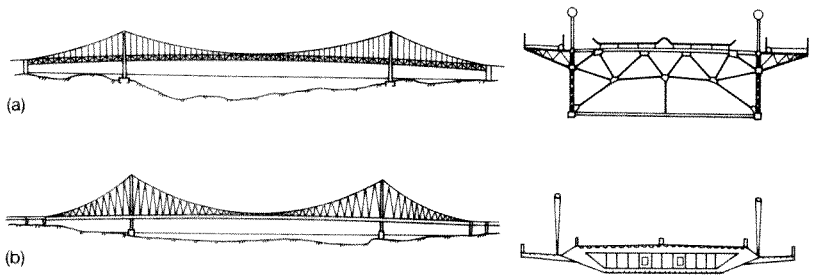


5.15 Refinement in suspension bridge design: comparison of the outline and cross-sections of the Forth Road Bridge (1964) and the Severn Bridge (1966). (Engrs: Freeman Fox and Partners.)

Flexibility in planning

In conclusion it must be emphasized that there is a school of thought which holds that because precise functional requirements change as lifestyles, industrial processes, and social needs develop, building envelopes should not be designed too tightly for one particular function. On the one hand are those like the hospital planners and especially the proponents of the 'high-tech' movement in present-day architecture who attempt to design flexibility into their buildings. On the other are those like the architect Mies van der Rohe and the modern office developers who provide simple basic space on the assumption that the occupier will make the modifications that best suit him.

Blake (1977) argues strongly that many old structures, designed at the turn of the century, are with modifications serving modern functions far better than buildings designed a few years ago. However, this is true mainly for space-enclosing structures with few services and is largely due to the happy coincidence that old building methods provided a larger number of alternative load paths.

Thus even when the relationship between function and form is dubious, the design team is unable to abdicate its responsibility to provide as best it can for future use, and this has a very evident effect on the structural system.

6

Architects, architecture, and aesthetics

Introduction: relevance to the work of the structural engineer

It is perhaps difficult for an engineering student to see why he or she should take an interest in architects, architecture, and aesthetics. The reason is that the majority of structural engineers in the consulting field, and many of those in government and 'package deal' enterprises, work on buildings or other structures with a considerable architectural component. It is the architect who is responsible for the functional planning of dwellings and office buildings and, more frequently these days, of industrial buildings. In these cases, the architect is usually the leader of the design team. Thus as we have seen in the case-study of the Sydney Opera House, the personality, attitudes, and aims of an architect may have an enormous impact on the quantity and difficulty of the work that is required of the structural engineer.

Furthermore, the increased political power of community groups concerned with the environment has made it essential that executive engineers give careful consideration to the aesthetics of prominent structures and that they be able to argue the aesthetic merits of the scheme in public debate. In many cases they may not have the services of an architect to assist them in this.

The interaction between architect and engineer should not be a one-way process. As a non-specialist in the field of structures, the architect is often unsure, during the initial stages of design, of the potential of different forms of construction and of different structural systems. Many architects complain that structural engineers are too willing to accept the form of the building as initially proposed by the architect and content to simply 'make it stand up' by choosing suitable sizes for the members. These architects would prefer a more positive contribution in which the engineer presents them, at least conceptually, with a range of structural options or is willing to suggest modifications which are structurally feasible and will enhance the effects for which the architect is striving.

Unfortunately, there are a number of factors which make it difficult to achieve an ideal interaction between architects and engineers. Of all the professionals with whom the structural engineer has to work, the architect is probably the one he finds hardest to understand. The mechanical and electrical engineer speak the same language and have the same basic philosophy. Even the financier and developer have a quantitatively defined objective which the engineer can easily comprehend. The lawyers like to order experience and set it down in a form which looks superficially much like an engineering specification, or a code of practice.

In contrast, the architect's methods and objectives appear quite nebulous. When asked the reasons for the demands and restrictions which he places on the engineer he often seems unwilling or unable to rationalize them. The reaction of even the more sympathetic engineers is characterized by Arup's enigmatic pronouncement:

> The engineer's chief headaches are created by the Architect for possibly perfectly good reasons.

It is generally accepted that the disciplines of engineering and architecture attract people with differing personalities; that these differences are reinforced by traditional professional training; and that they are then maintained by the fairly rigid institutionalized structure of the professions. Engineers and architects even speak different languages. The words 'design', 'function', 'economy', and even 'structure' may have quite different meanings for each, depending on the context in which they are used. Added to this is the fact that each is concerned, within the design team, in looking after different aspects of the same task and the requirements of, say, aesthetics may conflict with those of structural efficiency. Tension is almost bound to arise during the process of resolving these clashes.

Some practitioners deny that any problem exists, but as we shall see in later sections, the topic is so often raised in the literature, not only in the English-speaking world, that it must be a matter of concern to a great many people. A different, and quite valid viewpoint, is that a certain degree of friction provides a healthy and necessary stimulus to creative design. This is true as long as the debate contains positive criticism and proposals which improve the design while respecting the competence and responsibilities of the other professionals. Unfortunately it sometimes degenerates into mere bickering and, worse, to retreat behind closed doors and hostile silences. One of the most common causes of misunderstanding, as implied above, is an ignorance of the

abilities of the other members of the design team and of the pressures which are placed on them by their different responsibilities. The next chapter is therefore devoted to a brief resumé of the duties of the architect and the way in which he tackles them.

If the engineer is to interact positively with the architect in the initial stages of conception of form it is desirable that he should have a rudimentary knowledge of architectural philosophy so that what he proposes is likely to be in keeping with the architect's general aims. This is quite a tall order because it implies that the engineer should be able to categorize the ideas of the individual architect with whom he happens to be working, and to do so in terms of a vast literature and a continuing and lively debate. Fortunately, two factors make this somewhat easier than might at first sight appear. A number of basic motifs constantly reappear throughout the history of architecture such as the dichotomy between elegant simplicity and messy complexity and that between a concern for functionality and a self-consciously artistic expressionism. If the engineer can identify such basic themes in the thinking of the architect he can considerably improve his chances of making a positive contribution. The other saving factor is that no creative architect will fit exactly into any given category. His response to a project is bound to be complex and may even include mutually contradictory facets. His philosophy will change over the years and he may even design different buildings in different modes concurrently. Thus if the proposals of the engineer correspond only roughly with the general thinking of the architect there should be potential for fruitful interaction.

A brief outline of the history of architecture, concentrating on recent developments is provided later in Chapter 10, and a brief review of some of the major themes of architectural philosophy in Chapter 11.

All this begs the question of whether the engineer should indeed cooperate with the architect if he is completely unsympathetic to the other's approach. Some views on this are included in later chapters. An individual consultant has the option of refusing the brief, but an employee in a large private consultancy or a government agency may be obliged to work with the architect as best he can.

An interest in aesthetics is of even wider use to the engineer than an interest in architectural philosophy. Engineers are generally content to leave the planning of buildings to the architect, even when they cannot immediately see the reasons for his more challenging demands on their skill. It is when he makes demands on them in order to achieve a

particular visual effect that engineers are liable to feel mystified or resentful and to talk scornfully of the 'whims' of the architect.

There have always been some engineers who have thought about the appearance of their structures but until recently too many have considered good aesthetics an expensive luxury. It is significant that, as recently as 1973, an author should feel the need to entitle his paper 'Appearance matters'.

However, it is now common for reports in engineering journals to include some comment on the aesthetics of new structures. Much of the impetus for this increased interest in appearance is due to the sensitivity of the modern public to projects which are likely to have a large impact on the visual environment. Bridges are often prominent features, particularly when they cross over valleys. When a bridge was proposed to carry a highway across a scenic canyon in Colorado the authorities built a full-scale *in-situ* plywood mock-up of sections of the bridge to allow the public to visualize the effect. Computer illustrations and artist's renderings were also provided.

It is clear that engineers as well as architects are prepared to spend money and go to considerable trouble in order to achieve a satisfactory appearance, and in recent years the power of the public and of government to force them to do so has been strengthened. It is therefore important for the structural engineer to be able to discuss principles of aesthetics with members of the public, government agencies, and architects.

The theory of aesthetics is another vast field, being a branch of philosophy. The brief treatment provided in Chapter 12 is necessarily limited to the more simple aspects, with an emphasis on practical applicability. An engineer who devotes even a small effort to the study of this subject will soon find that his appreciation of his visual environment is greatly increased and will soon understand how easy it is for the architect to lose touch with the undiscerning layman.

7

The architect and his work

Introduction

The three topics history, philosophy, and aesthetics will be reviewed very briefly in subsequent chapters. First, however, it is appropriate to look briefly at just what an architect does, how he sees himself and his work, and how others see him. The following chapter will deal with the major differences of outlook and approach between architects and engineers.

There is of course no such thing as a 'typical architect'. Some are sober conformists whose interest in life is in providing the client with the maximum of functional efficiency and physical comfort for least cost. Others think that once the client has appointed an architect he has no further rights whatsoever to interfere with the work of the 'artist' and should merrily foot the bill for (and live with) whatever turns up. These types have been classified as 'systems boys' and 'art boys' (Arup 1966).

