the quality of the capsule, with free movement allowed for the passengers as opposed to the usual fixed seating. A tower of this height and diameter requires significant damping to control vibrations and prevent passenger discomfort - the lowest natural frequency is approximately

Fig 20. I-360 Brighton (© Marks Barfield)

0.lHz (l0s period) so this is a very real problem that needs to be addressed at the start of the design, not an issue to be considered as an afterthought later on.

Fig 21. I-360 Brighton (© Marks Barfield)

Conclusion

I have been extremely fortunate to have had a stable, long-term involvement with a particular and unusual field of structural engineering. For exactly 25 years I have worked in the same office in Manchester and I have had the great fortune to have had a number of colleagues with whom I have worked with closely for, in some cases, the whole of that period! Engineering of major projects is a team effort and I wish to pay tribute to the teams involved in all of these projects, and to two people in particular, Dr Allan Mann (F) and Doug Dadswell (M), of this Institution, who have worked, between them, on each and every one of these projects. I certainly regard them and all my other colleagues as being part and parcel of this award, since it would not have happened without them all. Finally I wish to pay tribute m my family, and in particular to my wife Angie. We all rely, to a large extent on our family and those who are married to, or partners of engineers, surely have to put up with more than most in supporting our unusual and well documented personality and character traits. Providing support and encouragement that has allowed me to indulge my passion for engineering, and dragging them all over the world to sample theme park rides and attractions, is probably not how they would have chosen to spend their lives of leisure: But it is certainly how I have spent mine.

Thank you, again, for the great honour of awarding me the Institution's Gold Medal