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Front cover:
The Karasu Viaduct, Turkey. (Photo: © STFA)

Back cover:
Interior of bus station, Chur. (Photo: Richard Brosi)

Chur station roof
Alastair Hughes

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Ove Arup & Partners designed the glazed steel barrel-vault roof above the important new transport interchange at Chur in Switzerland. The structural concept for the tied arch was the work of Peter Rice. The roof recently won the Swiss ECCS (European Convention for Steel Construction) Award for 1993.

Mirror mirror on the wall . . . How fair is the engineer's image?
Sir Jack Zunz

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In the 19th century British engineering had a clear, strong, and positive public image; today this has been lost. This article looks at the causes of the decline in engineers' standing, and suggests some remedies.

River Aire Footbridge
Colin Harris
Mark Steele

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This prefabricated steel cable-stayed footbridge in Leeds was designed by the local Ove Arup & Partners office; both the 19m mast and the 56m deck were erected in a single day.

The Weardale Line
Adrian Gurney
Ed Humphreys

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An Arup team was commissioned by local authorities to examine the possibilities for development of a railway line in the upper valley of the River Wear, in County Durham. One section was to be closed, and among Arups' proposals was its re-opening as a steam line for tourists.

St. George's House, Manchester
Geoff Bickerton
Steve Burrows
Mark Elsegood

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This early 20th century example of reinforced concrete construction, originally built for the YMCA, has been refurbished as high quality office accommodation. Ove Arup & Partners Manchester designed the new works following a close study of the original structure.

The Kinali-Sakarya Motorway, Turkey
Alan Hughes
Andrew Lord

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A joint venture including Ove Arup & Partners supervised the construction of nearly 200km of motorway in Turkey, as well as considerable associated viaduct and tunnel works. A length of 45km was also designed by the joint venture.

Chur station roof

Architects:
Richard Brosi/Robert Obrist

Alastair Hughes

1. The 'hub' casting with mountains behind.

Introduction

The new station roof which has recently been completed in Chur, Switzerland, is worthy of notice on several counts. It is an impressive demonstration of the Swiss commitment to quality in public transport. It is also the fruit of an unusual degree of international collaboration, and in this respect the project may offer a pattern for the future.

Chur is the capital of the Graubünden canton in eastern Switzerland — the largest, and arguably the most mountainous, in the federation. As well as some of the most popular and fashionable winter sports resorts (Arosa, Davos, St Moritz), the region contains remote alpine valleys in which the Romansh language (Switzerland's fourth) survives. Chur itself has a long history based since pre-Roman times on its strategic position in command of trans-alpine routes. Today, one might describe it as a substantial town rather than a city, but its importance as a transportation centre is out of proportion to its size.

The station at Chur is an interchange point between inter-city trains from Zürich and beyond, which terminate here, and the regional transport network. This consists of two main components. The 1m gauge Rhätische-Bahn (RhB) was constructed in the late 19th and early 20th centuries. Legendary for its steep gradients, tunnels, viaducts and helical loops, the Rhätische-Bahn is no mere tourist railway but the everyday line of communication for the places it connects.

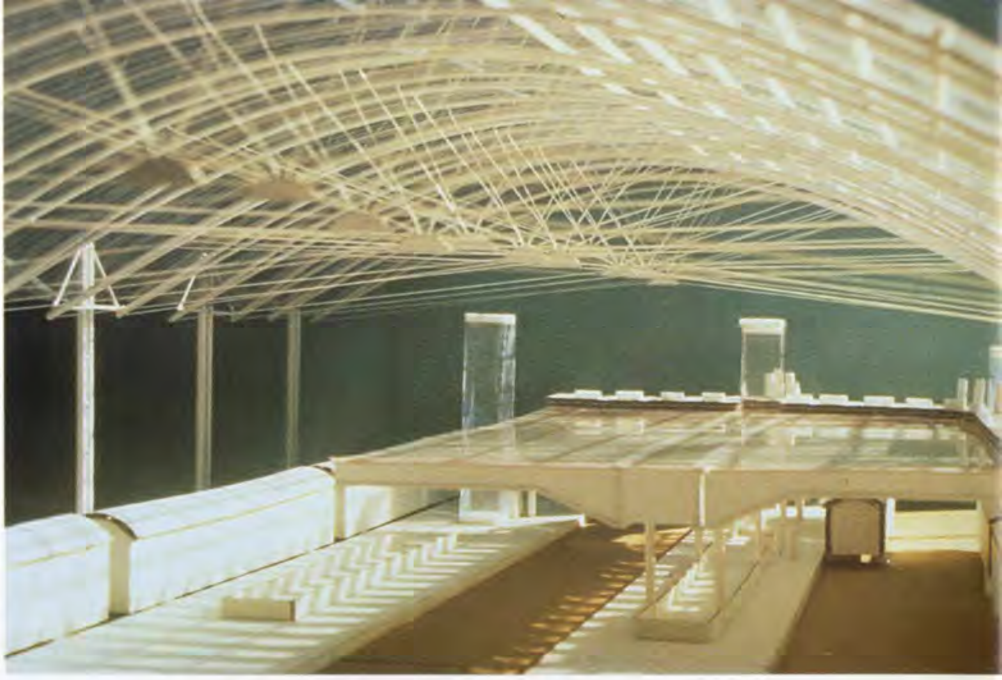
2. Chur location map.

Not every community is on the railway, but those which are not are well served by the other transport system, the postbuses of the PTT. These distinctive yellow coaches are co-ordinated with the railway services, and run with the same precision. Deregulation is an alien concept in Switzerland, and it is quite taken for granted that the same organization should run the rural buses as the national post and telecommunications services.

The Chur project, of which the station roof is only the most visible part, originated in a 1985 architectural competition for the whole area round the station, including associated postal buildings. Better integration of facilities, a visual upgrade, and more effective use of railway land were the objectives. The competition was sponsored by the three main users — PTT, RhB and SBB (the federal railways), together with the municipality. The lead client and project manager was the PTT, an organization with an impressive record of public sector architectural patronage. SBB is also active in this field — recent station reconstructions by Calatrava in Lucerne and Zürich (Stadelhofen) are noteworthy.

3. Right: Architects' model.

4. Below: Bird's-eye view of the competition-winning project. The original station building is in green; new postal buildings under construction are in blue. The red buildings are planned commercial developments on surplus railway land. The portion of the roof which has been completed is at the left-hand end and represents rather less than half of the longer section. It covers a new bus station built over the tracks.



Architectural concept

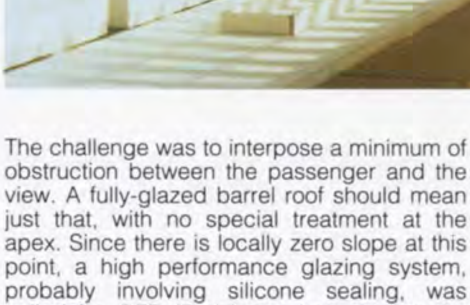
The competition was won by the architectural joint venture of Richard Brosi and Robert Obrist, based at Chur and St Moritz respectively. Their scheme proposed a glazed roof over the entire station, with a bus deck built above the tracks at the south end to facilitate interchange. Two new buildings and a system of subways for postal traffic were also included. The first phase, now complete, includes one of the buildings, the bus deck, and rather less than half the length of roof ultimately envisaged.

The architects' vision was of a fully glazed barrel-shaped roof, covering most of the tracks in a single span of just over 50m. This would, besides protecting users from the weather, act as a unifying feature and give the station an identity hitherto lacking. Although the station building itself, parallel to the tracks on the town side, is a 19th century construction of some character, the platform areas lacked distinction. The tracks are almost straight over the length of the platforms, and a classical steel arch design was judged appropriate. Feeling that inspiration could be gained from the tradition of 19th century train sheds in the UK, the architects invited Ove Arup & Partners to join the design team. A study tour was arranged, including Liverpool Lime Street as well as the obvious London termini and the glasshouses at Kew. It should be emphasized that the intention was not to recreate a period piece — the new roof was to be of its time, using modern materials to the best effect. A special emphasis was placed on transparency — unlike most British stations Chur is closely surrounded by mountains, which had not to be obscured by the new roof.

The challenge was to interpose a minimum of obstruction between the passenger and the view. A fully-glazed barrel roof should mean just that, with no special treatment at the apex. Since there is locally zero slope at this point, a high performance glazing system, probably involving silicone sealing, was called for. RFR (Paris) was brought into the team to undertake the design of this aspect.

Structural concept

The structural solution chosen has been described as a 'bicycle wheel arch' (although it does not stand too much comparison with a real bicycle wheel either in appearance or in structural action). It is a tied arch, with intermediate radial ties providing restraint against buckling to the principal compression member. It has something of the flavour of the trussed arches popular in 19th century railway stations, but again the comparison should not be overstretched. Its more direct context is the line of development of the work of Peter Rice, whose conception it was. Although agreeably simple in appearance, such structures call for a degree of analytical sophistication not available in pre-computer days. This, and the materials used, confirm the structure as one which is not in any sense backward-looking.



6. Architect's sketch of the 'bicycle wheel' origin of the arch.

Two variants of the bicycle wheel arch were developed — one a simple two-dimensional version and the other having the arch split into two members which diverge and reconverge, giving curvature on plan as well as in elevation. Besides the gain in visual richness, this obviated the need for bracing. The weight of steel is if anything less, but fabrication costs are inevitably higher since more members and more joints are involved. Both variants were tendered; in the event the three-dimensional one, dubbed the *Zitronenschnitz* (lemon wedge) was chosen, and this has been constructed. General opinion is that this was the right decision. That it was taken is to the credit of the client; in effect an aesthetic premium was accepted.

The *Zitronenschnitz* is formed by two principal tubular members each curved to a constant radius in one plane. Because they lean relative to one another the profile of the roof, viewed in cross section, is slightly elliptical (though the deviation from circularity is less than 25mm). Tie geometry relates to purlin locations, which in turn are dictated by equal subdivisions of the glazed surface to give standard-sized panes. All this geometrical complexity is handled with relative ease by CAD systems, but would have been to say

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5. The new roof dwarfs the existing station buildings.

7. View from an adjacent building: the external rails arrest snow and provide a track for the access equipment.

8. A view embracing virtually the whole of the glazed span produces a slightly peculiar perspective effect, but emphasizes the distinction between skeleton and skin.

9. The glazing system features silicone butt joints in the longitudinal direction.

the least a deterrent without them; perhaps this structure and others on our screens today will be looked back on as children of their time, in the same way as the '45° set-square' architecture of the '60s is now regarded!

The choice of the primary spanning system was only the first step in the design process, which involved close interaction between London, Paris and St Moritz. The most appropriate and efficient arch member was a 406mm diameter circular hollow section in grade 50 steel. It was decided that the secondary structure should also be tubular, and run longitudinally at approximately 2m centres. Since these purlins also act as ties between the divergent arch pairs of the *Zitronenschnitz*, they should occupy the same plane. However the skin of the roof, the glazing system, had to be set distinctly above the plane of the skeleton so as to make a clear differentiation between the two.