The majority, fortunately, lie between these extremes, trying to practise what has been called 'the most complex of arts'; one in which human reaction and sensibility must be considered alongside practical details of physical needs and all within the bounds of numerous scientific disciplines including, of course, the theory of structures.

The architect's roles

The majority of architects in the western world work as partners or employees in small private firms which provide a consultancy service. The role of the architect is thus most easily illustrated by sketching the progress of a consultant through the design of a small project for which he is the principal.

His first task is normally to discuss the client's needs and resources and inform him of the options open to him. This stage is necessary because the client often has only a vague idea of the sort of building he wants, and even if his ideas are firm, his concept may not be by any means an optimum design. If the project is a public building such as a school, hospital, or community housing, the architect may also consult

the people who will actually be using the building and, as we saw in Chapter 5, study their interaction and the flow of people and materials through their current buildings. If the project is a domestic house the architect may try to find out about the client's tastes and his life-style. Some architects have actually moved in and lived with their client's family for a period of months in order to do this.

As this period of research progresses the architect begins to form ideas about the nature of the building that would best suit his client. Depending on the individual, the process will be coloured to a greater or lesser extent by the architect's desire to express his own philosophies and to establish his reputation as a designer. This last is not simply a matter of conceit, because without a reputation he will not receive the commissions he needs to maintain his livelihood.

Even if the architect is concerned solely with the best interests of the client an ethical problem arises if the latter holds strong views which conflict with those of the architect. Is the architect the servant of the client? Should he follow directions against his will, or should he try to force the client to accept what he, as an expert, thinks he knows is best? Usually the architect accepts a compromise, going some way to meet his client's desires but at the same time trying to 'educate' him to accept professional advice. A practical-minded architect may save his client a great deal of money at this stage, while one with artistic inclinations may persuade him to expand his budget. There is room for debate about the ethics of 'educating' the client in this manner, particularly with regard to questions of planning and aesthetics, but this applies to all professions and will not be considered here.

As a result of these discussions, the architect will begin to conceive an arrangement of space, a choice of materials, and an aesthetic scheme which cater as far as possible for the desires and needs of the client within the available budget. At this stage he will produce preliminary drawings showing the major features of his scheme.

If the project is anything more than a small dwelling the architect will have to enlist at some stage in these proceedings the help of structural, mechanical, and electrical engineers. An accountant and quantity surveyor may be required to help work out the estimates and the financial feasibility of alternative schemes. To some extent the architect must now take the part of the 'client' to his engineering consultants. To a lesser or greater degree the advice of his consultants will cause him to modify his original concept.

By the time the basic form of the building, its structure, and its services has been determined, the architect should have considered an

enormous range of factors from functional planning, psychological impact, aesthetics, and relationship to the environment, through to lighting, insulation, and structure.

He must then approach government authorities for planning permission. This will require compliance with zoning regulations, and in some countries approval of the aesthetics of the building and its relationship to its neighbours. The local authority will also be concerned with such things as the location of the building on its block of land, and with room dimensions, window sizes, drainage, and sewerage.

If prospects for approval look good all parties will commence preparation of detailed drawings of those aspects of the building for which they are responsible. This requires close liaison because for instance, the architect may detail the finish to stair treads and the design and fixing of the handrail on a staircase for which the structural concrete and reinforcement is being detailed by the engineer.

Once approval is obtained the architect must with the aid of the specialist consultants call tenders for construction and advise the client on acceptance of the most suitable one. Again with the aid of the specialists he must then supervise the actual work to ensure compliance with the drawings and specifications and authorize progress payments to the builder as work progresses.

The architect thus has a great deal more to do than concern himself with aesthetics and the layout of rooms. It is easy to fall into the trap of assuming that 'architecture' is synonymous with 'aesthetics' and to forget that practical administration and building construction should be a part of any competent architect's repertoire.

The experience of architectural work

Introduction

Accounts of what it feels like to work as an architect are as rare as their equivalents in the field of engineering but provide a valuable insight into the experience. One of the most striking impressions is of the arduous nature of independent architectural practice caused partly by the struggle for survival in an over-supplied market, but also by a striving for excellence in the architect's own terms. Arup (1959) considered that the architect's role is harder than that of the engineer because he has to divide his personality over more contradictory fields, switching from exercising his artistic imagination to drafting contract documents and supervising construction.

Like engineers, architects see theirs as a grossly underpaid and overworked profession, and feel that they do not receive the recognition due to them from society. They seek their real reward in the conviction that they are reaching high standards in the performance of a worthwhile task, in the satisfaction of serving the community, and in their fascination with the process and products of design. Many speak of the euphoria that goes with finding the 'right' solution to a design problem.

There is considerable disillusionment for young architects when they leave the university, particularly if they work for a large firm where they are likely to find themselves assigned full-time to mundane tasks such as detailing stair treads while the principals carry out the conceptual design.

Like engineers, architects who remain with large firms find that their career paths lead towards executive duties by the age of about thirty-five, so that drawing and design must be left behind if they want to 'progress'.

The experience of architectural design

Most accounts of the nature of the *design* process in architecture tend to be highly systematized and the process appears as a series of well-defined consecutive stages. They give no real impression of the muddled and overlapping phases of design as it is experienced in practice (Chapter 13). There are, however, a few descriptions which attempt to capture the essential nature of the process.

Boyd's description of the experience is particularly good (Boyd 1965) and is worth quoting at some length. He begins by stating that often the client sincerely wishes the architect to produce a fine example of his art. The latter has first, however

> a puzzle to be solved, a practical matter, a useful shelter of some specific kind to be made as efficiently as possible. The puzzle is familiar, yet different with every new project that comes to the architect. The kind of shelter required may be quite new to him, and even if it is in a field with which he is familiar the relevant regulations and the budget and the available materials and the personalities involved may all be different this time . . .

Boyd draws the analogy of a jigsaw puzzle, the pieces lying in a jumble, 'some face down', and representing the design considerations mentioned in the previous chapter. The architect's objective is now

> to combine all the factors into a whole: one artistic form built so spontaneously and convincingly that it might appear to belong to some natural or intellectual pattern or creation.

The architect knows that somehow, subconsciously his mind will sift the pieces, and will throw up a 'guide picture' in which the pieces interlock inevitably. Once it has been conceived, this stays with him

> through the hopeful hours of preparation of sketch plans, through the early bold scribbles and the last satisfying details of planning.

Finally he is able to produce perspective drawings or a model and the puzzle may be considered 'solved'.

Turnbull in Shellenbarger (1979) confirms the importance of the 'guide picture' in producing the 'productive energy' necessary for the ensuing routine work.

> The secret is knowing what to do, and that's a really super day when you walk away and say yes, I know what the answer should be. That's a terrific day when you find it. Sometimes it carries for six months.

After this come weeks or months of labour on detailed working drawings and specifications. Lionel Todd, a partner in the firm which took over the Sydney Opera House commission after Utzon, describes the task of fitting out the interior.

> Often we advanced our drawings to approximately 95 per cent working-drawing stage and let our consultants work off accurate spaces and dimensions. Only after workshop drawings were prepared by the major sub-contractors (air-conditioning, electrical, special electrical and fire protection) could we confidently instruct work to commence. To carry out this drill, co-ordinate all the services and receive the green light from the structural engineers involved 16 stages of checking and proving. Any calamity in any one of these could lead to a complete re-design.

Then comes the 'prodigious routine' of supervising building to the plans. Most architects, wrote Boyd, reach even this stage with their confidence complete.

> Occasionally doubts crowd in . . . when pieces refuse to fit together, though usually these difficulties can be dispelled by modifications to the central idea.
>
> But sometime after this . . . the architect will tell himself, or a friend or critic will tell him, that his guide vision was not the only possible one after all, and was not even the best possible one. There were other solutions to the problem which would have been just as practical but perhaps less stylized, or more relaxed, or more imaginative, or more realistic, or less romantic, or less pretentious. Was he right in selecting the image he did?

The architect's task is thus, like the engineer's, '5 per cent inspiration and 95 per cent perspiration', but he is left at the end of it much more open to criticism and self-doubt.

The architect's approach to design

How does the architect set about the creative stage when he is trying to get the pieces of the puzzle to fall into position? What is he trying to achieve? What factors does he consider most important in his initial visualization of form?

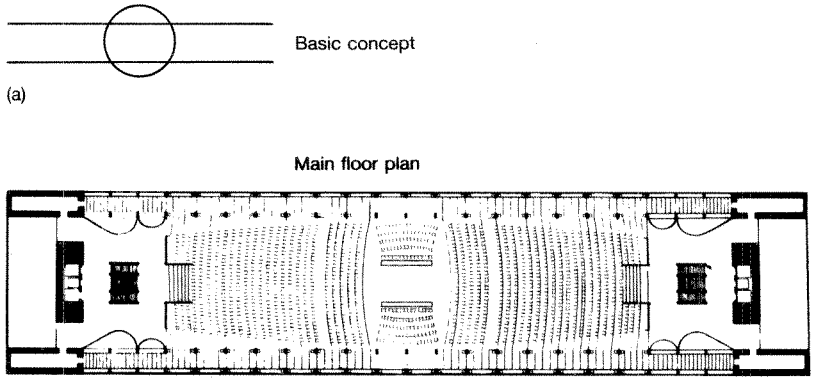
There are two major sources of answers to these questions: accounts of the work of major architects written by people who have worked with them or who have researched their designs *post facto*; and accounts given by architects themselves either in the form of books or recorded interviews. It is natural to assume that the latter would be the more reliable, but there is a school of thought that an artist or designer is less able to analyse the workings of his own mind than an independent observer.

