be rather more loosely connected. Thus in the design of a power drill, the motor, gearbox and chuck are inevitably very directly connected. The switch is linked to the motor but only electrically and therefore loosely, while any reversing control is probably more likely to be mechanical thus restricting its location rather more. This central role of internal constraints is demonstrated by a study of how Mike Burrows designed the revolutionary LotusSport bicycle ridden to a gold medal by Chris Boardman in the 1992 Olympic Games (Candy and Edmonds 1996). Throughout the process, it was the relationship between front and rear wheel, saddle and handlebars which had to be resolved. Eventually Burrows discarded the traditional diamond shaped tubular frame and adopted a monocoque structure.

External constraints

For the fashion designer external constraints range from the manufacturing process, whether it be handmade or mass produced, to the human body itself. Off-the-peg clothes are obviously designed around average bodily dimensions but for the one-off high fashion designer the external constraints of a particular shape, personality and occasion provide the inspiration for the design of unique garments intended to be worn in one specific context. In theatre design, neither the play nor the stage are under the control of the designer, but a particular combination of the two might provide the inspiration for a unique set. The dramatic demands of the play together with the visual and acoustic properties and problems of the stage comprise a highly significant collection of constraints. Sometimes external constraints virtually determine the whole form of design. What makes one bridge different from another are the site conditions, the span needed, and the position and quality of supporting ground. The Severins Bridge across the Rhine in Cologne posed its own unique problems generated by external constraints. The architect's sketches show a concern about the way a conventional two-tower suspension structure would have seriously obscured the down-river view of the massively impressive cathedral which dominates the skyline (Fig. 6.3). As luck would have it there was conveniently accessible supporting ground in shallow water about a third of the way across the river. The architect's sketch shows his proposal to the engineer that they might be able to design the structure with a single tower at this point.

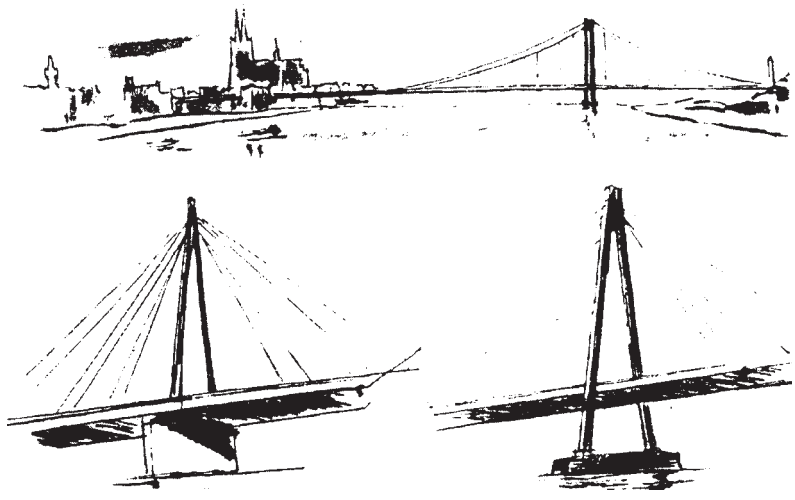

Figure 6.3
The architect's and engineer's sketches for a new bridge based on protecting the vista

However, not fully appreciating the engineering issues his sketch shows a catenary structure with its characteristic sagging cables. The engineer replies by changing these to taut cables and an 'A' shaped tower. Finally the junction between tower and deck is more satisfactorily resolved. Here then the external constraints, combined with the architect's concern not to destroy the Cologne skyline, have resulted in an extraordinarily distinguished and fresh solution to an age-old problem of civil engineering (Fig. 6.4).

Rowe reports several detailed studies of architects observed during a design process. In one of these experiments the designers were asked to work on a world bibliographical centre on a waterfront site in Chicago. Rowe describes how the subjects recognised the site as a major form determining influence or 'primary generator'. Rowe's designers considered 'establishing symmetry by extending out into the lake on a pier structure, similar to those (already there) adjacent to the site on the river side' (Rowe 1987). Only after this did these designers begin to explore the overall shape of their building. Then attention turned again to the site through a study of Chicago's downtown grid pattern of planning. Eventually the problem became one of resolving the two themes of creating a waterside landmark and extending the grid pattern of the surrounding city.

The scheme then developed as a linear grid-planned form terminating in a rotunda-like structure protruding into the lake. Later this was gradually altered as the actual requirements of the accommodation itself (internal constraints) were considered in detail. At