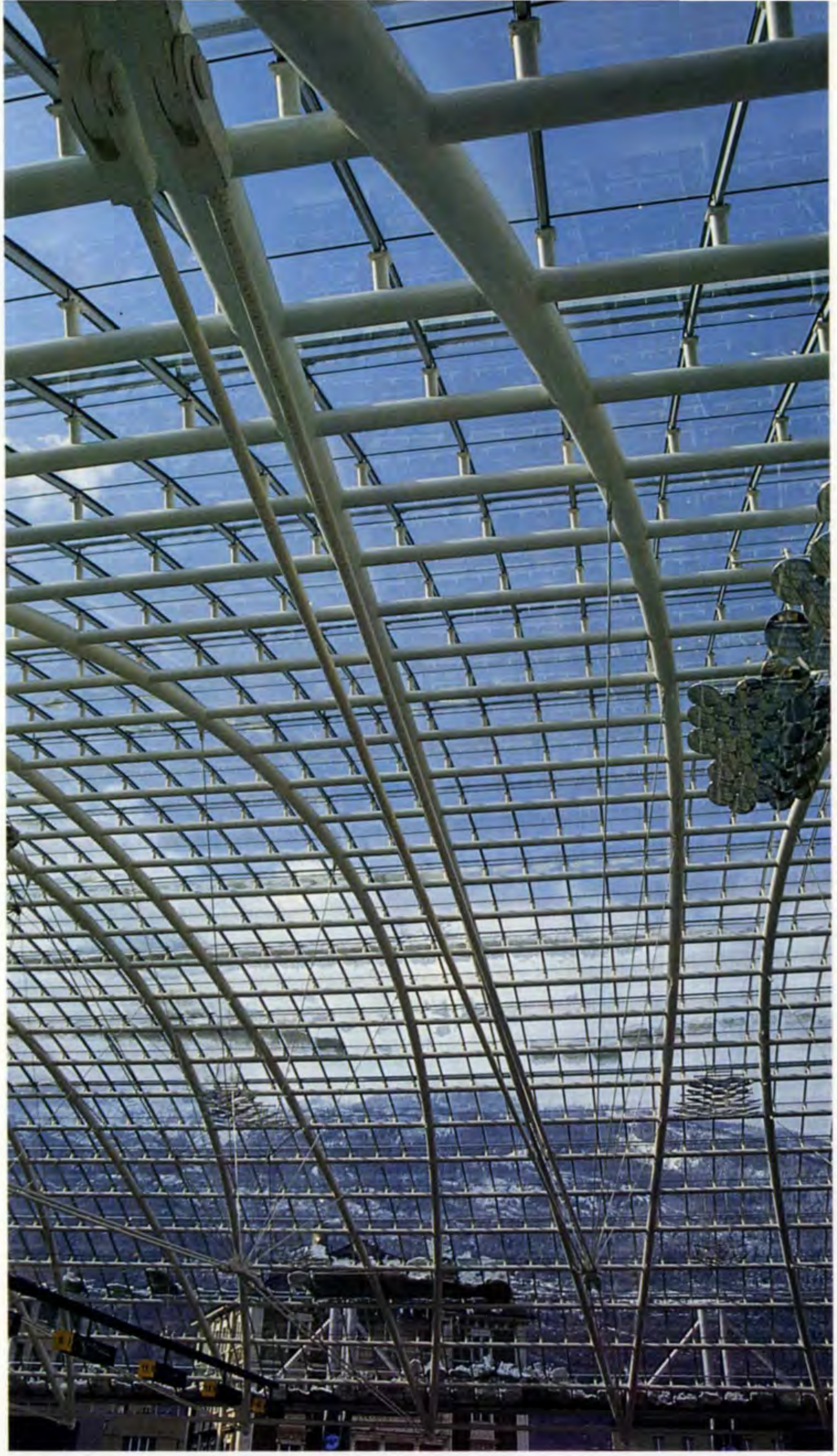
Glazing system

Fundamental decisions about the glazing system were that the material should be glass — nothing else would maintain the desired transparency in the long term — and that flat panes, 2m long, would make an acceptable faceted approximation to the curve of the roof. Laminated glass was required for safety, but double glazing was unnecessary — the roof is only a cover, with no sides. Any slight condensation was considered acceptable.

For transparency, and in order not to impede the flow of rainwater down the slope, silicone butt joints are used in the longitudinal direction. Conventional glazing bars and capping sections are used in the 'hoop' direction. This supports the visual differentiation between structure and cladding system, since no structural parts run in this direction.

With the uppermost panes inclined at little more than 1° to the horizontal, it is hoped that no unsightly puddling (leading to dirt encrustation) will occur. Toughened glass (as one leaf in the laminate) was considered but ruled out on cost grounds. Ordinary laminated glass, though less resistant to accidental breakage, has performed well in similar overhead situations, and the tenacity of the silicone on two sides can be expected to enhance the safety of the system.

RFR devised a glazing bar detail which accommodates, in the gap between the panes of glass, slim brackets to support the external snow rails. These are necessary to limit 'avalanching' of snow down the slope (which at its steepest is 40°) and also serve as tracks for the access gantry for cleaning and repair, which is essential equipment for a roof of this type. With the exception of the extruded capping piece, all the metal components associated with the glazing system are unpainted stainless steel, which further differentiates them from the white-painted structural steelwork.



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Support structure

The spacing of the *Zitronenschnitz* elements is approximately 7.5m, which allows the tubular purlins to be kept appreciably smaller than the arch members. To minimize impeding circulation at platform level, the perimeter columns are spaced approximately 15m apart. Each column is composed of a pair of 406mm diameter circular hollow sections, battened together at intervals, and reaches out, in the shape of two 45° triangles, to support the ends of two *Zitronenschnitzen.* A prominent fork-and-pin detail emphasizes the articulation at the suspension point.

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The columns themselves act as cantilevers from below, strong and stiff enough to resist lateral wind forces but not so stiff as to generate untoward resistance to thermal expansion or arch spread under imposed load.

It will come as no surprise that snow load, at 1.6kPa, is high by UK standards. In spite of this, wind uplift — to which a tied arch is inherently vulnerable — called for greater design effort. Specialist wind engineering advice was taken on design pressures, based on analysis of local wind records and site topography, but, because of the similarity of the roof to previously studied shapes, no wind tunnel testing was considered necessary. The conclusion was that the mass of the structure should be increased over the *Zitronenschnitzen* at each end where peak uplift pressures can apply, in order to maintain an ample factor of safety against reversal of load on the arch. A conservative approach was taken, partly because a decision had to be made before the final weight of glass was confirmed. The wall thickness of the main tubular arch members was increased to add the necessary mass: appearance remains identical to the others since the outside diameter does not change. To the structural purist it may be slightly disconcerting to add mass in the form of steel, but only a few arches are affected and the onlooker need never know!

One of the attractions of the *Zitronenschnitz* shape is that it lends itself to an elegantly curved end — on plan, as well as in elevation. A variety of non-standard glass panes, triangular and trapezoidal, is not too much of a problem with untoughened glass which can be cut to size after laminating. Only one end of the initial phase has been

10. The north-east end, complete with column.

11. The contractor opted for virtually all-welded construction, with good access from the bus deck under the greater part of this phase.

12. Various stages of assembly can be seen in this view, from the almost isolated *zitronenschnitz* unit on the right to the completed glazing at the end.

13. Construction under way at the temporary end. Escalators down to the railway platforms have yet to be installed, and the whole span is temporarily supported.

14. The bus deck: lingering snow creates the dapples on the roof.

15. The clusters of convex mirrors, and the spotlights which project onto them, are clearly seen in this view at the north-east end of the first phase.

16. The curved end of the roof seen from the bridge at the south-west end of the station. Buses enter under the building on the left.

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given this treatment; the other is a straight 90° end, destined to be converted into a movement joint with the Phase 2 continuation over the railway tracks.

To return to the columns, the substantial bending moments at their feet (due to cantilever action to resist lateral wind load) have obvious repercussions for foundation design. In fact, very substantial footings are required in any case, to resist stipulated impact loads just above platform level (notional forces, measured in MN, to represent derailed trains). Consequently the penalty for cantilevering the columns is not as severe as might be imagined. The majority of the Phase 1 columns are attached to the bus deck in any case, and advantage is taken of this in the design. Future Phase 2 columns, which do cantilever from ground level, will require a small increase in diameter compared to those of Phase 1.

Construction

Working above an operational railway station, with overhead electrification, makes the influence of erection method on design more than usually critical. While a working platform, in the shape of the bus deck, was available for most of Phase 1, this will not be the case in Phase 2.

The strategy developed was for pairs of *Zitronenschnitzen* to be preassembled over the working platform (which in Phase 2 will be a wide footbridge to be constructed across the middle of the station) and rolled or slid as a self-stable unit along temporary staging down each column line. Only the minimum of purlin connections had to be made at height. Columns could then be lifted into place, or restored to verticality, to allow the pinned connection to the arch to be made.

Tubular structures look best if fully welded, and for a structure on this scale that inevitably includes site welding. This particular nettle was grasped at a very early stage in the design process. However, it was regarded as essential that all site welding should be relatively straightforward — tube-to-tube butt welds unimpeded by intersecting members or simple fillet welds. An 'invisible' bolted detail, suitable for the purlins at their point of contraflexure, was devised in order to avoid welding in difficult circumstances over the tracks. It was foreseen that the complex tubular intersections where the arches converge at the tip of the *Zitronenschnitz*, and the slightly less complicated 45° junctions of the columns, could most economically take the form of steel castings. Details were developed on this assumption. In the event, the successful tenderer preferred to fabricate the majority of these details by welding in the conventional way.

The fabrication contract was won, against international competition, by a joint venture led by Tuchschmid, a firm based in north-east Switzerland specializing in both steel structures and glazing systems. Several UK companies contributed as suppliers or sub-contractors. Erection of the roof took place during the summer of 1992.

Phase 2, which will more than double the total length of the roof, is not due to be constructed for a few years at least and may have to wait for an upturn in the economic climate, to which Switzerland is not immune.

While this description has concentrated on the roof, mention should be made of the bus deck from which it springs. This is also a steel-framed structure, treated in an architecturally interesting way.

Services

The lighting installation is unconventional and most impressive. It is another example of international collaboration, involving the Austrian consultancy of Prof. C. Bartenbach. Virtually all the illumination is indirect, originating from powerful spotlights mounted on the columns and reflected off convex mirrors in clusters, rather like grapes, at roof level. The effect which is desired, and achieved, is different from the uniform intensity of floor-level illumination which many electrical engineers would regard as their objective.

The electrical risers and the downpipes from the gutters (stainless steel box sections with full-bore outlets) are enclosed within aluminium channel sections clipped to the columns. Apart from a system of departure indicators for the buses, and the clusters of mirrors, no services are suspended from the roof itself. Provision is made for an internal access system, but this will not be installed until Phase 2; for the present, cleaning and maintenance can be done from mobile equipment operating on the bus deck.

Conclusion

Until recently, a project of this kind would, no doubt, have been viewed as an extravagance in a British city — we are accustomed to accepting a public realm which is visually and otherwise impoverished by comparison with the private one, and nowhere more so than on public transport. (Change trains at Leeds or Birmingham, say, or try to change between train and bus, to experience the result.) But there are signs that this attitude is changing. Perhaps the Chur project may stand alongside its more glamorous counterparts at Waterloo, Lille and Roissy as an example of what can be achieved.

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Credits
Lead client:
PTT/RhB/SBB
Architect:
Richard Brosi/Robert Obrist
Consulting engineers:
E.Toscano AG/Hegland & Partner AG
Sub-consultants for roof design:
Ove Arup & Partners
Alastair Hughes, Peter Rice,
Mehrdad Bolourchi, Matthew Lovell
Sub-consultants for glazing system:
RFR
Lighting sub-consultants:
Bartenbach AG
Illustrations:
1, 5, 11-13: Photos: Tuchschmid AG
2: Courtesy Swiss Federal Railways
3, 4: Obrist und Partner
6: Robert Obrist
7-10, 14-16: Photos: Kurt Gahler

Mirror mirror on the wall . . . How fair is the engineer's image?

This paper is based upon a talk given to the former Old Centralians, the alumni of Imperial College, London, on 13 May 1992.

Sir Jack Zunz

Decline and fall?

You may recall that the wicked stepmother in *Snow White and the Seven Dwarfs* consulted her mirror frequently; yes, she was the fairest of them all — except for Snow White. The self-delusion that she was the most beautiful woman was cruelly exposed by the mirror. I believe self-delusion to be an endemic and debilitating ingredient of our professional infrastructure; more of that later.

Britain's industrial decline is real and serious, and has been going on far longer than most people are willing to admit. It is only comparatively recently that there has been general, if not total, realization of this home truth, and open discussion on how to halt and reverse the decline has become more commonplace. The status and hence the image of the engineer are intimately interwoven with this industrial decline.

Statistics are often suspect, but if a series of indicators all point in the same direction, perhaps one should sit up and take note. Whether it is per capita GNP, percentage market share, currency strength, growth rate, or any of the plethora of indicators dreamt up by an ever-increasing army of economists, they all present the same plain message and it is stark. Our industrial performance is not good enough. Successive governments have come to power with a variety of panaceas to cure Britain's ills — to little or no avail so far. The 1992 General Election campaign and its fundamental adversarial nature failed once again to bring home to the public at large the necessary disciplines and measures which in time *might* bring about a more productive and economically more successful society.