To an engineer, the major impression gained from these accounts is of a strange mixture of pragmatism and romance, of logic and emotion. To Wright a cube was a noble form, so his Unity Temple had to be a cube. But then it had also to house 400 people at low cost, so it had to be made of unfaced concrete for cheapness. In keeping with the current architectural ideal, the fact that flat roofs were more expensive than pitched roofs and present greater problems with waterproofing was ignored.

The following extract from Cook and Klotz (1973) illustrates how Louis Kahn arrived at his basic concept for the plan of a projected Congress Hall in Vienna (Fig. 7.1), by going to a blackboard and drawing a circle, then cutting off the top and bottom of it by a pair of parallel lines.

> I don't know how one identifies the first idea, but for me it is usually the sense of the building in its core, its full meaning, its nature, *not* its shape. Its nature was that of involvement, of participation. A simple shape which only emphasizes a direction doesn't have the nature of participation in it. It is, on the contrary, analogous to watching or hearing, not participation. The circle, to me, was participation. The fact that I could adjust to a site which was narrow has to require that one side looked to the other. But the shape could not be adjusted to that narrow site in such a way that it becomes purely directional, because there would be no participation.

Note that if practical matters such as sight-lines and acoustics were considered at this stage, Kahn did not feel the need to mention them in his account. It may take more than these brief glimpses to convince the reader that real buildings are actually conceived in this way, but there is a mass of evidence in the literature.



7.1 Project for Congress Hall, Vienna (Archt: Louis I. Kahn). (a) The basic concept: 'participation' within a narrow site. (b) The resulting detailed floor plan.

Of course not all architects approach their work in this romantic fashion. Many adopt a largely pragmatic approach. The philosophy of Welton Becket, head of a large and successful firm in the USA, is described by Hunt (1972). To paraphrase Hunt:

> Welton Beckett knew where he was going at a time when most architects were searching for a philosophy. He made a lot of money producing architecture which was, perhaps, not the sort that many young people looking for 'relevance' or 'commitment' might appreciate. It was derided as 'Businessman's Architecture' but it was saleable to clients at a profit, valid and worthy, and ordinary people liked it.

The results, amply illustrated in Hunt's book, are very different from the products of the more celebrated individual architects.

Thus Boyd sees the architect faced with a real dilemma as he enters the initial creative phase. Should he

> do the best possible with the scientific or rational approach, knowing it can take him a long way but never to the end—or should he scrap science and rely on intuition, springing on ahead to any place his imagination will lead him?

Granted the complexity of their task and the difficulty of tackling it, it is small wonder that many leading architects have written 'manifestos' setting out a simplistic guiding philosophy which can be seized upon by the less secure. The most well-known of these is probably Le Corbusier's *Vers une Architecture* (1923). These tracts provide a further insight into the approach of the architect and they will be discussed briefly under the heading of 'philosophy' in Chapters 10 and 11.

Images of the profession

If one wishes to work well with another person it is useful to know how he sees himself and his role in relation to the common purpose. Richards (1974) and McLaughlin (1962) provide straightforward accounts of the architect and his profession for those considering a career in the field. Presumably these represent the image that the average career architect would like to project to the public.

One of the more romantic descriptions of the architect and his work is given by Fry (1969). He described the creative act as a 'sort of falling in love' and sees the final stage of design as

> a re-descent into the world in which the architect is in his workshop with his assistants about him, the centre of a great coming and going of technicians, experts, engineers and estimators.

The re-descent obviously gives cause for regret and Fry wishes that the more mundane tasks were not a part of architecture. In his workshop the architect finds himself

> directing with exactitude a hierarchy of technicians . . . It would be better if such exactitude could be dispensed with . . .

The architect also has an educational role to play:

> The engineer who tells me that I must have eight air changes in a certain room knows little of the struggle to preserve a humanised interior, and must either go away with a flea in his ear or widen his horizons; and for lack of this humanising contact with architects . . . structural engineering in this country [the U.K.] became mechanical and stupid.

To most engineers these pronouncements would sound arrogant and irresponsible. Fry is however an architect who was nurtured in the 'heroic' age of the 'Modern Movement' in architecture prior to the Second World War. In recent times there has been a great deal of soul-searching in reaction to what is seen as the failure of the Modern Movement to live up to early expectations and a related failure of the profession to earn the respect of the general public. At the other end of the spectrum therefore come comments such as these by Ivan Chermayeff, a partner in a successful New York practice:

> It's too bad that architects are commonly so egocentric as to actually believe, despite evidence to the contrary, that they are best qualified to make architecture. The best of them have all died, the second-best prove limited points, the third-best do the obsolete and unnecessary superbly, the fourth drop out into academia and discuss the irresponsibility of those who stay in, and the balance just make a living or try to, wisely ignored, along with their more intelligent and talented colleagues, by 80 per cent of those really responsible for building and developing.

Although this statement is obviously made tongue-in-cheek, many practising architects admit that routine design, specification writing, and contract administration are their weakest points. And we have already seen that many consider themselves overworked, underpaid, and unappreciated.

Such contrasting attitudes as Fry's and Chermayeff's demonstrate something of the schizophrenia which characterizes the profession's view of its role in the world. The reason for this state of mind seems to lie in the fact that most architects embark on their training with an artistic or idealistic outlook, which the schools do nothing to temper. Allsopp (1974) states that

> In the hot-house atmosphere of a school of architecture, or in the committee rooms of a professional institute, it is only too easy to be infected with the belief that architects control the social climate in which they work. One is prone to take the biographies of the masters of modern architecture at their face value and see the architect as a god-like being . . . the architect is conscious of his superior nature and his mission to mould the environment for the good of mankind. In the hard world of commercial practice this vision quickly fades . . . but the architects, and their assistants, have learned a way of design which tends to stay with them for the rest of their lives . . .

However, the hard world of commercial practice does take its toll on the artists and idealists. Boyd estimates that

> of all who enter architecture schools only two or three in each generation will achieve distinction; only one in a hundred will reach eminence in his home town; only one in twenty-five will become a private practitioner with any reputation. Of the few fortunate ones, most are kept busy with a hundred routine jobs other than designing. Only an hour or two per week is spent by the average practitioner in designing even a detail.

Those who become resigned to this situation

> make no pretence of wishing to create anything other than a commercially satisfactory shelter using appropriate empirical structural methods with a sensible application of the latest manufactured components; standard windows, doors, facing panels and so on, all selected with moderate imagination and care in regard to their neatness of appearance as well as their practicability.

In Boyd's view, one of the major reasons for this is that the aspiring artist–architect needs a patron with a great deal of money. Whereas a painter can throw away his first sketches without great financial loss, an

architect must achieve a fair degree of competence with his first attempt or he is unlikely to get another chance. Even if he does obtain a first commission, he is likely to be 'led by bread-and-butter reasons to such stern concentration on the practical business' that he has 'no time or talent left for communication of any visual ideas'. Nevertheless, a great many architects still cling to their vision or at least see it as an ideal towards which they should continually strive. This produces collective schizophrenia of the profession, with some of its members yearning for the role of god–architect, others angrily rejecting it, and most torn between the dream and the reality.

The average engineer is thus likely to encounter an average architect whose attitude lies somewhere between the extemes of resignation and inspiration and many indeed alternate between the two. Of course the engineer will himself have suffered something of the same sort of disillusionment on leaving university, but he would have been perhaps less idealistic in the first place, would have suffered a more humbling experience in grappling with a course in which his lecturers are most of the time demonstrably right and he demonstrably wrong and incompetent, and entered a profession in which the 'cult of the individual' is the exception rather than the rule.

While Boyd declared himself concerned that the profession still retains the autocratic image of the old 'frock-coated gentleman'; the lone artist in a world full of specialists, where crafts have been replaced by modern technology; even he could not fully relinquish the ideal.

> One man only must be in final control if the building is to work physically, not to say artistically. So the architect tries still to understand all and finally to shape all, just as great-grandfather did.

This insistence on leadership of the design team is one point on which the profession is virtually unanimous and there are many engineers who sympathise with this view. According to Arup:

> the design which does justice to the three-fold disciplines of art, building and commodity can only be done by a team. And the question we must then ask is: How can a team produce art? The architect would say: by putting me in charge. This insistence on leadership by the architect is more than a lust for power, or job-greediness. It is the natural point of view of an artist.

To sum up, it might be predicted that the more successful an architect has been in the commercial sense of the word, the more likely he is to want to take the opportunity to express his artistry and the more difficult it will be for the engineer to understand him. The more depressed

members of the profession—those who are resigned to concentrate on minutiae—will appear to the engineer to be sensible and dependable.

