4 Building exterior

Introduction

In many urban locations site boundaries and recession planes determine architectural form. Particularly for medium- to high-rise buildings, economic and pragmatic necessity give rise to ubiquitous rectilinear forms that require architectural approaches other than the manipulation of building massing for them to contribute positively to the urban fabric. With the exception of those buildings completely clad in mirror glass or some other type of opaque cladding, many buildings world-wide share the common feature of some exposed structural elements on their façades. Arising more from an appreciation of the functional advantages perimeter structure affords, than intentionally exposing structure for its own sake, structural members are often exposed. While such structural ordering and patterning of façades often merely reflects that of the surrounding built environment and therefore tends to proliferate architecture of indifferent quality, some architects take a more proactive stance towards exposing structure. They are aware of its potential to enrich exterior architecture.

Before considering in breadth the diverse contributions that structure brings to building exteriors, the chapter begins by examining one building more deeply, the Hong Kong and Shanghai Bank, Hong Kong. A study of the exposed structure on its main façade sets the scene for discussing many of the roles exterior structure plays that this chapter explores.

One of the bank's most distinctive features is its exposed structure on the main façade (Fig. 4.1). If this structure were to be concealed behind cladding, one of the world's best-known commercial buildings would no longer be recognizable. Devoid of its iconic structure it would merely merge with its neighbours' more conventional architecture.

▲ **4.1** Hong Kong and Shanghai Bank, Hong Kong, China, Foster and Associates, 1986. Main façade.

Development of the unusual structural form arose primarily from the client's insistence on retaining an existing historic banking chamber that occupied the side. Foster and Associates' first sketches for the competition to select an architect show large exposed bridge-like trusses spanning across the building and supporting suspended floors beneath.[1] After being commissioned, the architects continued to develop long-span structural schemes. Although the client eventually decided to trim the budget and demolish the banking chamber, commitment to a long-span structural solution was justified by studies that showed large column-free areas yielded significantly higher rental returns than shorter-span options. The client also appreciated the high level of planning flexibility that long spans provided. After abandoning the relatively crude bridge-truss design, a series of structural iterations that always included strongly exposed structure were continually refined until the final structural scheme emerged.

So, how does structure contribute to the exterior architecture of the bank? Beginning with its visual qualities, one notes how the structure is located in front of the cladding. Separated from the façade, structure modulates it, providing depth, pattern and order. The vertical structure, namely three hanger-rods and two ladder-like masts, create a symmetrical and rhythmical ababa composition. On a macro scale, the horizontal trusses subdivide the façade vertically, while beams within the ladder frames that can also be described as vierendeel masts, articulate individual storey heights at a finer scale. From a distance, structural scale relates well to the overall building scale. Structure, clearly distinguished from other building elements such as cladding, can be read clearly as such, yet a sense of structural monumentality is avoided. To my eye at least, structural scale verges on the minimal, even without allowing for the thickness of protective layers of cladding that encase the steelwork. However, close up, and especially inside the building, those apparently slender façade structural members appear huge. An interior column located within a single-storey space exerts an overwhelming presence due to its relatively large scale in such a confined volume.

As well as structure's contribution to the visual composition of the façade and the way its exposure links the interior and exterior architecture, structure can also be read as playing several expressive roles – such as expressing structural actions, building function and conceptual issues. The triangulated geometry of the double coat-hanger trusses shows how they transfer loads from their mid-spans and end tension-hangers to the vierendeel masts. At a more detailed level though, the expression of structural actions is somewhat inconsistent. While the increasing diameter of the tension-hangers towards the underside of each truss accurately reflects the accumulative increase of weight from the suspended floors, the enlargements at the ends of truss members suggest rigid connectivity rather than the reality of large structural pin joints. At a functional level, the mega-frame subdivides the façade to reflect functional and organizational aspects within the building. Masts separate service areas from the main banking hall and offices, and vertical spacing between trusses expresses five broadly separate functional divisions within the bank. Overlaying this functional expression, exposed structure articulates the High-Tech and state-of-the-art qualities of design and construction.

The following section of this chapter examines the aesthetic quality of exterior structure in more detail. Then, after illustrating how architects use structure to create strong visual connections between exterior and interior architecture, the chapter considers the relationship of exterior structure to building entry. Finally, it concludes by exploring the expressive roles played by exterior structure.