The populist exhortation to be part of the 'enterprise culture' is not enough. To be enterprising, to go out and establish new ventures and businesses is all very laudable when there are appropriate skills to back up the enterprise. But so much of this much-vaunted 'enterprise culture' is built on froth and it is beginning to show. Simplistically, wealth is created by one of, or a combination from, three processes — growing things, mining things, or most important of all, making things. Other economic activity pushes this basic wealth around. Service industries are becoming ever more sophisticated, but they need something to serve. Major service industries — banking, insurance, advertising, telecommunications, entertainment, leisure, retailing, distribution, transport, travel and so on — ultimately depend for their existence on the three wealth-making processes, both for their paying customers as well as for their equipment and machinery.

In that context an enterprise culture, based on wealth creation, can only flourish if it is underpinned by a large cadre of broadly-trained and educated professional engineers. Without this foundation, the enterprise culture will remain a castle in the air.

The American historian Martin J. Wiener published a book about 10 years ago called 'English culture and the decline of the industrial spirit 1850-1980'[1]. Wiener's thesis is that since the middle of the 19th century English, or more broadly British, culture has experienced a profound polarization. On the one hand 'Englishness' has become identified with a pastoral image of a green and pleasant land, while on the other hand 'industrialization' has come to be associated with dark satanic mills, ugly cities and general squalor.

He goes on to argue that the generations following the heroes of the Industrial Revolution were absorbed into the landed gentry and that a revulsion against the less pleasant aspects of industrialization and the adoption of the rural idyll as the desirable aspiration of modern life have resulted in more than a century of psychological and intellectual de-industrialization.

Wiener's arguments, though flawed in some detail, are substantially valid — and nothing is more persuasive as to their validity than the successive attempts to make appropriate reforms to education and training in this country.

This peculiarly British disease of industrial decline is therefore not new. It is deeply rooted in our society and, as Wiener says, goes back to the beginnings of the Industrial Revolution. For nearly 150 years individuals and official bodies, men of vision and Royal Commissions, have attempted to convince public opinion and governments that the battle for export markets, for economic wellbeing, was being lost in the schools and quadrangles of Britain. It comes as a surprise to many that this debate has been going on for as long as it has. Cardinal Newman, one of the most influential men in education in Victorian times, apparently thought all 'useful' knowledge to be trash — he was more interested in the cultivated gentleman and providing him with a so-called 'liberal' education.

Why liberal and scientific/technological educations should be mutually exclusive I shall never know, but it is a theme which for a number of reasons has become deeply entrenched in the culture, in the education system, and indeed in the minds of the people of this country.

Correlli Barnett in his excellent, somewhat frightening, and salutary book 'The audit of war'[2], articulates only too well why successive governments, spurred on by commissions of inquiry and other official bodies, have failed to take the advice given them and to heed repeated warnings on the consequences of the lack of appropriate education in general, and technical education in particular. Barnett writes: 'The exponents of what Newman called "liberal knowledge", i.e. knowledge unrelated to what is "particular and practical" and enshrined in such disciplines as the classics or mathematics, won a particular success which was to determine the character of the British state bureaucracy for the next century. For, thanks largely to a coterie of Oxbridge alumni, the entrance examinations for the newly reformed civil service were framed on the assumption that governing an industrial nation required exactly the same kind of "liberally educated" intellects as might otherwise seek a career in the Church or even the university. Thus in the early 1850s was born the Whitehall mandarin, able at a touch to transmute life into paper and turn action into stone.' And thus the corridors of power have since been manned by Newman's 'liberally educated' gentlemen.

The image of the engineer is inextricably interwoven with that of industry. The engineer is the basic, the essential ingredient for a successful industrial society. Without the engineer, civilization would not survive — we owe our health, our wealth, our means of transport, our shelter to engineers and engineering. That is not to say that other disciplines do not contribute to a civilized society.

But technology and its applications are both the saviour and the potential threat to humanity. To use Cardinal Newman's terminology, 'liberal knowledge' may be a key constituent of a civilized society, but without technology society will not survive, let alone prosper. So for the sake of our continued wellbeing, let alone survival, a cadre of highly gifted, educated and trained *and* committed engineers is a core requirement. The most able and talented young people must be attracted into the profession. Can this be done? At present the signs are not promising.

When Samuel Smiles published his 'Lives of the engineers'[3] in the mid-19th century the Prime Minister, Gladstone, wrote: 'It appears to me that you have given practical expression to a weighty truth — namely, that the character of our engineers is a most signal and marked expression of British character . . .' 19th century British engineers appeared to be heroic figures — symbols of a great age, much like the sea captains of Elizabethan times. Even today, many members of the public have heard of Brunel and his singular achievements, of Stephenson's locomotive, and Watt's steam engine; Stephenson and Faraday are even displayed on our banknotes. But the museum in which Watt's engine is displayed is called the Science Museum, even though most of the displays when I last looked at them were of an engineering nature — so why is it not called the 'Museum of Engineering' or at least the 'Museum of Science *and* Engineering'? What went wrong?

More than 100 years after Gladstone, our current Prime Minister John Major said (some five months *before* the Election): '. . . and that places a special premium on the skills of those who can make things happen, those who can apply scientific knowledge, those who can make sure that scientific knowledge uses nature's resources to benefit mankind. And that in the wider application is what engineering is about and it is because of what engineers have done and the fruits of their work that these days we live healthier lives, longer lives, in many ways more comfortable

1. The epitome of heroic Victorian engineering: the Forth Rail Bridge, completed in 1889. (Illustration: Simon Miller, from the forthcoming book 'Bridges', courtesy of Mitchell Beazley Publishers.)

2. Engineering can be as visionary and challenging today as in the 19th century: Collage of La Defense, Paris, showing planned location of the 426m Tour Sans Fins, the slenderest tall office building in the world. Architect: Jean Nouvel; structural engineer: Ove Arup & Partners. (Photo: Georges Fessy)

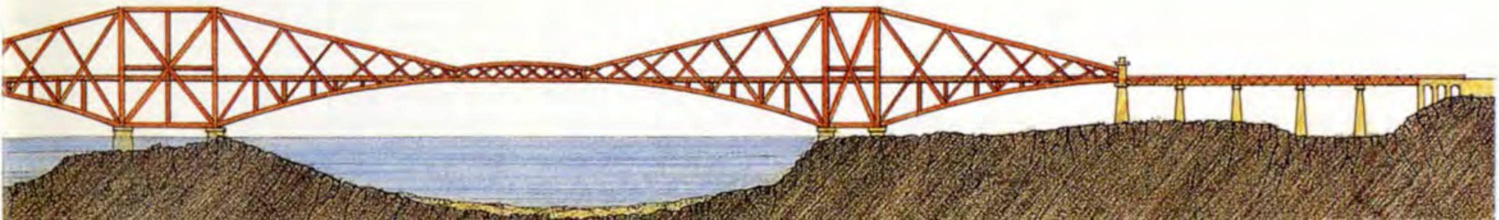
lives than previous generations. Maybe politicians occasionally take the credit for it but the reality is that it is the innovation and brilliance of men and women who have been engineers who have actually brought about so many changes . . .'; and again: 'In years gone past, over generations, I feel we have been less good than some of our main competitors at getting enough of the best young people into engineering. And the reason for that is one I feel deeply about myself and have touched upon on many occasions. It is that instinct embedded deep in our culture that previously tended to disdain industry and give more kudos to classical education than to technological education.'

Rather poignantly, there is a significant difference between Gladstone's sentiments and Major's. Gladstone spoke with admiration of the perceived standing of the engineer at that mid-19th century time, whereas John Major expresses *a need* for approbation, for recognition of engineers in contemporary Britain. The one referred to a social verdict, whereas the other to a social need. This can only be achieved by a cultural shift. The image of the mid-19th century engineer was clear, and heroic; the image of the engineer today is, to say the least, obscure.

What then is the image of the engineer today?

In 1990 Gallup carried out a survey for the CBI to establish attitudes of 17 and 18-year-olds intending to enter higher education establishments. It indicated that 5% aimed to study engineering; about 8% were pursuing a career in 'Research, design or development including engineering' — a composite heading which only pollsters totally ignorant of the needs of industry and the country would dream up. But the trend is clear and the figures don't indicate the quality of the students attracted to engineering; there are strong indications that on average they are not the brightest and the best. In the same survey the rating of industry, in terms of interest and status, was near the bottom of the students' perception. Doctors, accountants and lawyers were at the top in perceived status, interest and pay.

The engineer today is an enigmatic, mysterious figure whose perceived skills vary from being able to tighten bolts to repairing broken water mains. Our environment is generally perceived as being the creation of architects, planners, surveyors and builders, while our industry is under the control of managers who employ workmen of varying skills, including of course technicians and last and usually least, designers. This deliberately rather caricature-like picture is to make the point that the engineering world is lost in a kind of semantic and conceptual miasma. The image of the engineer, the professional engineer, has become lost in the mists of time — that time being the latter part of the 19th century.



3. Principal navigation span for the Öresund Link between Sweden and Denmark, in the shortlisted design proposed by the ASO Group, led by Ove Arup & Partners. The pylons are 200m high and the span 490m; the double deck, rare for a cable-stayed bridge, is designed to carry a roadway above and rail below.

What then is to be done?

The first thing is to stop whingeing. I have no patience with those who complain about our lack of status — we get the status we deserve. We the engineers must go out and do something about it. There is unquestionably a vicious circle which has to be broken and turned into a benign circle. The vicious circle goes something like — low rating in image and status, low appeal to talented young men and women, low expectations, low hierarchical achievement and so back to status and image.

It is as well to pause here for a moment. At the first United Kingdom Engineering Lecture, given at the Royal Society in February 1992 by Akio Morita, the Chairman of the Sony Corporation, he said *inter alia:* 'In Japan, you will notice that almost every major manufacturer is run by an engineer or technologist. However, here in the UK I am told some manufacturers are led by chief executive officers who do not understand the engineering that goes into some of their own products. Someone once mentioned to me that many UK corporations are headed by chartered accountants. This strikes me as very curious . . .'

And so it should, for it is a kind of madness which has overwhelmed industry in this country, and can only be properly articulated by a foreigner who can look at us dispassionately and clearly. In our lawyer/accountant-dominated economy, technology is something to be bought, like groceries at a supermarket. Engineers are not thought to be proper persons to head enterprises because their education, their training, and hence their outlook and performance, are thought to be too narrow and inadequate.

Add to this the cult of the professional manager which has become the vogue in the past 15 years or so. This is propped by the burgeoning management consultants industry which feeds on the incompetence of the industry it purports to serve. A manager can manage anything from a mail order business to an aerospace industry, or so the conventional wisdom goes. But anyone who understands even the basic elements of leadership (and I use this word advisedly — not 'management') knows that in general, leaders will only win the support and respect of the led by example and performance. And this respect is most readily gained by a feeling of identity, which can only be achieved when the leaders are steeped in the industry they purport to lead. The oft-repeated proposition that engineers make poor managers and captains of industry is nonsense — and is often made by those who have a vested interest in protecting their position. It is true that not *all* engineers make good managers, but then not all engineers are good designers. Nor are all doctors good diagnosticians. An engineering (or more generally an industrial) enterprise needs leaders with a variety of strengths and talents. What *is* pertinent is the depth and width of education which engineers in this country receive to enable them to aspire to leading roles in industry, so as to make it more successful against foreign competition. Education of engineers is relevant not only to industry but also in manning the corridors of power in government.

It is a difficult issue. The 'two culture syndrome' is deeply embedded in the system. I believe that in order to break into the vicious circle more engineers have to be visible rôle models for young people to emulate, not just for the status and monetary rewards they might (and should) attract but also and, more importantly, for what they contribute to the wellbeing of society. I quoted earlier Correlli Barnett's reference to the Whitehall mandarin whose education was expected to follow what could broadly be termed 'Classical lines'. One would expect that great Departments of state like Transport, Environment, not to mention Trade and Industry, would have many engineers at the most senior levels. There are very few. The private sector is even more deficient in engineering leadership. It is salutary to examine the boards of the leading technical companies in this country and compare the directors' qualifications with that of their peers in Germany, France, Japan and so on.

It is too much to expect effective change in our secondary education system, in the short term anyway. The government's thinking is still inspired by the selfsame mandarins who consider A-levels to be the gold standard of the English education system. Maybe someone will tell them that the rest of the world has gone off the gold standard, but in the meantime we have to make do with what we have. And this is where the engineering institutions could take some initiatives.