Given the ferocity with which architects point out the short-comings of their own kind it might be thought hardly necessary for others to join in. However, sociologists and anthropologists criticize them for an alleged lack of concern for the real needs of the human beings who must use their buildings. The assumption underlying this criticism is that a building should first and foremost satisfy the physical and social requirements of its users and that it is only secondarily a work of art. This functional rationale is common to most engineers and will therefore be considered in the next chapter on relations between the architect and the engineer. The reader may feel at this stage that not enough space has been given to those architects who think that the profession does perform its task competently. However, until it recently became necessary to defend the Modern Movement, people have not felt the need to write specifically on this topic. Their views are presented, like Fry's, as a straightforward exposition of the practice and significance of architecture and this attitude will be reflected in Chapters 10 and 11.

One very complimentary study of architects was that carried out by the psychologist MacKinnon (1962). His investigation was intended to discover the personality traits of 'creative' people. MacKinnon chose to study architects because he felt architecture was an obviously creative profession. The 'creative' architects to be studied were recommended by a panel of five professors of architecture. Second opinions were obtained from editors of architectural journals and from within the group of architects themselves. This procedure may be criticized on various counts, but the chosen group would obviously represent the image held up to the average architect by the architecture schools and the journals as the pinnacle of achievement.

Sixty-three of these recommended architects were invited to attend Berkeley for a weekend of assessment by a team of psychologists. The latter built up the following composite picture of the characteristics of the creative architect, who:

(1) enjoys aesthetic impressions, is aesthetically reactive;
(2) has high aspiration for self;
(3) values his own independence and autonomy;
(4) is productive; gets things done;
(5) appears to have a high degree of intellectual capacity;
(6) genuinely values intellectual and cognitive matters;
(7) is concerned with his own adequacy as a person;

(8) is a genuinely dependable and responsible person;
(9) has a wide range of interests;
(10) behaves in an ethically consistent manner;
(11) has social poise and presence;
(12) enjoys sensual experience;
(13) is critical, sceptical;
(14) appears straightforward, forthright, and candid in his dealings with others;
(15) is a talkative individual.

The creative architects were seen as confident in social situations, but having no special need to be sociable; intelligent, outspoken, sharp-witted, demanding, aggressive and self-centred; persuasive and verbally fluent, self assured, and uninhibited in expressing their worries and complaints.

The control group of architects of average ability also showed up very well on the tests. Their personality profile was considered a remarkably favourable one.

'The high points are on . . . the drive to achieve in an independent fashion' (rather than a conformist one), 'capacity for status' and 'interest in and responsiveness to the inner needs, motives and experiences of others'. The general impression 'is of men who are good citizens, responsible, productive, sensitive and effective'.

In general, MacKinnon noted that 'one who studies a successfully practising architect will soon be impressed by his juggler-like ability to combine, reconcile and exercise the diverse skills of businessman, lawyer, artist, engineer and advertising man, to say nothing of author–journalist, psychiatrist, educator and psychologist'.

As might be expected, architects themselves soon attacked this glowing account. Broadbent casts aspersions on the accuracy and significance of psychological tests and agreed with Abercrombie's description of the profile as 'sugar and spice and all things nice'. However, the viewpoint of the psychologists represents a human assessment of the architects regardless of the validity of the psychological concepts and tests. The researchers were obviously very impressed with their subjects and if this influenced their measurements the general impression is no less real.

8

The engineer–architect relationship

Differing styles of interaction

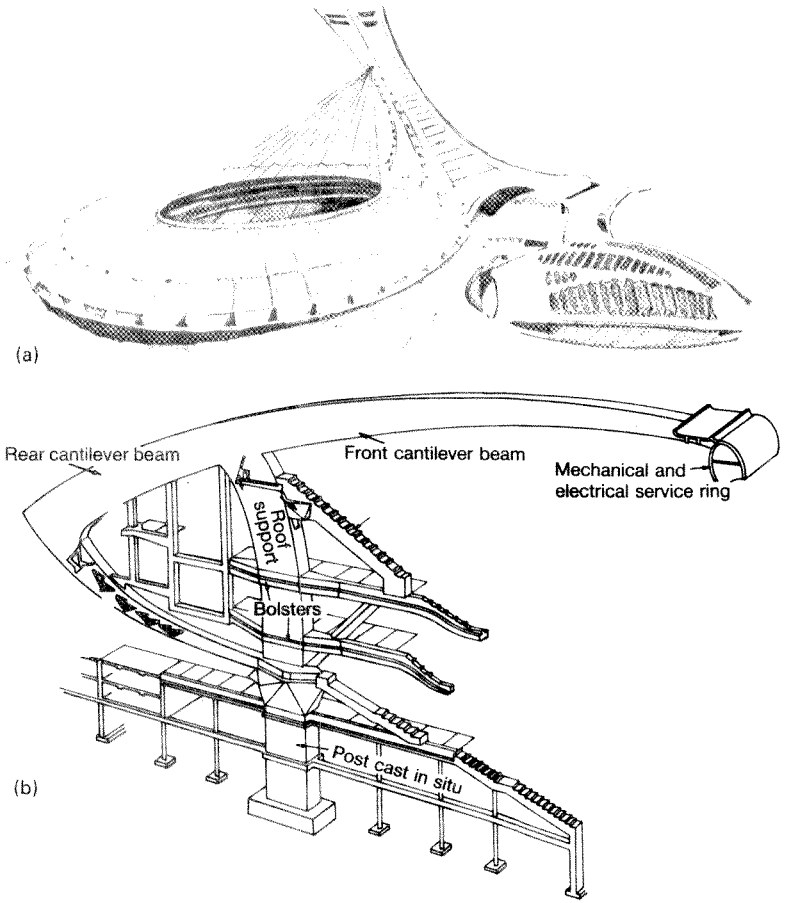
Candela, the Spanish–Mexican architect who made his reputation though his ability to design shell roofs (in the engineering sense of the word) and then build them, described the tension between the engineer and architect in the following terms:

The second design phase . . . consists of a tremendous battle between the structural engineer and the architect—the former willing to introduce modifications which, although sometimes necessary, many other times should be unnecessary . . . On the other hand, the architect wants to maintain his preconceived idea, but has no weapons to fight against the scientific arguments of the technician. The dialogue is impossible between two people who speak different languages. The result of the struggle is always the same: science prevails and the final design has generally lost the eventual charm and fitness of detail dreamed by the architect.

This is, of course, a simplified and generalized account and few engineers would agree that the architect always loses. The attitudes of both parties can vary considerably and as a result there are differing styles of interaction.

At one extreme some engineers are happy to work as the 'right-hand man' to the architect. This attitude was expressed frequently at a debate on the controversial Montreal Olympic Stadiums (Fig. 8.1) organized by the American Society of Civil Engineers (ASCE). The structural efficiency of the chosen forms had been heavily criticized by Tedesko and Zetlin, two prominent New York consultants who considered that the structural engineer should have been called in early in the design process and allowed to influence the original architectural concept. In defence of the architect, Vigneault, a structural engineer who had collaborated on the project, made the analogy that if one bought a Picasso painting one did not try to change it.

Similarly, the idea . . . of the architect for the Olympic Stadium was bought



8.1 (a) Model of the stadium for the Montreal Olympics (1976). Tower not completed. Engineering in the service of art? The subject of a lively debate. (b) Structural element of the main stadium. (Archt: R. Taillibert.)

and the entire world has accepted the project. I believe it was the proper role of the engineers to complete the design and construction with the use of the modern methods at our disposal.

Záleski, an engineer who had assisted the same architect, said:

His creations have to be considered as works of art; they are large scale sculptures. As a designer I gave him structural support without ever wanting to change anything.

Another consultant who had worked on the project agreed that the structure could have been more rational, but said:

. . . if we agree that these structures are to be considered sculptures with a certain function, esthetics should be left to the architect . . .

His company took it as a challenge to make the structures stand up following the shape given them by the architect.

If we agree that the esthetics should not be touched by the consulting engineer, I think another objection to these structures—cost—cannot be discussed either.

The architect who prefers this type of relationship is typified by Fry whose references to 'his' technicians have been quoted above. Many architects not surprisingly tend to see the engineer as a willing servant. In the 1850s, Professor Robert Kerr tried to persuade architects to act as 'a servant of the public for the efficient design of buildings, precisely like the engineer'. Jencks (1973) refers to 'The traditional values of the engineer; self-effacement, service orientation, efficiency, openness to change, quantifiability, etc.'

In the middle ground come the many architects and engineers who prefer a relationship in which the engineer makes a positive contribution to the conception of form. In 1974 the *Architectural Record* initiated a mid-August series on engineering in architecture in order to 'give recognition to engineers in building for their inventiveness and resourcefulness in work with architects to achieve economical and rational (as well as beautiful) buildings'.

In the debate on the Montreal Olympic stadiums it was, typically, an architect who said he was

shocked to see that the architect is treated as god, and that the engineer has been born to be his slave and do whatever the architect wants.

The engineers who criticized the project all advocated better and earlier collaboration between the two professions and one stated that the architects who retained his services expected him to give frank and honest opinions about their proposals, including aesthetic as well as structural aspects.