Aesthetic qualities

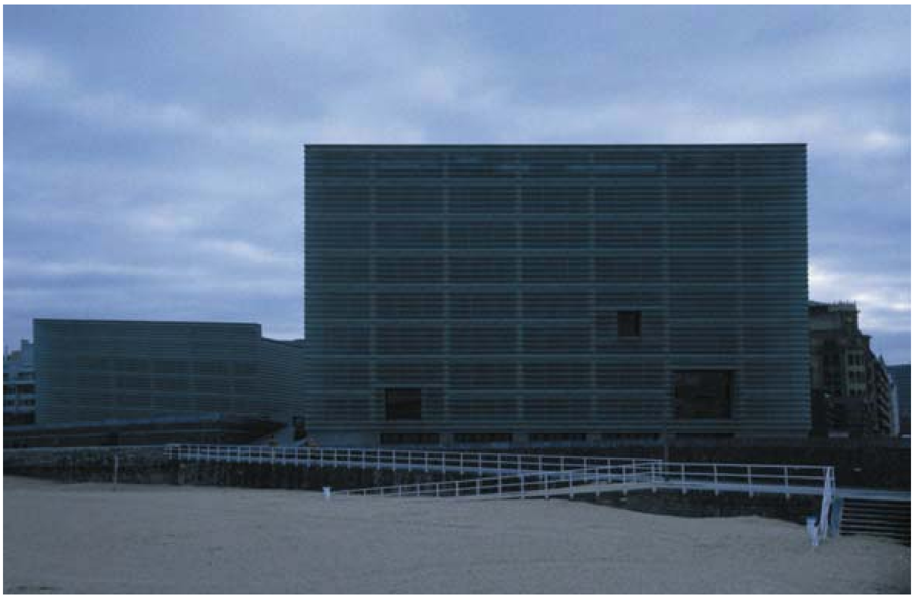
The exterior character of a building is often determined by how structure relates to the building envelope. Architects frequently explore and exploit spatial relationships between these two elements in order to express their architectural ideas and generally enrich their designs.[2] Structure plays numerous roles in contributing to the visual appearance of a building façade, through modulation, adding depth and texture, and acting as a visual screen or filter. Some of these roles are seen at the Hong Kong and Shanghai Bank. In all of them the structural scale must relate appropriately to the scales of the surrounding elements in order to achieve the desired outcome.

Modulation

Where beams and columns modulate a façade, they usually visually subdivide the skin vertically and horizontally, creating a rectangular ordering pattern over the building surface. Within these structural modules, secondary structural members, perhaps supporting glazing and themselves an order of magnitude smaller than the primary structural modulators, may further subdivide the surfaces.

Modulation generates patterns that potentially introduce variety, rhythm and hierarchy, and generally increases visual interest. Patterned or textured surfaces are usually preferable to those that are planar and bare. However, as seen on many office building façades, if the modulation is too repetitious it ceases to be an attractive architectural feature. Given its ubiquitous nature, modulation hardly requires illustration, but five rather unusual examples are discussed.

In response to its beach-front marine environment and an architectural concept centred on the beaching of crystalline rocks, a glazed envelope encloses the Kursaal auditorium perimeter structure at San Sebastian. Although not exposed, structure is visible, albeit dimly. The deep external wall structure that rises over 20 m to the roof is sandwiched between two skins of translucent glass panels. Structural framing that takes the



▲ **4.2** Kursaal Auditorium and Conference Centre, San Sebastian, Spain, Rafael Moneo, 1999. Structure behind translucent glazed panels modulates exterior walls.

form of vertical or slightly inclined vierendeel trusses that are tied together by regularly spaced horizontal members is therefore perceived as shadowy forms from both inside and out (Fig. 4.2). Although considerably subdued visually, structure still modulates the large exterior and interior wall surfaces, and on the side walls its geometrical distortions accentuate the building's subtle inclination towards the sea.

A more typical example of structure modulating a whole façade can be observed at the Yerba Buena Lofts, San Francisco (Fig. 4.3). Visually dominant primary structural elements – walls and slabs, play two roles simultaneously. While modulating and ordering the façade they also alter one's perception of the building's scale. Concealment of the mezzanine floor structure behind glazing in each double-height apartment means the ten-storey building is read as five storeys. To prevent the repetitive structural elements becoming over-bearing, translucent textured glass cladding to half of each apartment combine with set-back glazed walls to form balconies and provide welcome depth to the façade. Four recesses in plan along the building length, including one at each end, introduce even more variety.

At 88 Wood Street, London, structure is selectively exposed – in this case at the base of the building. Perimeter columns are set back 1.5 m from the street frontage to reduce the span and structural depth of interior floor beams. By minimizing structural depth, the developers gained an extra storey height within a restricted building volume. On the upper floors, a floor-to-ceiling glazed skin extends in front of the structural grid,

▲ **4.3** Yerba Buena Lofts, San Francisco, USA, Stanley Saitowitz Office/Natoma Architects, 2002. Walls and slabs modulate the front façade.

▲ **4.4** 88 Wood Street, London, England, Richard Rogers Partnership, 2000. Columns introduce rhythm and modulation at ground floor level.