Snow White's stepmother was flirting with self-delusion. I am afraid that the engineering establishment in this country has been doing just that for many years. The fragmentation of the profession does not help. Buchanan's book 'The engineers'[4] is an interesting account of the development of the engineering professions in Britain from 1750 to post-World War 1, and graphically relates how the profession has split into its sub-tribes, to the detriment of its standing with the public.

The number of institutions representing the engineering sub-disciplines is a major factor in professional engineering not being effectively presented to the public and to government, with a consequent diminished influence and status. The Engineering Council has little real power and the vested interests of the individual institutions prevent it from presenting a common front as do other professions. The current efforts of Sir John Fairclough to

4. Concorde
(Photo: courtesy of British Airways)

bring about a more united profession deserve wholehearted support. But it is one of those situations where most of us agree in principle that something needs to be done, but somehow there is institutional inertia to be overcome. Why we can't have a Royal Institution of Engineers speaking on behalf of *all* professional engineers seems odd to me, but one must hope Fairclough's efforts will take root. The image of professional engineers would be immensely enhanced if a respected central body was able to speak, and on certain issues to act, on their behalf. This is particularly important in this age of media power, when it is important to have simple concepts which can be easily communicated and understood.

But the institutions in their present guise as learned societies have a more important immediate role. I said that secondary education will not change overnight to give our most talented young men and women a fundamentally broader educational base. It will come in time — maybe influenced by increasingly common European standards, or by the example of others. In the short term the institutions can by their entry requirements gradually introduce those skills which most young engineering graduates now lack.

Proficiency in languages including English, history — at least an historical understanding of the context of their chosen profession — skills in communication: these are but a few examples of the kinds of subjects which could be introduced gradually into the entry requirement.

This could have some interesting consequences. First and most important, young chartered professional engineers would be educated and trained to the same standards as many of their foreign counterparts. Their consequent self-esteem would make it impossible for them to be ignored when top jobs in industry and government came up. At the same time the challenge of becoming a professional engineer might lure more and brighter young men and women into the profession. It could be one way of breaking the vicious and creating a benign circle — rôle models would appear for others to follow. The institutions are really central to changing the engineer's image. Self-delusion, the idea that all that is British is best by definition, has for too long played a part in institutional thinking. The maintenance of the status quo has been paramount — all very understandable when it is viewed as a residue of the Imperial hangover, mixed with a generous measure of post-Victorian pomp. But there *are* signs of hope. In some institutions there is undoubtedly a wind of change. But the most important factor in the first place is for us *all* to agree that there *is* a severe problem in our public image and that collective action with perhaps some personal and corporate sacrifice may be necessary to bring about change. We must rid ourselves of any residual self-delusion, our performance must be improved and must be seen to be improved before our image and hence our status are enhanced in our society.

That brings me to the question of our relations with the public at large. Communications, physical and non-physical, are probably the most significant accelerators for change in this century. As a consequence, the power of the media is a fact of life: we have to live with it, like it or not. I will touch on just two aspects of the media which affect our image. Sydney Opera House was designed by Jørn Utzon, or so the guide who conducts thousands of visitors to the complex will have you believe. No-one else is mentioned in the hour-long tour. The fact that what is now standing in Sydney Harbour was built without a single drawing or instruction from Utzon is beside the point. Our society likes its instant pop images — if they require some fabrication that's alright provided the paying customers are satisfied. And so everyone knows that the Lloyd's building in London was built by Richard Rogers, and that (for those old enough to remember) the Festival of Britain Skylon in 1951 was designed by Powell and Moya. I am a great admirer of Utzon, of Rogers, and of Powell and Moya, and have on many occasions waxed lyrical about their talents. But to imply that they individually created these artifacts is like suggesting that Botham won the Ashes single-handed. I once tried to find out who designed Concorde, surely one of this century's most impressive ikons. It is near impossible — the creation of Concorde was apparently the result of a number of developments with many contributors, some more seminal than others. To raise the image of the engineer in the public's eye we have to strike a fairer balance between obsequious anonymity on the one hand, which is the general case at present, and unfair exploitation of the cult of personality and the 'I did it all' syndrome on the other. This is not easy, but with some imagination it *can* be done.

This brings me to my second point concerning the media. Television is unquestionably the most powerful communicating medium. The key rôle of the professional engineer is seldom if ever seen in documentaries, nor is it generally featured in light or serious drama. Rôle models of lawyers or doctors are regular features in television soaps, and artists or architects regular subjects of documentaries. While we as a breed may not be as exciting as Perry Mason or Dr. Kildare, what we do is often quite breathtaking. The story of some of the century's great engineering achievements, some of which the public now take for granted, are exciting tales and in the hands of imaginative producers could make good viewing. This may be thought superficial, but it does matter if we want to attract young people into the profession. The young, their talents and commitments are central to enhancing the standing of the engineer, and television and of course other mass media are powerful means whereby the young can be influenced. Again the institutions, particularly if their resources can be pooled, can play a central role in introducing engineering in a stimulating manner to the media.

To sum up then, our image is not as fair as it could or should be. The industrial wellbeing of this country is inextricably interwoven with our image because only with a fair image will talented young men and women be attracted to engineering. We must not complain: the solution is in our own hands. Putting our house in order will go a long way to enhancing our image, as will broader educational requirements and greater public exposure. It will take a long time and while looking into the mirror is not all bad news, we should not delude ourselves that all is rosy in the garden — it is not. But it is up to us to get out there and do something about it. No-one else will.

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River Aire Footbridge

Colin Harris
Mark Steele

Introduction

The River Aire Footbridge is the first river crossing to be built in Leeds for more than 100 years. It is sited in the oldest part of the City, separated from the Parish Church by The Calls, a road linking Leeds Bridge and Crown Point Bridge, both of which also span the River Aire.

In 1988 Leeds Development Corporation (LDC) carried out a study to identify the strategic connections between the City and the South Leeds Urban Regeneration Area. A vital pedestrian link was identified from the Corn Exchange through to The Calls across the Aire to link with the south side and the Clarence Dock basin in particular — a site since identified for the Armouries Museum. In May 1989 Ove Arup & Partners were appointed by LDC to carry out a preliminary appraisal for the pedestrian bridge.

The ground conditions comprise alluvial sands and gravels, overlain by made ground associated with warehouse development along the banks of the River. The underlying bedrock contains lower coal measures of the carboniferous age: mudstones, sandstones, siltstones and coal seams. The Black Bed coal seam is present close to rockhead but no evidence of shallow mineworking was established at the abutment sites.

Constraints

The geometric constraints of the site defined a very narrow envelope in which to fit the bridge structure. The relatively short approach possible on the north bank from The Calls to the River edge, combined with a maximum gradient, defined the upper bound of this envelope, whilst the requirement for a navigation clearance to match that of the adjacent Crown Point Bridge, together with flood clearance at the river edges, dictated its lower limits. A further requirement, that there should be no support within the River, necessitated a structural form with a relatively thin deck supported largely above soffit level. All these constraints led to a study of through-girder, suspension and cable-stayed solutions.

1. Location plan.

2. Lifting the deck, 10 June 1992.

The asymmetry of the warehouse buildings on the north bank and open space on the south bank suited a single mast, cable-stayed solution. A through girder using the girders as parapets would have been reasonably efficient but of solid appearance, and it was also considered that attempts to replicate the tracery of the adjacent Victorian bridges would be contrived. The single mast solution was selected and further studies undertaken to optimize the design.

The solution

Following sketch schemes with varying numbers of cables, different inclinations of the mast and parapet types, the final built form was selected. The design intent was to achieve simple uncluttered detailing, possibly reflecting the nautical flavour of masts and cables in such important elements as parapets and handrailings.

During the scheme studies the advantages of combining the principal structural elements as part of the parapet were recognized, particularly as a relatively thin deck could be achieved. Studies of main members spanning between cables led to the selection of vierendeel girders. The top boom (400 x 200 x 16mm rolled hollow sections (RHS) in grade 50 steel) forms the lower part of the parapet, whilst the bottom boom (250 x 150 x 16mm RHS in grade 50 steel) forms the support to transverse beams (205 x 102 x 25mm universal beam (UB) grade 50 steel with the top flange removed to form the profile).

The short vertical members of the vierendeel girder were also formed from 400 x 200 x 16mm RHSs.

The 8mm thick grade 50 deck plate is stiffened by 100 x 100 x 8mm rolled steel angle (RSA) members running between transverse members and parallel to the centreline of the deck. A curved 8mm cover plate is provided on the outside of each vierendeel girder to give a clear drainage path for deck surface water away from the vierendeel girder, as well as clean simple detailing for the external elevations. The adoption of twin vierendeel girders with the deck spanning between enabled a simple boss cable connection fabricated from a stiffened circular tube and a stiffened fabricated connection to 400 x 200mm RHS members.

A concrete mast was appropriate, bearing in mind the largely compressive forces and the sculpted cross-section. The selection of tension stainless steel wire parapet between vertical posts cut from 203 x 133 x 30mm UBs, and timber handrails, was in response to the slender deck profile and the nautical aesthetic. Conventional pedestrian parapets would detract from the slender appearance, particularly from a distance. The stainless steel wires pass through the parapet uprights and are isolated by nylon grommets at each location.

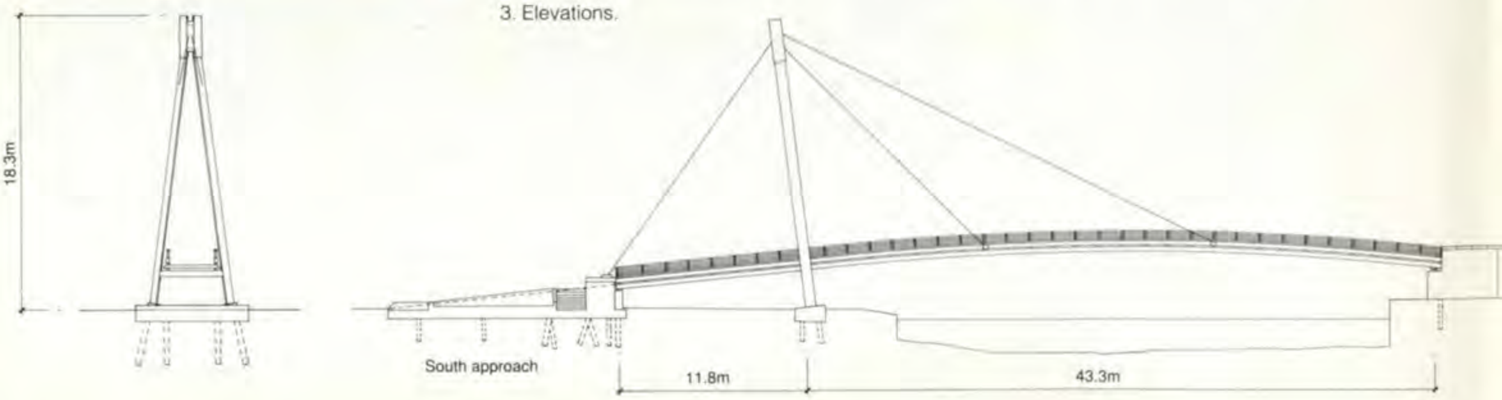
Construction

The foundations comprise 230mm diameter mini-piles founded in sandstone. During construction the piles beneath the south abutment/kentledge block supported its self-weight until the dead load reaction from the backspan cables relieved some of this load. In extreme flood conditions an increased factor of safety is provided by the same piles acting in tension.

A Department of Transport paint specification was selected for the steelwork, comprising blast clean, metal spray sealer, and MI0/chlorinated rubber undercoats and finish. A total dry film thickness of 200 microns was achieved. The deck footway surface is a two-component coal tar epoxy manufactured by Cicol. All exposed concrete finishes including the mast were treated with anti-graffiti paint.

The deck steelwork was fabricated by Billington Structures and delivered to site in three sections, welded together on temporary staging to achieve the correct profile prior to erection. The white concrete mast was precast by C.V.Buchan and delivered to site as one complete unit. The contractor elected to erect the deck and mast in one operation using 500-tonne and 200-tonne capacity mobile cranes from the south bank. In a 12-hour operation in June 1992, the mast was lifted vertically, the steel deck threaded through, and the two components lowered onto the permanent bearings. Three months later the project was completed with the landscaping and approach works.