The RIBA Handbook gives a very sensible appraisal of the engineer's contribution:

In the field of building it can generally be assumed that the structural engineer

is working as a member of a design team with the other disciplines involved . . . In this situation the engineer not only contributes his own special expertise but equally contributes to the combined work of the team; the whole as usual being greater than the sum of the parts. Thus while the engineer has the responsibility to prescribe the conditions for structural efficiency and stability, he also has a co-operative role in the design contribution of others, which in turn will affect the overall structural form.

These differences in attitude are reflected in the organizational relationships to be found within the industry. Thus at the other extreme to the architect who demands individual leadership are some architectural firms willing to work as equal partners with other consultants in a package deal under the overall direction of the promoter. A few architects are willing to work under the direction of a chief engineer and some engineers work without an architect. These situations occur mostly in government departments and very large private organizations concerned with the design of 'engineering structures' such as power stations and bridges. Architects are rarely content under such conditions because as we have seen they are by training and inclination prepared for a completely different role. In an interview with Shellenbarger (1979) a senior architect in the design offices of the international construction company Bechtel Inc. described architects in the Power Division as 'there to put facades on power plants'.

A large number of structures have in the past been designed entirely by engineers without the advice of architects. These include dams and their associated facilities, bridges, power stations, industrial structures such as mine-head frames and bulk-loading facilities, gantries, silos, warehouses, and factories. In many cases, especially factories, the omission was as much due to a lack of interest amongst architects. This situation is rapidly changing.

Engineers like Torroja and Nervi who had the sensibility to design structures of beauty without the aid of an architect (though both frequently collaborated with architects as principal or consultant) are in a class by themselves. Probably inspired by these examples, and the general dissatisfaction with conventional arrangements, there have been suggestions that the engineer should take over as the 'master-builder' of the future. However, there is little chance that a master-builder of the future would be a direct descendant of either of the present professions. Practising architects probably see the current trend towards the use of professional 'project managers' as a greater threat, resulting in the relegation of their own profession to the level of the other consultants.

Differing viewpoints, differing skills

The fundamental cause of the difficulties in the engineer–architect relationship is the complexity of modern constructions. This necessitates a division of labour and hence differing education systems. The differing roles attract people with differing personalities and the educational training reinforces their disparities so that the graduates emerge with incompatible scales of values.

A fact which many architectural commentators forget is that in the English-speaking world most structural engineers are educated in schools of civil engineering, so that structural knowledge forms only a part of the course alongside transport, water resources, and other material of a general mathematical, scientific, and civil engineering nature.

The major practical difference in the educational training is that the architect is encouraged to take an overall view of a problem with the accent on synthesis while the engineer is trained to tackle problems piecemeal and the accent is on analysis. An architect who had trained originally as an engineer pointed out in one debate that the first thing he had been asked to design in his engineering course was, in the very last year, a small bedplate for an industrial sewing machine. From there he went straight to the first-year class of an architecture school and was immediately set the task of 'designing' a swimming pool.

He also pointed out that the 'studio' system of teaching used in architecture schools gives the courses a much less organized character. It is common in studio sessions for the lecturers to be practising architects who devote perhaps one or two days per week to teaching. Students thus have an opportunity to work on their projects shoulder-to-shoulder with teachers who are in contact with the real world of design.

A feature of the interviews mentioned in the previous chapter is the frequency with which architects identify with one 'hero' amongst their teachers, particularly at postgraduate level. The contrast with the average engineering course is obvious.

As we saw in the previous chapter architecture courses place great emphasis on imagination, synthesis, and planning, whereas engineering courses emphasize analysis, factual information, and computational techniques. As a result the graduates emerge with very different skills. The Bechtel architect reported by Shellenbarger found there was much that the two professions could learn from each other when obliged to work together.

When you get an architectural project in an office the first thing you do is pro-

gram it. Programming was something that [the engineers] didn't know anything about.

An architect hired to work with a team of engineers on the design of sewerage and water-treatment plants found that the engineers tended to lay out the plant as a physical manifestion of its flow diagram.

This sort of planning apart from generally ending in disorder was also inefficient . . . even the best process engineers have not been trained to ask questions about space and circulation that are second nature to an architect.

The engineer's original conception of a scheme usually left out consideration of the people working in the plant, particularly their need for ease of access to equipment and shortened lines of communication. The architect's influence resulted in a more compact arrangement which, besides improving the appearance, simplified road access and personnel control, and improved HVAC efficiency, piping layout, and zoning for the isolation of gas. On the other hand the Bechtel architect stated:

I'm learning things that I would never have exposure to in an architectural firm: means of controlling cost within a project; means of letting a client know how much his costs are going to be . . . And you seldom if ever see those kinds of methods used in architectural firms. By the time you get around to getting an estimate in an average architectural office, you're 75 to 95 per cent of your way through working drawings . . .

In considering how the engineer and the architect can best contribute to the stages of the design process as described in the RIBA *Plan of work*, Armstrong and Jack (1970) make several references to the differing approaches of the professions. They describe the first stage ('Inception') as mainly an information-gathering exercise and feel the 'logical and analytical approach of an intelligent engineer would contribute considerably . . . especially where the architect is not as objective and analytical as the process demands'. The 'Feasibility' and 'Outline proposals' stages involve synthesis to a large degree: 'a key stage for the architect, the time for conceptualising. Considerable assistance can be given by the engineers but to contribute effectively means having a more fluid approach than is customary amongst engineers'. Both of these authors are partners in the 'Building Design Partnership', a multidisciplinary consulting firm, one being an engineer and the other an architect.

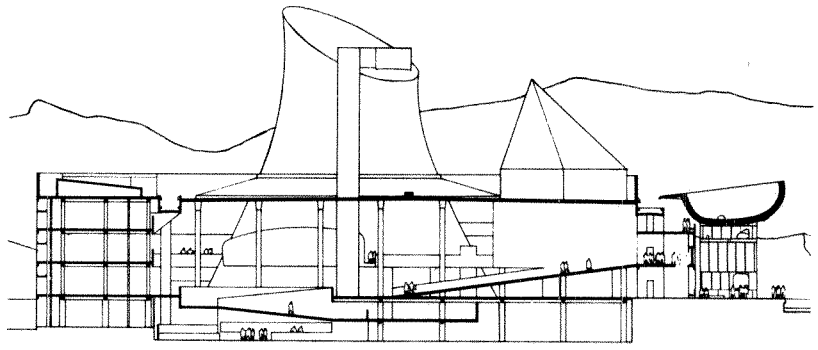
They also point out that the architect's broader viewpoint means that he 'is all too often guilty of making assumptions on an intuitive basis . . . his tendency is to ignore established work procedures if they

seem irrelevant or tedious and there are few architects, in the authors' experience, who achieve high standards in all the main related areas . . . '. The architect thus attempts to function as a generalist and is easily faulted when he enters the territory of any of the specialists. On his part he is able to criticize the specialists for their lack of knowledge of subjects outside their specialty, and their inability to take the overall view. According to Dunican (1966),

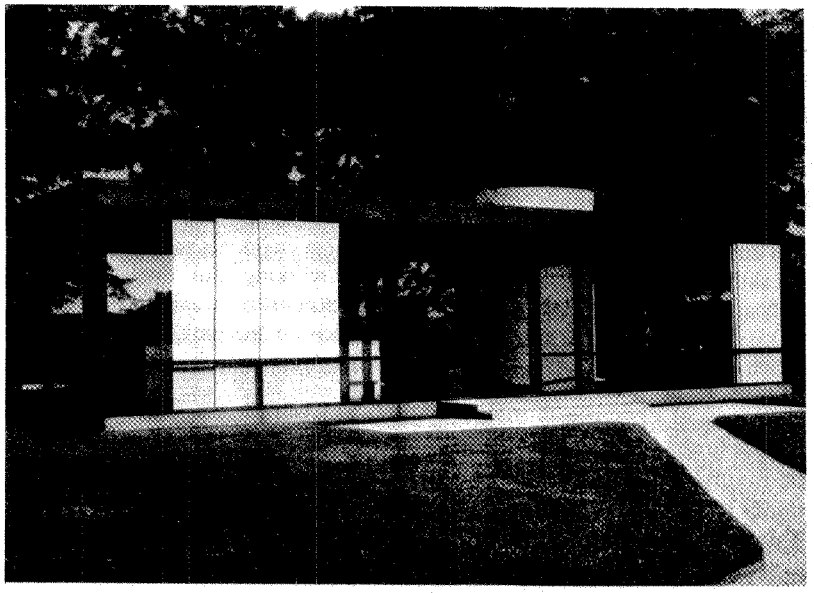
it is unfortunate, but nevertheless true, that most engineers suspect the technical skill of the architects with whom they are working. This does not necessarily apply at the top level, but this suspicion certainly does exist in the drawing office. This often leads to technical arrrogance on the part of the engineer, which conflicts with the apparent intellectual arrogance of the architect.

A typical example is in the cladding of buildings. Engineers often accuse architects of being unable to keep the rainwater out of a building or maintain the structural integrity of the cladding. There have certainly been many failures in this area, some of them extremely costly. The architect's impatience with the more mundane aspects of design, noted in the previous chapter, is one of the major sources of friction, particularly when he relegates creature comforts to a low priority.

It is interesting to compare Fry's rhapsodic account of Corbusier's design of Chandigarh (Fig. 8.2) with Evenson's list of the complaints of its users. The low level of interest in functional efficiency may be due to the architect's own disregard of comfort and convenience in pursuit of aesthetic principles. In certain architectural circles 'monuments' are considered to be in bad taste, but when the famous American architect



8.2 Assembly Building, Chandigarh, India: does the bold symbol of the hyperbolic cooling tower function efficiently as a debating chamber? (Archt: Le Corbusier.)



8.3 Glass House, New Canaan, Connecticut. Architect and owner; Philip Johnson, who would 'live in a barn' in the interests of art. (Photograph by Ezra Stoller, © Esto.)

Philip Johnson was asked whether his Glass House (Fig. 8.3) was a monument, he replied: 'Of course. It has nothing to do with a house. I live here, but I'd live in a barn.' When asked whether a certain building was successful in functional terms, he replied:

'That's mighty low terms to be successful.'

If architects tend to be preoccupied with the broader and grander aspects of the project, the engineer has been accused, justifiably in many cases, of submerging himself in detail for defensive reasons. Fazlur Khan, responsible for the innovative structure of many American multi-storey buildings, pointed out that while there was a growing tendency for the architect to ask the engineer's opinion on the best solution for a problem, 'too often the engineer would opt out of the extra responsibility', being happier when solving '200 simultaneous equations'.

A contributing factor must be that the average engineer bases his thinking on 'natural laws' or procedural rules handed down by Newton, Terzaghi, the local Standards Association, or the appropriate Design Handbook. Even the more adventurous, like Torroja, are obliged to

carry out proof or model tests before putting a new idea into practice. In argument he is therefore more likely to say: 'This is so, because Newton said so', or 'because my tests indicate it', or 'we should take this course of action because calculations indicate it will be cheapest'.

Architects on the other hand feel able to say 'This wall should be brick because I feel it will express what I want to say about the nature of this building'. Some architects do feel the need to quote the old masters' aphorisms, but on the whole the difference is evident, and contributes to charges of 'arrogance' on both sides. Perhaps the studio system and the adoption of heroes has something to do with the architect's self-confidence.

Broadbent (1973) also sees engineers as having opted for the relative certainties of structural design rather than the ambiguities of architectural value-judgements. He questions the conviction of many engineers that their work is as a result more demanding than that of the architect.

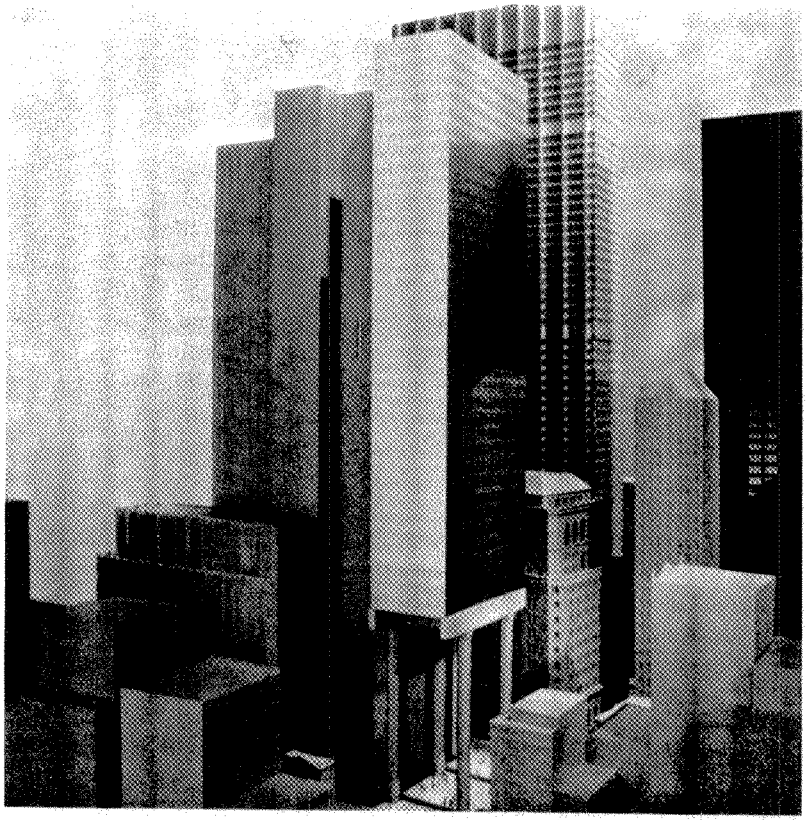
Probably the major single cause of disagreement between architects and engineers is the difference in their attitude to money. The whole rationale of the engineer is based on the maximization of the benefit-to-cost ratio. To the idealistic or artistic architect, money is simply a means to an end, and the more he can get of it, the better he can fulfil his aims. One engineer recounted how after much hard work he and his team devised an improvement to the structural system of a building which they calculated would reduce its cost to the client by $10 000. When they informed the architect his response was 'good, that means we can afford to have aluminium cladding' and he promptly diverted the money to this end.

In discussing his design for the Federal Reserve Bank Building, New York (Fig. 8.4; abandoned just prior to the start of construction), Kevin Roche is quoted as saying: 'It needs to relate to the tall office buildings on the block, and to the other large rectangular buildings in the vicinity.' Referring to the planned development of other buildings in the locality, including the World Trade Center, he continues:

Our building will be surrounded by these monsters. They would place us in a hole . . . We say we don't want a lobby (at ground level) . . . Also we would like to get out of the hole. Let's take the whole building and move it up! Let's move it up to be in line with the cornice of the old building across the street.

As a result the design incorporated enormous legs 11 feet (3.35 m) in diameter supporting the building 165 feet (50.3 m) above the plaza.

The engineer's incomprehension of this type of approach is indicated in a letter Arup wrote in favour of the proposal to support the acoustic



8.4 Federal Reserve Bank Project: a building to be set on stilts so that it would not be overwhelmed by its neighbours. (Archt: Kevin Roche.)

ceiling of the auditorium in the Sydney Opera House from a steel framework rather than a timber one, as proposed by Utzon.

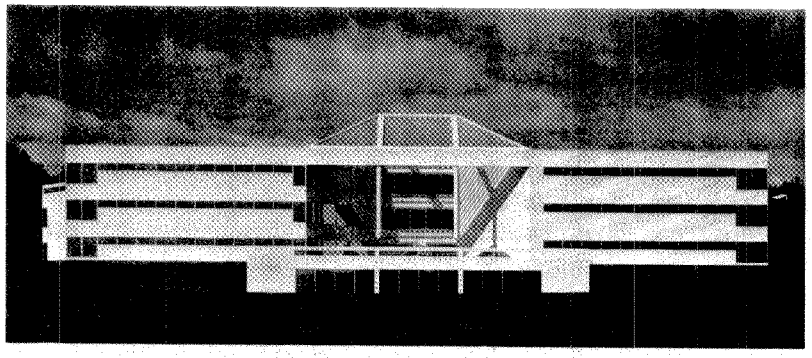
> as far as I understand it (the steel alternative) gives exactly the same outward appearance as your scheme. But it weighs much less and can be built and costs less. So what is so frightfully wrong?

Of course, not all architects have this cavalier attitude towards money and structural imperatives, but the scale of values with regard to aesthetics and function is always different from an engineer's.

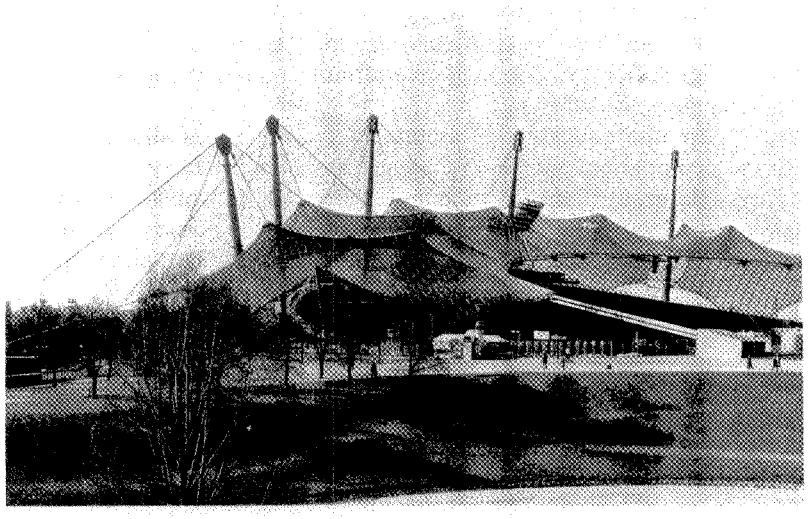
An extreme example of this is the 'structural joke'. In the West Building of the John Deere Financial Centre (Fig. 8.5) the columns

which apparently support the portico above the entrance are in fact suspended from it and do not touch the terrace below. Corbusier's cooling-tower from the Government Assembly Building at Chandigarh, India (Fig. 8.2), may be seen as an enormous joke at the expense of the politicians.