3. Elevations.

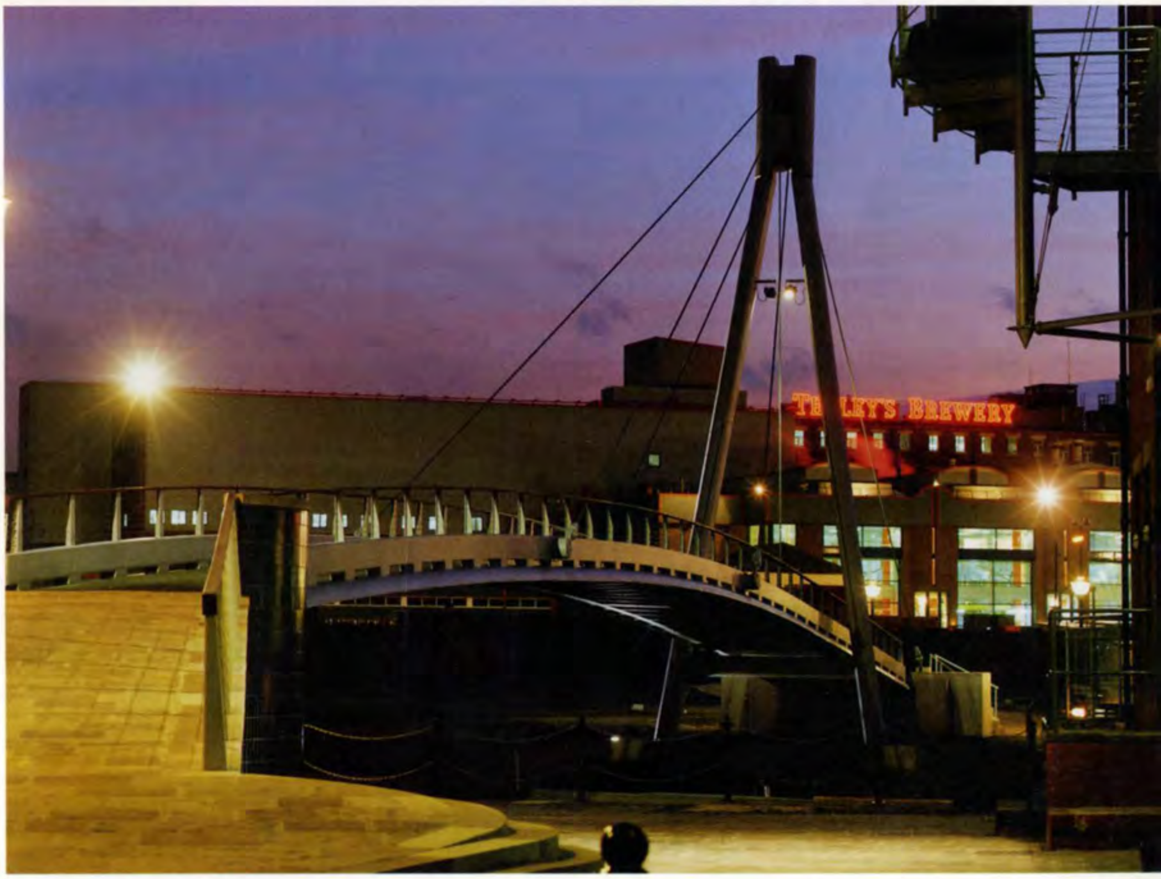


4. Underside of the deck, showing transverse and longitudinal stiffening.

6. Backstay anchorage and the 'nautical' handrail on the southern bank.

5. The bridge viewed from the east.

7. The bridge at dusk from the north bank. In the background is the Tetley 'Museum of Pubs' (building and civil engineers: Ove Arup & Partners Leeds).



Credits
Client:
Leeds Development Corporation
Structural engineers:
Ove Arup & Partners Leeds
Colin Harris, Mark Steele, Gillian Blake, Adam Crewe, Peter Chamley
Main contractor:
Kier North-East Ltd
Illustrations:
1: Martin Hall; 3: Steve Capper
Photos:
2: Chris Shaw Photography;
4-7: Paul White Photography

North approach

The Weardale Line

Adrian Gurney   Ed Humphreys

Introduction

The history of Weardale, the upper valley of the River Wear in County Durham, is closely connected to that of the Industrial Revolution, and particularly the railways' role in that Revolution.

In the lower dale there has been coal mining since the 14th century. By the 18th century the demand, particularly from London, meant that means were sought to connect the South Durham coalfield to Teesside. After a canal proposal failed, it was the Stockton and Darlington Railway which provided the outlet to the sea in 1825. Witton Park was the western terminus of the line.

In the upper dale, limestone, iron ore and lead mining companies were the major employers by the 19th century. Opposition from local landowners and the high expenditure involved meant that a rail connection to Stanhope was not achieved until 1862 and to Wearhead only in 1892, by which date the mining boom was over.

Weardale is now predominantly an agricultural area, with few signs of past industry. The upper dale is now part of an Area of Outstanding Natural Beauty and the lower dale an Area of County Landscape Value. The towns and villages are also of high visual quality and are protected by Conservation Area status.

The de-industrialization which began in the 1890s meant that the Weardale Railway never carried the amount of traffic forecast prior to construction. The passenger service from Bishop Auckland was withdrawn in 1953, and by the 1970s the only freight use was related to the cement works at Eastgate. In 1992 Blue Circle reassessed its national distribution system in the context of long-term decline in the cement market, and the increasing costs of rail usage. Transfer of freight from the Weardale line was announced to take effect in April 1993.

The brief

The local authorities in the area led by Durham County Council together with the Countryside Commission, and supported by a large number of local groups, sought an independent study to assess, prior to the closure of the line:

(1) whether there was any possibility of Blue Circle reverting to rail use in the short or long term

(2) what effect the withdrawal of freight might have on the remaining passenger line from Bishop Auckland to Darlington, and whether there were any actions needed to ensure its continued operation

(3) what opportunities there might be for other uses of the line planned for closure between Bishop Auckland and Eastgate.

Arups' Newcastle office requested assistance from Arup Economics and Planning and Arup Transportation in undertaking the study. The work required close liaison between the different groups involved in the project.

1. Steam locomotive at Shildon Tunnel, 28 March 1993.

2. Weardale Line location plan.

The Blue Circle decision

Discussions were held with Blue Circle and British Rail to clarify the reasons for the decision and its implications:

- Recession had led to lower demand for cement and keen road competition.
- The volume of cement moved from Eastgate was already below the 300 000 tonnes minimum required by BR, at which a cost penalty was to be imposed.
- The reduction in Blue Circle's national network of depots meant that the sophisticated system of shunting and trip working needed for rail movement was no longer viable.

A short-term change of decision was therefore extremely unlikely. For the long term, consideration was given to the possible impacts of privatization, and the changes in grant support currently proposed by government to encourage diversion of freight traffic from road to rail. An illustrative example was developed to indicate whether a private freight operator might find rail haulage financially attractive.

Based on previous research by Arups, assumptions were made about average carrying distance, road and rail haulage costs, and depot charges. Application of the proposed grants was estimated to reduce rail costs below road haulage costs at about 300 000 tonnes per annum. Reversal of the decision would, however, require assured movement of about 400 000 tonnes — equivalent to the previous maximum rail usage at peak production.

Darlington to Bishop Auckland

Information from BR Regional Railways was used to assess the existing financial performance of the line from Darlington to Bishop Auckland — it was broadly average for regional railway services. Since the freight usage by Blue Circle only covered the marginal costs incurred there would seem to be no immediate threat to this section of the line. However, future opportunities for further traffic were examined:

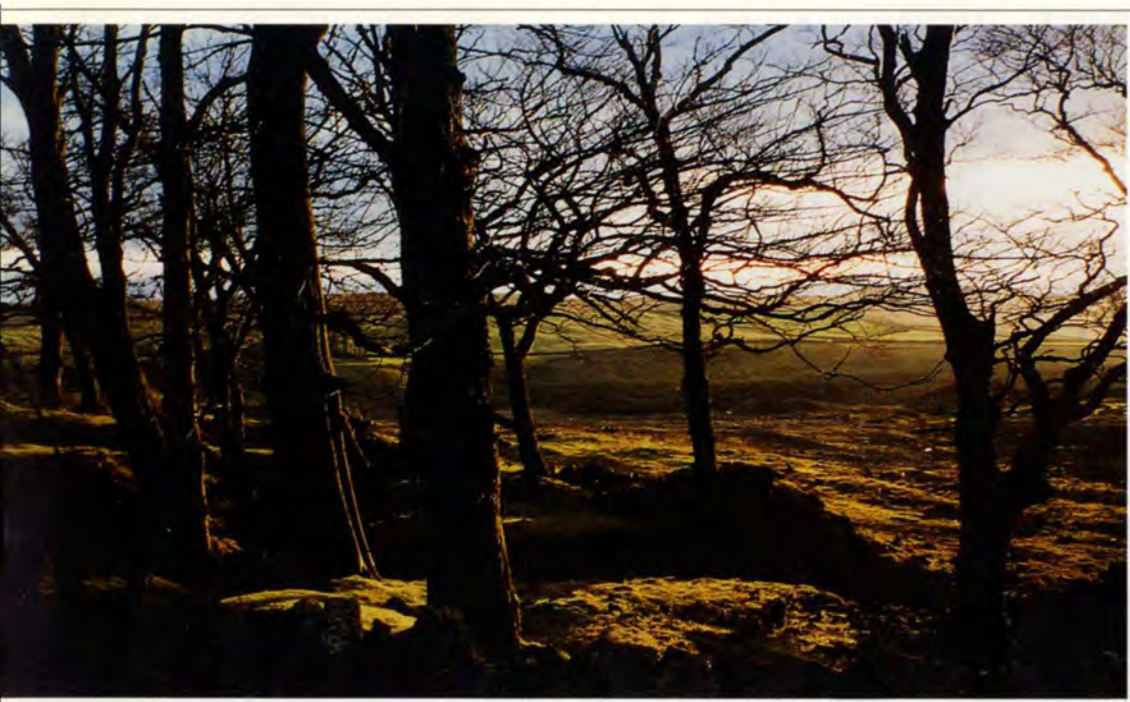
(1) Improvement of the existing passenger service by introducing a regular hourly service was found to be practical and cost-effective. With an increase of only £50 000 on top of the renewal/upgrading costs needed in any case to maintain the present service, an increase in net revenue of about £170 000 p.a. was forecast. The study also suggested that an additional station could be worth pursuing in terms of revenue increases.

(2) The opportunity for development of a freight depot at Faverdale (north of Darlington) had been the subject of a previous study, but without consideration given to the economic case. Comparisons were made between road and rail haulage costs, suggesting that there could be a promising role for private sidings or a specialist terminal geared to wagon load traffic, and to/from long-haul destinations in central and southern Europe.

Bishop Auckland to Weardale

The line into Weardale was seen as potentially providing public transport access for the local community, an opportunity for further freight use enabling waste disposal to be developed in the Dale (in worked-out quarries), and possible development of a steam railway to attract visitors.

Extension of the existing passenger service into Weardale from Bishop Auckland was unlikely to be cost-effective. There would be major capital costs for station development, and an operating cost of £350 000 p.a.



3. Newlandside West Quarry, Stanhope.

4. Level crossing and former station building, Witton-le-Wear.

5. River Wear, Durham Wildlife Trust Nature Reserve, Witton-le-Wear.

The low population in the Dale meant that an annual revenue of under £100 000 could be expected.

With regard to waste disposal, the opportunity for connection to the railway at Heighington Lane waste transfer station and at Stanhope quarries had both been maintained. The study indicated that rail had a cost advantage over road haulage only if over 500 000 tonnes p.a. were transported over distances greater than 80km. This would only be likely if large quantities of waste from surrounding counties were to be available, indicating the need for a major shift in comparative costs of incineration and disposal.

Steam railway

A summer Sunday service into Weardale has been supported by the local authorities since 1988, and various studies have suggested that development of a steam railway could form a key feature of a tourism strategy for the area.