The separate education of architects and engineers allows them to develop completely different languages in which the same words mean entirely different things. An example is the way in which the two professions use the word 'design'. Many architectural books attribute the 'design' of the cable net roof for the Munich Olympic Stadiums (Fig. 8.6) to Frei Otto. However, the original idea came from the architects Behnisch and Partners, and Otto was involved as a specialist consultant as was the engineering firm of Leonhardt and Andrä. The form originally proposed by Behnisch was modified for stability reasons and Otto's contribution came from his wide experience of tensile structures and his model techniques, leading to the adoption of a practical form, definition of the resulting dimensions, and preliminary calculations. The engineers' contribution resolved into the traditional task of 'making it stand up' without necessitating further major changes in form. The exact definition of form is so important in cable net structures that Professor Argyris and his colleagues spent a full year in developing a mathematical approach. Then followed extensive computer analyses and specification of detail on the part of the engineers. Even so, most



8.5 John Deere Insurance H.Q. Moline, Illinois: A modern-mannerist joke. The architect, Kevin Roche, said: 'This is another of our buildings that you see momentarily through a gap between the woods as you flash past in your automobile. On the right of the central section there is a real shadow on a solid wall, on the left there is a reflected shadow because the surface is a mirror. Two columns come down the front; as you flash past you see them and they form part of the composition, but because you can span that width with steel you don't need the columns so they don't go right down. There is a rather nice terrace and they would spoil the view.'



8.6 Roof of the stadium for the Munich Olympics (1972). Tension was not confined to the mechanics. (Archts: Behnisch and Partners with Frei Otto. Engrs: Leonhardt und Andrä.)

architects would still consider that the Behnisch firm and Otto did the 'real' design; the difficult first step of conceptualization and definition of form; while engineers would tend to feel that anybody may dream up a fancy shape and that Leonhardt and his colleagues made the most important contribution in turning the concept into reality. The history of the project included political intervention and tension between architect and engineer. Personal accounts (in German) are given by Leonhardt (1984) and Otto (Klotz 1977).

The problem of language will be discussed again in later chapters concerned with 'function' and 'economy'.

Once the graduate has left his school, the division is maintained by the institutionalization of the professions. We have already seen something of professional jealousy in the rival claims for leadership of the design team and disputes concerning the design of cladding. Many engineers also feel that architects are reluctant to involve them fully in structural design because they wish to retain as much as possible of the consulting fee for themselves.

Architects have also been accused of retaining control of the specification of cladding in multi-storey buildings when this really required the attention of an engineer owing to the high wind loads and the extent

of thermal and long-term movements in the structure. They are accused of doing this because the associated fee, being a percentage of the cost of the cladding, may be as large as that which the structural consultant receives for the entire structural design.

There are also complaints of a tendency on the part of architects to exclude the engineer from the supervision of construction, or to employ him to inspect only minor portions of a difficult nature. In the latter case, complex problems may arise if the engineer happens to notice faulty construction in portions of the structure which he has designed but has not been engaged to inspect. Professional liability and simple ethics require that he correct the situation once he has become aware of it, but he may have difficulty in obtaining adequate recompense for his *de facto* supervision.

Despite these many differences, architects occasionally display quite positive attitudes towards engineers. The Architectural Association of London held an exhibition in 1982 devoted to 'The Engineers' and in a recent article the critic–architect Peter Cook lavished praise on the engineers involved in the British High-Tech movement. It is now routine for reports of new projects in the architectural journals to list the engineering consultant and common for recognition of their contribution to be included in the text.

In contrast it is still common for engineers to publish papers on such projects without once mentioning the fact than an architect was involved or that architectural considerations had any influence on the design. Admittedly this is partly due to the convention which engineers have adopted from the world of science that such papers must be written in the passive voice in order to give the impression that inexorable logic rather than conscious choice governed the evolution of the design. It may also reflect the 'team mentality' of the engineer in contrast to the individualism of the architect.

Nevertheless architects seem more ready to give public recognition to the contribution of engineers than vice versa. Is this entirely due to the fact the engineers do a better job?

History of the division between the professions

The history of the separation of the two disciplines in the Western World is traced to the middle of the eighteenth century; specifically to the founding of the École des Ponts et Chaussées in Paris in 1747 and the School of Military Engineering at Mézières in 1748. The distinction was at first blurred, with architects still designing bridges and engineers

being fully responsible on occasions for the design of warehouses and even churches.

As the scientific content of the work increased during the nineteenth century, with the establishment of theories of the strength of materials, the professions moved further apart. It was, however, still possible for architects to design fully the small-span masonry and timber buildings of that time using the old 'rule-of-thumb' methods for proportions. Engineers confined themselves to large-scale structures where precise calculation was essential and later on to the introduction of the new materials; cast iron, steel, and finally reinforced concrete. As Stone (1969) has pointed out it was this latter development that around the turn of the century finally consolidated the position of the structural engineering consultant as we now know him.

However, the split can hardly be thought of as a simple divergence of interest, starting from a common original position, which Collins considers to be due mainly to a difference in scale. In Britain the architect was something of a 'gentleman' and distanced himself from the craftsmen and labourers, whereas British engineers of the nineteenth century often rose from a simple background with a leaning towards the trades and were as much involved in mechanical as structural engineering.

In Italy, when the Gothic tradition was abandoned, architecture was taken over by painters, sculptors, and draughtsmen. It was only in France, where architecture was considered the 'art of building' and in Germany where traditions were carried on in direct line from the cathedral builders, that a simple schism may be considered to have developed. In these places schools of architecture and civil engineering at first co-existed with academics moving easily from one to the other. Thus calls for reconciliation and debate about reasons and possible remedies commenced almost as soon as the split itself.

Meanwhile, the majority of architects, locked in their internal battles over styles, became little more than appliers of ornament to the facades of buildings, convinced that they could not surpass the perfection of the past and thus seeking inspiration from literature, history, archaeology, and the fine arts. The engineers, riding on the wave of the Industrial Revolution, became preoccupied with the testing and development of materials and the use of computational techniques, looking for their inspiration (when they were not conducting their own investigations) to the physicists and mathematicians.

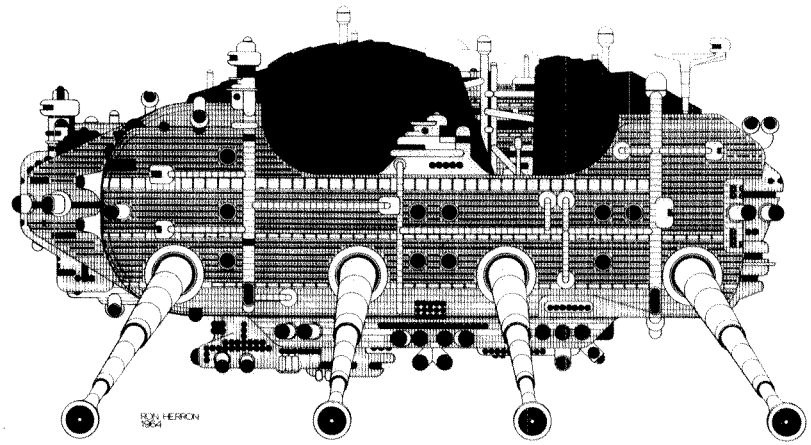
However, in the later nineteenth century architects began to see the 'functional' approach of the engineer as a key to breaking free from their own preoccupation with style and ornamentation. Their attitude

to engineers thus became somewhat complex. Even Frank Lloyd Wright wished to be recognized as a master engineer. Le Corbusier wrote in his *Vers une Architecture*: 'our engineers are healthy and virile, active and useful, balanced and happy in their work'. (Unfortunately, he spoilt this picture by threatening elsewhere that an architect who fails to reach artistry will reveal himself as a 'mere engineer'.)