The Arup study looked at previous work and assessed whether the proposal was worth pursuing further. Comparisons were made with other steam railway ventures in the region to judge how far the Weardale Line could offer an attractive alternative to visitors. The main conclusions were that:

- The railway would need to rely on tourist visitors holidaying in the area for the majority of its income and would be competing with the North Yorkshire Moors Railway for such custom.

- Its direct accessibility from the East Coast Main Line and the A1 and A68 corridors, plus the range of current and proposed visitor attractions, would provide some significant advantages.

- The area's connection to the railway heritage of the early Industrial Revolution provided a strong focus for development of the line.

- A strategy would need to be developed which concentrated on integrating appropriate attractions, and marketing the railway at associated tourist locations in the region.

- There were several key conditions for the success of the venture which would need to have realistic commercial objectives.

Conclusions

The steam railway was the one initiative which could be directly influenced by the client bodies, and enable retention of the line in the timescale required. It was therefore recommended that the client undertake a business plan for the steam railway and that BR be asked to postpone a decision on the re-use of the redundant track, to enable progress to be made.

With regard to the other possible initiatives, BR expressed particular interest in the possibilities of improvements to the passenger service between Darlington and Bishop Auckland. As to freight and waste disposal, long-term opportunities suggested that continued safeguarding measures were likely to be appropriate.

The report was prepared within a very short timescale and the client has expressed considerable appreciation of its usefulness. In view of the current changes on the railways it is likely that similar studies will be requested in the future, and Arups are building up a significant body of experience to assist in such work.

Credits

Clients:
Durham County Council,
Wear Valley District Council,
Sedgefield District Council,
Darlington Borough Council,
Countryside Commission.
Consultants:
Ove Arup & Partners Newcastle Office
Mike Brown, Ray Noble
Arup Economics and Planning
Mark Bostock, Adrian Gurney, Andrew Marsay
Arup Transportation
Ed Humphreys, Ben Still
Arup Highways
Richard Foster
Illustration:
2: Jon Carver
Photos:
1: North News and Pictures;
3-5: Adrian Gurney

St. George's House, Manchester

Geoff Bickerton
Steve Burrows
Mark Elsegood

Introduction

In 1908 the Young Mens Christian Association (YMCA) identified a brief for a prime 1100m^2 Manchester city centre site (Fig. 2), adjacent to the Midland Hotel and the Central Public Library. The proposal included a cafe, billiard room, kitchen, shops, offices, two auditoria seating 1000 and 160 respectively, classrooms and lecture theatres, a swimming pool, gymnasium, running track and two fives courts.

The planning height limit of 30m on the façade set the overall criteria, and determined the need for eight levels including a basement. A design was developed based on a masonry-clad steel frame, and was put out to design-and-build tender. Five contractors bid on the basis of a performance specification and each was asked to produce a designed response and a construction programme. Four of the returned tenders were deemed to have met the brief, and the contract was awarded to the second lowest tenderer, J.Bentley & Co. of Bradford. They were chosen because of their unique response: they had designed the building with the swimming pool at fifth floor level and the running track suspended from the roof. The large auditorium was on the first floor, occupying two storeys on the north side of the building. No tanking or waterproofing was proposed to either the roof or basement and the structural frame was to be formed using a new material — reinforced concrete. The tender sum was £35 000.

The building (Fig. 1) was completed in 16½ months and proved a tribute to the skill and confidence of the designers — The Trussed Concrete Steel Company Ltd of Detroit, USA, who paid for the design to be checked by a British Chartered Engineer as requested under the terms of the contract.

1. The building as originally completed in 1909.

Original building design

Reinforced concrete was not recognized by the Manchester by-laws in 1908, so the city authorities involved themselves closely in the design and indeed the basic design criteria. For example, the engineer proposed that each floor carry a superimposed load of 8kN/m^2, but the local authority insisted upon 11kN/m^2 — over four times the current British Standard recommended loading for offices (2.5kN/m^2). The city also required prototype testing to destruction of concrete elements to prove the design assumptions.

The original designers, however, still managed to incorporate many unusual features with the new material. Even the 9m high flagpole was in reinforced concrete, though the original designer noted that during a stiff breeze 'the pole whipped about like a piece of lance wood, moving about four inches out of the perpendicular in each direction'.

Interesting construction techniques were also used, including erecting the elements of the terracotta façade adjacent to a single-sided timber former and then filling the void with concrete using the terracotta as permanent formwork.

The principle structure is of square reinforced concrete columns, with hooped reinforcement cages supporting reinforced concrete beams. These carry reinforced concrete ribs with hollow terracotta infill blocks known as the Kahn floor system, a peculiarity of which was the use of bent up steel wings attached to the rebar which supposedly acted as shear reinforcement. Additional shear link reinforcement was rare.

Each floor is covered by a structural screed to achieve composite and diaphragm action. Stability was secured by a combination of framing action together with vierendeel effect of the stout external terracotta-clad façades.

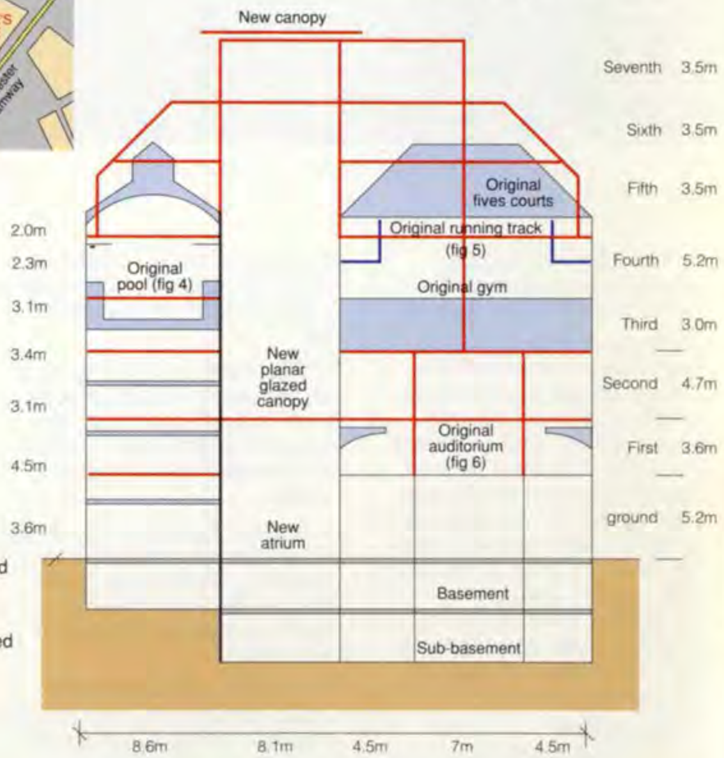
In areas which required large spans such as over the auditorium (Fig. 6), full storey-height walls acted as beams carrying two floors. A large opening at mid-span formed the corridor between cells formed by the wall beams. Concrete portal frames were used at roof level to span over the running track (Fig. 5), which was suspended by reinforced concrete hangers. The concrete was hand-compacted with timber poles.

The only area in which the designers' confidence in reinforced concrete appears to have wavered was beneath the fifth floor level swimming pool (Fig. 4), where steel plate rivetted trusses encased in concrete carry the considerable loads to the reinforced concrete columns. It is important to recognize the pioneering nature of the original designers and the significant learning curve which the builders went through during construction. However, the deficiencies of the time were also abundantly evident in lack of compaction, large tolerances, and initial setting-out errors. Despite this, the building fulfilled its purpose for 80 years: testimony to the robustness of reinforced concrete.

Investigation

In early 1990 Arups were appointed by Manchester and Northern Developments Ltd., on behalf of Eagle Star, as structural engineers for the refurbishment of the building. The structure was listed both internally and externally as Grade II by English Heritage, which meant that a relatively simple façade retention refurbishment was not possible as mini-

2. Location plan.



3. East-west cross-section showing the relationship between original structure and new-build.

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mum demolition of the structure itself was required by the listing. It was thus important to understand fully the limitations of the existing building in order to design the refurbishment. The structure's unique nature and its specification caused much interest in 1909 and generated a number of technical articles which revealed the theoretical design basis for the building. However, only limited 'as built' drawings existed, and because of the pioneering nature of the job, some on-site modifications were expected. Original linen architects' drawings were held by the City Archivist and this information formed the basis for a visual appraisal of the building's performance over its first 80 years.

Various adaptations had occurred over the years, the most significant being the sub-division of the large auditorium, horizontally and vertically, to provide extra accommodation during World War 2. The flagpole had also disappeared although it is not clear whether this was planned! Generally, the structure was found to be in reasonable condition, although the presence of finishes limited the scope of the initial investigation.

The primary visible defects centred around the consequences of the level of workmanship, as well as poor detailing of sensitive areas such as the swimming pool. This had obviously leaked for a long time, and there was much evidence of attempted repairs. The consequent reinforcement corrosion was a particular feature throughout the structure.

The next stage of the investigation involved a physical examination and testing programme to establish the residual strength and variability of the originally specified concrete strength of $16N/mm^2$. From test cores taken, a design strength of $11N/mm^2$ was determined by statistical analysis although values as low as $8N/mm^2$ were recorded. Modern standards require $35N/mm^2$ for durability, so this deficiency needed to be addressed. Chemical testing revealed that no chlorides were used in the original mix but carbonation depths up to 100mm were recorded. Cover to reinforcement was variable: some areas had over 100mm while elsewhere the reinforcement was exposed.

A geotechnical desk study of the site suggested that the foundations would be on Bunter Sandstone immediately below the sub-basement slab. This is typical of the geology in this part of Manchester and no problems in this regard were anticipated for the new building design.


7. The new three-storey building above the refurbished terracotta.

8. Concrete deterioration to soffit of Kahn floor system.

Due to the need to carry out a soft strip of finishes and then to open up areas of the building for more detailed investigation, it was decided that this work was best done once the contractor was appointed. Consequently, a tender was prepared and a contractor appointed.

The investigation work in the early stages of the construction programme had three aims:

- supplementation of the initial investigation following the removal of finishes
- dimensional checking of the as-built structure
- co-ordination of the temporary works support with the new design.

This latter requirement was a key part of the construction works, as it was vital to understand fully the constraints the building imposed on the construction sequence and use this, together with the contractor's buildability expertise, to co-ordinate demolition and reconstruction. This phase of the investigation proved the variability of the frame construction and emphasized the complexity of the task that lay ahead.

The rib sections of the beam and pot floor were notably poor, due to lack of initial compaction of the heavily reinforced small sections. It was also clear that the quality of workmanship improved as the builder became more familiar with placing reinforced concrete; thus the higher level concrete was quite good but the lower levels were honeycombed and poor. Unfortunately for the columns this is the opposite to the loading pattern, so while structural investigation suggested that the floor plates were adequate for the new use, the columns were deemed inadequate, especially at the lower levels.

Architectural design concept

Central Manchester's office stock is not generally of high quality in terms of spacial and environmental performance. St George's House was to be an exception: high quality, well-integrated, visually interesting, and with a high performance HVAC system. The nature of the existing building, with its variable volumes and differential levels, generated difficulties but also opportunities to achieve these ideals.

The circulation concept provides a pedestrian entrance to the office accommodation off Peter Street at the centre of the primary frontage, naturally sub-dividing the ground floor into two retail units. A car park below the ground floor level has access off Mount Street to serve both office and retail users. The retail accommodation is accessed from the street level on the primary frontage.

Above ground floor, rationalization of floor levels was needed so that the eastern half of the frame could be demolished and reinstated to match the generally retained levels in the other half. Additional floors were also to be added to the retained half to sub-divide the large two-storey auditorium space and add upper levels.

A tubular entrance to the office accommodation would link with a vertical circular atrium to integrate the levels and provide vertical access and natural light to the interiors. This atrium would be treated as an external space above first floor level by using a simple open canopy at roof level with a sealed drained glazed canopy at second floor. Above the existing roof parapet a new three-storey, glass-clad building would rise to a plant level with the building services expressed externally.

The result is a building which is formal externally, respecting the heritage of the façades but dramatically light and airy inside.

Sequence and method of construction

The requirement to retain substantial areas of the existing floor and all the façades impacted on the sequencing of demolition, temporary works and reconstruction operations. The temporary works included the following key items:

- propping the two-storey high basement retaining wall to an adjacent building
- propping the unsupported edge of five storeys of retained floors at the rear of the building
- installing temporary stability bracing to these retained floors
- façade retention for half of the elevations.