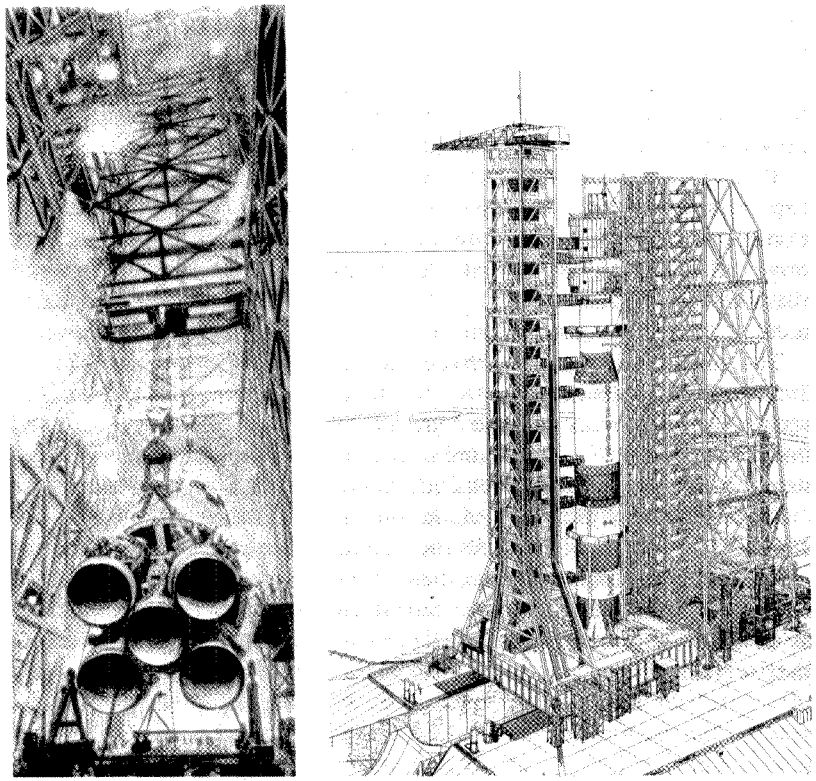
Thus, in conjunction with the various functionalist theories, the concept was born of the engineer as a noble savage who was liable on occasions to create beauty because he was obliged to obey, and thus now and again fully express the 'natural law'. Arup was able to write that, by the 1920s, 'When I started my collaboration with architects . . . the engineer was almost a kind of hero—in theory at least.'

The functionalist ethic survived the Second World War, and in the 1950s the drive to incorporate structural engineering in architecture received new impetus with the demand for large stadiums, auditoriums, and arenas, and the development of analytical techniques capable of dealing with the new forms required to enclose such large volumes.

Admiration for the work of the engineer surfaced again as late as 1970 when Blake referred to the visions of the Archigram Group; mobile buildings and plug-in cities towering into the sky or built on stilts over the sea. These were received with contempt in many quarters as obviously impractical; but in Blake's words 'somebody forgot to tell these certifiable lunatics down at Cape Kennedy' who built the Vehicle



8.7 'Walking City' Project (1964): do the visions of architects enlarge the horizons of engineers? (Archt: Ron Herron.)



(a) (b)

8.8 (a) Vehicle Assembly Building, Cape Kennedy (1966). A mega-structure large enough for clouds and rain to form within its envelope. (Engrs: Roberts and Schaeffer Co. Archt: Max Urbahn.) (b) Mobile Launcher and Mobile Service Structure with Saturn V aboard. Two 'walking buildings' of the sixties. (Archt–Engrs: Reynolds, Smith, and Hills for Kennedy Space Center.)

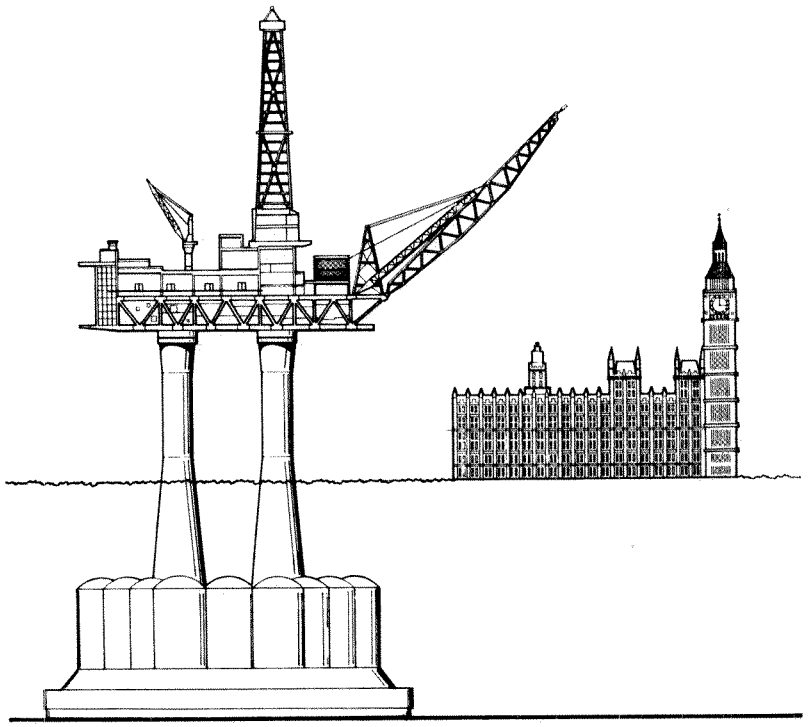
Assembly Building (Fig. 8.8) so big that clouds form inside it—a mobile structure as high as a twenty-two storey building with plug-in workshops lifted by cranes—and the engineers who created 'cities' built on legs in the form of offshore oil drilling platforms (Fig. 8.9). This interest has been continued in the 'High-Tech' movement (Chapter 10) which is particularly strong in the UK. On the other hand, developments in architectural philosophy, inspired partly by the energy crisis and partly by a desire for a more human scale in buildings, suggest that

many architects may give less prominence to the role of the structural engineer than in recent times.

Possible solution: interdisciplinary organizations

Because attempts at reconciliation between the two disciplines have been going on more or less continuously since 1840 it appears that the problem may be intractable. To begin with, the construction industry is extremely complex and the ideal of the master-builder is unlikely to be realized in any but the occasional genius such as Nervi. As Boyd observed:

> The rapprochement between engineer and architect after World War II was welcomed immoderately by some idealists who believed that it heralded the end of the art–science split and the reappearance of a master designer: architect and engineer rolled into one, to the great benefit of building.



8.9 Current form of North Sea Oil Platform in reinforced concrete. A city built on stilts?

He pointed out that if the argument is carried to its logical conclusion, this composite person should possess the skills of all the other consultants as well. This is especially true for some buildings where provision for energy control dominates the form and sometimes overshadows the cost of the structure. Boyd also pointed out that with continually increasing complexity in all fields it is more likely that further subdivisions will occur, with structural engineers splitting into shell specialists, tensile-roof specialists, and so on.

The future therefore seems to lie with the well-knit team rather than with the encyclopaedic talent of single individuals. Nervi naturally advocated the ideal of the master-designer, but himself recognized the immense problems of educating such an individual and called for 'the sincere collaboration of different people, each contributing the specific knowledge lacked by the others'.

The complex administrative arrangements involved in conventional architect–engineer interaction interfere with this process of collaboration. One response to this is the multidisciplinary practice in which engineers and architects belong to the same firm.

Truly equal partnerships are probably the best hope we have of achieving all-round design. However, the establishment and operation of such ventures is not without its problems. The founder of the Building Design Partnership, architect G.G. Baines, felt that many experiments in multidisciplinary practice had failed because of the inability of individuals to see the complete picture, and because they grouped together for the wrong reasons. Many had come together because they were frightened of competition from larger firms and package deal contractors. A paper setting out the philosophy of the partnership states that the greatest problem is that difficulties still bring to the surface the narrowness of professional training so that instead of grappling with them from a united position 'the inbred tendency is to run to our professional corners and fight the matter out from the shelter of our individual skill . . . it is inescapable when this happens that there are always more architects than engineers'.

One consulting engineer was reported to have said that because the architect's fee for a project was about three times that of the engineer's, if he wished to amalgamate with an architectural firm he would have to find one with a staff three or four times the size of his own, 'and how many architects have a staff of two or three hundred?' A similar reasoning, applied in reverse, prevented the architectural firm of Yorke, Rosenberg, and Mardall from employing its own engineers on the grounds that the resources they could maintain internally could never

match the talent they could call in from outside. Furthermore, multidisciplinary work is not suitable for all types of personality. Armstrong and Jack (1970) in describing the successful operation of the Building Design Partnership state

> It has been noticeable in the BDP offices how much certain individuals in the engineering profession enjoy working within the team, whereas others are happier working in a more sequestered environment surrounded by their fellow professionals . . . Those who favour the professional group tend to be more reactionary, conservative and narrow-minded and, therefore, less inherently able people, and gradually it is hoped to diffuse the professional boundaries so that the individual in any profession is allowed to extend himself more completely to contribute effectively in a total sense to the design team according to his talents, abilities and ambitions . . .

Martin, of Ove Arup and Partners stated that in the present circumstances it is still the architect who ends up 'boss' of the team, and it requires an exceptional individual to inspire the whole team. Often the architect is unable to do this, and the various members of the team go about their business automatically in the conventional manner.

In Ove Arup's office there were three types of engineer. The first made a long-term commitment to a stable interdisciplinary group. Martin described this as being 'almost like going into a monastery'. The engineer tended to lose his distinct professional identity as he learned more about architecture and services and became able to turn his hand to any aspect of design. The disadvantages were that by its nature such a group is limited to projects of small to medium size, and that after a while the engineer found the work of the team's architect entirely predictable and thus less stimulating.

The second type of engineer was part of a multidisciplinary team of engineers only. This was allocated to whatever architect happened to be concerned with a particular project. The work of such a team was therefore more varied and the size and composition of the group was more flexible.

The third type of engineer was the more conventional, with an interest in pure technology and a liking for the challenge of unusual and complex engineering structures such as transmission towers and large bridges.

There are thus many possible styles of interaction between architects and engineers and the secret of success is perhaps to know which of them best suits the individual's personality.