The contractor developed a complex and inter-related construction sequence involving simultaneous demolition, propping, and reconstruction within the confines of the retained façade and floors. This was continually re-evaluated and re-scheduled as construction progressed.

Before any internal demolition had taken place, a vertical cantilever scaffold façade retention system was constructed on Mount Street and part of Peter Street, anchored into existing columns at basement level and into a ground beam on mini-piles in the external pavement.

The rear basement wall propping system and the five-storey high floor propping and stability bracing were both erected whilst demolition was under way. The basement wall was supported laterally by using vertical channels anchored through the wall with high strength tie rods grouted into the sandstone bedrock under the adjacent building. This provided a clear working space within the building for subsequent demolition and reconstruction. Floor supports and stability bracing were provided by a system of soldier beams braced with scaffolding.

New construction and repair or strengthening of the retained structural elements began as soon as areas were clear and safe from adjacent demolition operations.

Structural design

Any proposal to retain parts of an original structure and insert new elements elsewhere naturally leads to a variety of design solutions. Finding the most appropriate solution inevitably revolves around the flexibility of the design and its ease of integration into variable and often unknown situations.

This requirement for flexibility tended to favour a design based on reinforced concrete as the predominant material. However, the complex sequence of temporary support, demolition, and reconstruction would have been further complicated by the formwork and falsework needed for reinforced concrete, so the choice fell on a steel frame with metal decking acting both as permanent formwork and in composite action with the beams. The use of steel was considered to be of best advantage only if the connection details could made both repetitive and flexible enough to cope with the dimensional vagaries of the original frame. These criteria dominated the design development and detailing of the structural elements.

The limited storey heights imposed by the original building pushed the choice further in the direction of steel. These required a minimum structure and services zone which could only be achieved by integrating these elements in the same horizontal plane. A series of design rules were prepared to enable the services engineer to determine the zonal location and size of tolerable apertures in the steelwork and these were then formed in the beams using web stiffeners.

Although a composite deck was chosen for the floor plates, the piecemeal demolition and

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reconstruction required a lateral stability system to be developed which could remain serviceable throughout the works. The original stability system — a mixture of framing action and vierendeel action of the façade — would be severely disrupted during demolition.

Furthermore, the need for flexible steel-to-concrete connections favoured a simple pinned design, so the rear stair cores were designed as stability elements with axial load and eccentric lateral loads applied to them throughout the works. The floor plates act as horizontal diaphragms to carry loads to the cores and the external walls simply assist the cores in providing overall torsional stability.

This system provided a number of constructional benefits by permitting the works to be sequentially completed from the bottom upwards in a traditional manner parallel to the core wall construction.

At each level of the building the basic design solution varied.In the sub-basement, trial pits validated the geotechnical desk study and new mass concrete piers were cast to carry new column loads to the sandstone.

A pumped drainage system to the sub-basement raised the groundwater, which penetrates the untanked walls up to basement level and into a gravity drainage system. In the basement car park, designated as a utility grade space due to the lack of tanking, the existing ground-bearing slab was repaired in damaged areas but otherwise remained as original.

The low strength existing columns at most lower levels were inadequate to carry the increased loads from the new building, so to supplement this a reinforced concrete collar was placed around each internal column. The new collar design was sized to carry the superimposed loading on the floors, with the original column checked for capacity under the building's self-weight. The new and old concrete is connected by resin-fixed high-yield dowels. This system enabled fire resistance to be achieved, as well as providing simple flexible connections to the new steel frame. The principle of either collars or cheeks (a thickening on one side of the column only) to the existing columns was used throughout to effect a repetitive and flexible detail.

The ground floor forms a fire barrier between the retail accommodation and the basement car park, and this involved the first upgrading of an existing suspended floor, its western half being retained with the eastern half new-build. The retained floor exhibited the worst aspects of the inadequately compacted Kahn ribbed units with exposed corroded reinforcement in many areas. Each unit was repaired by removing loose concrete, blast cleaning the reinforcing bars, and repairing with SBR modified mortar to achieve durability. Fire resistance was provided by additional sprayed concrete. To allow excavators access for removing demolition material, the floor was propped in part, with a screed added later to complete the fire rating of four hours. This rather elaborate method of bringing a listed structure up to modern standards calls into question the value of retaining the element. It is difficult to justify the historic value of a 1908 slab repaired with SBR modified mortar, sprayed with concrete, and screeded. The original first floor level (the original auditorium floor) was retained with a new floor to the eastern half. The floor plate is interrupted by the circular atrium void, enclosed by a stainless steel planar glass canopy suspended by cables from the second floor perimeter beams. Two scenic lifts service the upper floors within the atrium void, which is clad in rainscreen cladding above first floor level.

The second floor level is completely new and effectively fills in the mid-level of the auditorium in the northern half of the building.

At third floor level the western half of the building originally comprised wall beams between the third and fourth floors to span the large auditorium. In this half of the building the column grid below third floor does not align with that above. The scheme required removal of the walls together with retention of

9. A detail of the stainless steel canopy within the atrium showing the support system for the glazing.

10. The curved metal and glass atrium.

11. The cable and boom support system of the lower glass roof.

12. At roof level the glass umbrella keeps the worst of the weather from the upper atrium space.

13. The drama of the office accommodation is demonstrated by the old columns meeting the new glass wall.

14. Maximum contrast was intended between the terracotta façade and the interior space.

15. The rear stair cores provide stability and contain high quality concrete finishes with integral stair support and lighting details.

16. The terracotta reproduction of Donatello's St George gazes down from its arched niche at third floor level above the main entrance.

Illustrations
1, 4-6: Reproduced from:
LAKEMAN, A. The YMCA building, Manchester. *Concrete & Constructional Engineering*, Vol. 6, 1991.
2-3: Trevor Slydel
7, 9-16: Photos: Peter Mackinven

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the third floor but removal of the fourth, achieved by inserting a pair of steel beams parallel to each wall directly below third floor level. A slot was then cut in the wall and a central steel column inserted to the fourth floor level and supporting fourth floor steelwork. The new fourth floor was then cast on top of the existing by using it as a former and the wall and floor subsequently removed.

Consequently a transfer system was installed without the need for extensive falsework.

The fifth floor is entirely new, being the running track level to the western half of the building. Trimming beams between existing columns support the new three-storey steel-framed building above, which has a different column grid from the frame below.

At sixth, seventh and eighth floor levels, cranked steelwork formed from castellated universal column sections supports a composite steel deck and a planar solar glass roof with externally expressed services.

Conclusion

The result of the highly variable integrated design is a unique blend of heritage and high-tech. It incorporates several significant construction achievements, which strive to match those of the original designers, and which give the building a new lease of life. In terms of the heritage value of the decision to retain the interior, it is clear that the upgrading to modern standards has completely covered up any original structure. Under these circumstances, the planning conditions imposed are difficult to substantiate. However, what has been demonstrated is that reinforced concrete structures are extremely adaptable and robust even when relatively poorly constructed and maintained.

The resulting accommodation sets an important standard for the Manchester office scene and is an example of the true meaning of refurbishment. The irregular nature of the interior maintains visual interest at all levels with little repetition.

St George's statue remains over the resplendent terracotta entrance, in a façade which has seen Manchester's tram system disappear and return, and he is expected to be there well into the next millennium.

Credits

Client:
Eagle Star Developments Ltd.
Architect:
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Structural engineer:
Ove Arup & Partners Manchester
Geoff Bickerton, Steve Burrows, Mark Elsegood, Mark Ruddle, David Hughes
Services engineer:
W.E.Hannan Associates
Quantity surveyor:
Banks Wood and Partners
Main contractor:
Balfour Beatty Building Ltd.

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The Kinali-Sakarya Motorway, Turkey

Alan Hughes
Andrew Lord

This article is a sequel to an account by Andrew Lord in an earlier Arup Journal[1] *of some geotechnical problems encountered on parts of this job. The present paper takes a broader survey of the whole project, as well as updating some of the geotechnical aspects. To make the latter intelligible, a certain amount of duplication from the earlier article has been necessary.*

Introduction

The Thracian and Anatolian motorway in Turkey forms part of the proposed trans-European motorway, commencing in Poland and entering Turkey through Bulgaria near the old Thracian capital Edirne. The first length of this Turkish section, some 36km, was built between Gebze and Izmit in the early 1980s by Turkish contractors. The next section proposed for construction was between Kinali, the point about 90km west of Istanbul on the coast of the Sea of Marmara where the main roads from Greece and Bulgaria meet, and Sakarya, about 160km east of Istanbul on the way to the capital city, Ankara. The two unequal halves of this would adjoin each end of the existing Gebze-Izmit section.

Four design agencies were commissioned to design this part of the motorway, which included the Second Bosphorus Crossing. They were Freeman Fox, Sir Owen Williams & Partners, Ove Arup & Partners (each with a Turkish Joint Venture partner), and Gemas, a Turkish consulting engineer. The construction contract was tendered prior to completion of the detailed design, on the basis of a preliminary design from which quantities were estimated. Thus the client invited tenders for the construction contract prior to awarding the design contract for the Camlica-Gebze section to the group which included Arups.

A consortium of Japanese, Italian, and Turkish contractors was awarded the construction contract, based on a tender of US$555M, a three-year construction period, a December 1985 start date, and a five-month mobilization period. This gave an effective start date of May 1986 and completion by December 1988. The consortium divided the contract so that the Japanese contractor constructed the Second Bosphorus Crossing, the Turkish contractor (STFA) the motorway on the European side of the Bosphorus, and the Italian contractor (IGL) the section on the Asian side.

Arups' involvement

In January 1986 Ove Arup & Partners, with joint venture partners ENET (Turkish), and De Leuw Cather (US), successfully tendered for the supervision contract commencing in May 1986. At that time it was thought likely that the successful tenderer might have to raise the fee money for the supervision contract on the international money markets. ENET, nominated as lead consultant, had considered it advisable to include De Leuw Cather in the joint venture and, because of the then weakness of sterling, for the foreign element of the bid to be expressed in US dollars. The tender consisted of time basis rates against named posts and defined times in man-months. 169 of the posts were for Turkish nationals and 36 for foreigners; of the latter, De Leuw Cather took seven leaving Arups with the remaining 29, of which six were for short-term visiting experts.

The part of the construction works supervised by ENET/Arup was in three distinct sections or Lots:

- Lot 1, on the European side of the Bosphorus, between Kinali and Mahmutbey, approximately 70km long, and designed by Freeman Fox/Botec, consisted partly of dual two-lane and partly dual three-lane motorway through rolling and mainly agricultural countryside.
- Lot 3, on the Asian side, was the Camlica-Gebze section designed by Arup/ENET: approximately 45km of dual three-lane motorway plus 15km of dual two-lane link roads, partly in urban and partly in rural surroundings.
- Lot 4, also on the Asian side, from west of Izmit to east of Adapazari, comprised about 70km of dual two-lane motorway designed by Gemas, through semi-urban, very hilly terrain to low-lying rural agricultural land alongside a large lake.

Lot 2 was the section including the Second Bosphorus Crossing.

The challenges

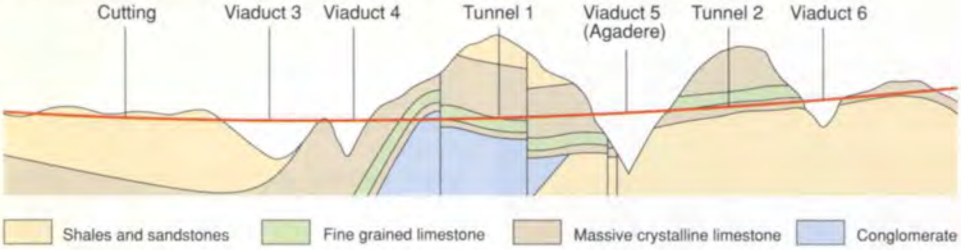
In comparison with most UK motorway projects, the scale of the Kinali-Sakarya project is huge. The contract lengths were typically about 80km — in the UK they only average 15km. As can be imagined, on a project of this size the works were very diverse and challenging, both in scale and technical content. There were many bridges and viaducts, which prompted the contractor to base his design on a standard 40m-long, trough-section, precast concrete beam.

2. Deck beam being transported between casting yard and viaduct location.

3. Apparatus for launching deck beams on structures.

Of the 18 viaducts involved, the longest was the 2km Karasu Viaduct on Lot 1 (front cover photograph). Arups' supervisory role included geotechnical appraisal; since the original site investigation had only encompassed about 300m length at each end of the viaduct, Arups recommended further extensive investigation at alternate pier positions.

1. Route plan of Kinali-Sakarya section of motorway.



4. Approximately 5km section of strata on the Izmit Bypass.

As a result, Arups were involved in redesign of the piling, which eventually were installed as large diameter cast in situ concrete piles, bored under bentonite, up to 45m long. Half of the Karasu Viaduct was constructed over a subsequently flooded reservoir.

Of the 14 interchanges constructed, six interconnect with other motorways and vary from occupying tight urban locations to spacious rural ones.

The section of Lot 4 (4A) by-passing Izmit was particularly challenging, the alignment crossing a series of deeply incised valleys with intervening high mountains. The topography was such that it required seven viaducts and two tunnels to carry the motorway only 7km. In one location, it passed from a viaduct into a 1200m tunnel, out onto the 100m high Agadere Viaduct, back into another tunnel 700m long, then onto yet another viaduct — all reminiscent of the much admired motorway alignments in the Alps.

In Lot 4B, running alongside Lake Sapança, there were several problems to be overcome. In the low-lying areas the topsoil thicknesses were in excess of 1m with thick layers of soft clayey silt underneath. A system of transverse sand drains and sand blanket was used to stabilize this area over a length of several kilometres.

Surcharging the fills for up to nine months to allow the underlying deposits to consolidate was found to be sufficient, although the contractor on the adjoining contract in exactly the same conditions found it necessary to pile his embankments.

5. Tunnel 1 on the Izmit Bypass under construction.

Gemas' original design required the motorway to pass around the Sarabayir headland. This would have entailed building a rock platform out into the lake to accommodate the diverted existing state road and the main Istanbul-Ankara railway line, with the new motorway occupying the original alignments of road and railway. Arups' original geotechnical appraisal of the problems of embankment construction in a lake in a highly seismic area has been described[1], the conclusion being that such a design posed unacceptable problems. The recommendation to realign the motorway through the Sarabayir headland was accepted by the client.

Geotechnical problems

The range of geotechnical problems was as diverse as is ever likely to be met on such a construction project. In comparison with the UK, the geology of Turkey appears complex; this is partly due to its the sheer size, which inhibits geological mapping (the best geological maps available are at 1:500 000, 10 times poorer than any for the UK). Mainly, however, it results from the highly tectonic nature of the country, which has caused an almost universal faulting and folding of the strata on a scale seldom experienced in the UK. One consequence of this is that correlation of strata encountered in boreholes should always be undertaken with great care — there may be one or two faults or folds between boreholes!

The first major problem involved the design of cuttings and embankments in Lot 1 which passed through or were located on landslipped Istanbul Green Clay. This was predominantly a mudstone, which after excavation for a cutting would soften very quickly, leading to rapid failure of the cut slopes. The major problem when tackling these areas was the high natural groundwater table, resulting from very high winter rainfalls. In one location near the line of the old Orient Express railway, the motorway had been designed to run through a 26m deep cutting with side-slopes of 1 in 3. During excavation, when the cutting depth had reached 5m the side-slopes became unstable and began to slide.

To overcome this problem it was necessary to redesign the vertical alignment of the motorway to reduce the maximum cutting depth, and to flatten the side-slopes of the cutting. This resulted in the vertical gradient from the nearby interchange being increased more than was desirable, but this was the optimal solution.

6. Local work-force.

7. Viaducts 3 (background) and 4 (foreground) on the Izmit Bypass under construction.

8. 15m deep cutting in sidelong ground, Lot 1.

Where alignment or side-slope changes proved impossible, the 1:3 design side-slopes were provided with a regular array of counterfort drains sufficient to lower the groundwater level in the slope and so ensure stability. However, in one 900m long, 15m deep cutting in sidelong ground, counterfort drains were insufficient. Instead it was necessary also to provide a rock fill toe weight to support the cut slope. Arups' design report, which recommended that the rock fill toe should not be constructed in more than 25m lengths at a time, proved particularly prophetic — the hillside was so unstable that it became necessary to install the rock fill in bays of 10m maximum length at any one time, despite dewatering the overlying sandy layers at the top of the slope. A record of the exposed face at the back of the excavation of the rock fill revealed the full extent of the faulting and folding, sometimes at less than 50m intervals, which had dictated why certain areas of the cut had slipped while others didn't.

Adjoining this cutting, fill up to 7m high had to be placed on Istanbul Green Clay which was already part of a landslip. In order to avoid surcharging this already unstable material, counterfort rock fill trenches up to 5m deep and 1m wide were dug at approximately 8m intervals at right angles to the line of the fill. Capped with a 1.5m thick rock blanket, these rockfilled trenches transfer the weight of the fill to the intact clay beneath, and lower the water levels in the landslip debris, so improving its stability.

Unfortunately the advent of the motorway has generated a rash of nearby industrial development. As a result of a failure to understand and appreciate the slope stability problems, one industrial development in the above location has triggered a landslip which originally started at a stream about 600m downslope of the motorway but has now rapidly spread uphill to threaten the motorway itself. In such circumstances it may be necessary to provide a bored pile wall solely to support the motorway from the effects of this instability.

Slope stability problems also have been experienced elsewhere along the route, particularly around interchanges and motorway toll booths at Kumburgaz and Mahmutbey, where insufficient land take has created over-steepened slopes.

Probably the most interesting redesign problem on the project was connected with the Agadere Viaduct. Part of Arups' geotechnical appraisal of Lots 1 and 4 involved examination of various alignments of the Izmit Bypass based on air photo study and site walkovers. A major landslip was identified, involving limestone boulders on one side of the Agadere Valley. Responsibility for the design of the viaducts and their foundations was given to the Italian contractor. The Arup report quietly gathered dust for some 2½ years, until an earthquake of magnitude 4-5 caused an entire 40m pier of the then uncompleted viaduct to slide down the hillside about 300mm. The pier had also tilted, giving a horizontal movement of 220mm at the top. The deck beams had not yet been erected. The precise cause was identified by extensive site investigation: the pier had not been founded on solid rock but on some of the limestone boulders, about 3m across, which the tremor had shifted. Backanalysis of the slip permitted the assessment of residual strength soil parameters for the landslipped debris, which was then used to design the remedial works.

The Italian designers of the structure proposed pinning the pier base with micro-piles. This, however, was not successful and eventually, after further movements, the base was stabilized with four 3m diameter caissons, one at each corner, extending 25m below the original base level. Extensive slope regrading and drainage works were also incorporated. Much of this redesign was either undertaken by Arups (on behalf of the Turkish Ministry of Public Works and Settlement) or agreed by them in close consultation with the contractor. The foundations to all the piers of the viaduct were also examined, and in some cases redesigned.

The landslip also affected the western portal of Tunnel No.2, immediately adjacent to the eastern abutment of the Agadere Viaduct. On a motorway, responsibility for tunnel portal design frequently falls between those concerned with tunnels, with approach viaducts, and with slope stability. The situation was further compounded at the western portal of Tunnel No.1 where an extension to the tunnel portal, with infilling above, was necessary to ensure the stability of the hillside above the tunnel in the event of the maximum predicted

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earthquake. The situation was resolved by Arups acting as go-between the two design consultants, allied to a substantial contribution to the design.

For the design of the realigned motorway through the Sarabayir headland at Sapança, the site investigation was not entirely conclusive, largely because of poor recovery, revealing predominantly granular strata. There was, however, slight evidence of possible clay seams which might just, if continuous, dip out of the face of the cut, which was to be up to 80m deep. Accordingly Arups advised that the cut, to be made over two earthwork seasons, should first be taken to half its maximum depth, with a series of man-sized inspection shafts up to 20m deep to examine the strata which would be encountered in the remainder of the cut. Examination of the exposed faces of the cuts, together with these inspections shafts, revealed a remarkable alternating sequence: a yellow brown or reddish brown, very gravelly sand up to 1½-2m thick alternated with bands of very stiff, light blue, very silty clay, 50-100mm thick. The clay bands were continuous and easily identifiable in the face of the cut — to assist in mapping them so as to determine the dip of the strata, each was lettered in turn — very quickly running through the entire alphabet!

The site investigation certainly did not reveal what was eventually found but the cautious approach relying on observational techniques identified areas of faulting and folding which caused the clay strata to dip out of the face of the cut. These potential danger areas were safeguarded by the provision of vertical drains, down to the level of Lake Sapança, and well uphill of any of these potentially troublesome areas to avoid seepages on the exposed face of the cut or any possible build-up of pore water pressures.

Working in Turkey on such a wide range of geotechnical problems, with widely differing soil types, afforded the opportunity to work alongside Turkish geotechnical engineers and to help them with 'transfer technology'.

Contractual aspects

The contractual aspects were both challenging and interesting. The contract was let on an amended form of FIDIC with ENET/Arup/DCI as the Engineer under the Contract, and Safettin Sile, ENET's Project Director, named as the Engineer to act on behalf of the joint venture.

Highway supervision works, because they are predominantly in the ground, tend to generate a large proportion of redesign work. Supervising the construction of the works, including necessary redesign, is not the only major duty devolving on the supervisory organization. It is usual in highway work for many changes to take place, mainly due to unforeseen ground conditions, expropriation problems, and changes in client requirements. For instance, on a typical UK motorway of c.£25M, well over 1000 Variation Orders will be issued, resulting in many months being spent by the supervisory staff in revaluing the work, assessing extensions of time, and valuing claims.

It was much more so on this project due to the incomplete state of the design when the construction contract was let. The client required extensive changes early on, resulting in nine months' extension of time being awarded to the contractor at the end of the first year. Major expropriation problems occurred, affecting both the availability of borrow areas and the making available of large areas of the site to the contractor. The many geotechnical problems added to the pattern of delay, involving both re-design and additional works. Substantial areas of design had either not been completed or not carried out at all. For instance, well over 200 small structures, many involving watercourses, had been omitted from the original design of Lot 4 alone.

The effect of all these changes had to be assessed in terms of both time and cost, and of necessity a large amount of Arups' input was attributed to this. Ultimately, as part of the site supervision activity, more than 15 man-years of redesign work was carried out by Arup staff, out of an overall total of 80 man-years.

Financial restraints on the contractor were another major issue. The value of the US dollar fell substantially during the course of the contract. To allow the work to continue, the client introduced a dollar escalation clause into the contract to compensate the contractor for his loss of earnings in real terms.

Not surprisingly, this contract ran far beyond its original completion date of December 1988. The phased opening of sections went on for three years, and the motorway was not fully open to traffic until autumn 1992. Even at the time of writing, Arups' involvement is not yet finished. Contractual problems invariably lead to disputes and arbitration procedures involving over US$200M are in progress. Depending on the outcome of this, the final value of this contract is likely to be in the order of US$1000M.

Reference

(1) LORD, A. Turkish roads. *The Arup Journal, 23*(2), pp.20-21, Summer 1988.

Credits

Client:
Turkish Ministry of Public Works and Settlement
Designers: Lot 3; Supervisors: Lots 1, 3, 4:
ENET/Arup/De Leuw Cather
[Ove Arup & Partners Dennis Radcliffe, Alan Hughes, Phil Burch (Project Directors)
Tom Smith, John Bevan, Robin Urquhart, Jerry Shapley, Phil Balman (resident engineers)
Andrew Lord, Terry Gordon, Ian Statham, John Redding, John Gabryliszyn (geotechnics)
Jack Lawrence, Bill Ward (tunnels)]
Illustrations:
1, 4: Trevor Slydel
2: The contractor
3: Ove Arup & Partners
5, 6, 13: Harry Sowden
7, 10: Jack Lawrence
8, 9, 11 : Andrew Lord

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9. The Agadere Viaduct (5) between Tunnels 1 and 2.

10. Additional reinforcement at the base of Pier 8, for the load to be carried on four 25m deep caissons.

11. Western portal of Tunnel 1.

12. The motorway, the state road, and the railway in the vicinity of the Sarabayir headland. Tennekelm headland, through which the motorway passes in a cutting, is on the far left of the picture.

13. The Agadere Viaduct: plus local family.

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