▲ **4.5** RAC Control Centre, Bristol, England, Nicholas Grimshaw & Partners, 1995. Structural piers modulate the base perimeter.

concealing it from the outside. The resulting double-height blind-colonnade that visually functions as a base to the building, runs along the Wood Street frontage until the skin moves further into the building to accommodate the steps and ramp to the main entrance (Fig. 4.4). At pavement level, due to their size and modest spacing, the columns contribute a strong sense of rhythm. In the evening, when down-lit, the concrete columns become pillars of light. Above the level where the columns disappear behind the skin, articulation of the suspended floors and the vertical joints between the storey-high glazed units modulate the façade at a far finer scale.

The RAC Control Centre, Bristol, also concentrates its structural modulation at ground level. Tapering piers emerge through gravel surfacing to follow the outwardly canting glazed skin (Fig. 4.5, page 55). The piers have the appearance of inverted buttresses. Given that their maximum depth occurs at first floor rather than at ground level, the intensity with which they ground the building onto its site is reduced. Equally spaced around the building perimeter, they punctuate the vertical glazed or louvred walls between them and set up a rhythm that is all the more noticeable due to their large scale. Their main structural function is to support the internal steel columns that follow the slope of the inclined glazed skin and bear the weight of the roof structure. One reviewer observes that the only visible exterior structural elements above first floor level are fine stainless steel cables, and criticizes the decision to not expose the columns:

> *Although this undoubtedly simplifies the technology, the three-dimensional modulation of the building could have been hugely enriched, and the building's horizontals and verticals represented more literally, had these perimeter props remained on the exterior to be seen in association with the brises soleil.*[3]

While agreeing with an opinion like this for many other buildings, in this case I support the decision taken by the architects. By restricting the exposure of any significantly scaled structural elements to the base of the building, they have not compromised the clarity of the building's attractive rounded form.

Whereas the primary structure of the RAC building comprises two concentric circular-like rows of frames and the perimeter buttresses that modulate the ground floor, the structure of Ludwig Erhard House, Berlin, consists of a series of equally spaced arches of differing spans that rise to a height of over eight storeys (see Fig. 3.16). As explained in the previous chapter, its structural form conforms to an irregularly shaped site, satisfies the city planners' building-massing restrictions and meets the client's need to keep the ground floor structure-free. Tension-ties hung from the arches support most suspended floor areas.

At each end of the building, the arches and tension hangers are sheathed in stainless steel and exposed. But any modulating effect they have is muted by their slenderness when compared with the stronger modulation from spandrel panels and window mullions behind them. More emphatic

▲ **4.6** Ludwig Erhard House, Berlin, Germany, Nicholas Grimshaw & Partners, 1998. Arched ribs modulate the rear surfaces of the building.

▲ **4.7** Velasca Tower, Milan, Italy, BBPR, 1958. Columns and struts enliven the exterior.

structural modulation occurs at the rear of the building where it turns its back to its neighbours (Fig. 4.6). Its arches project far enough beyond the skin to read as ribs that modulate and visually define the irregular form of the curved wall-cum-roof surface.

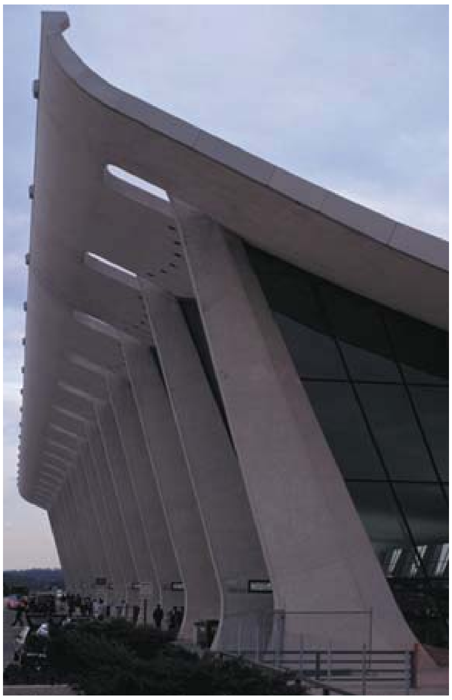
The Velasca Tower, Milan, provides the final example of modulation by exterior structure (Fig. 4.7). Its attached columns protrude from the building envelope up the height of the tower. They read as the outermost layer of an already visually rich and irregular façade modulated by fenestration, secondary structural members and vertical infill strips. Uninterrupted continuity of the column lines and an absence of similarly deeply projecting horizontal members accentuate verticality and thereby respond to the myriad of attached Gothic shafts that adorn the nearby Milan Cathedral.

The cross-sections of the exposed tower columns vary with height. Subtle and gradual dimensional changes in depth and width reflect a sculptural approach to column detailing that reaches its climax near the top of the tower stem. Depending on what façade is viewed, either four or six columns angle outwards to support cantilevering floors of the enlarged uppermost six-storey block. In this transition zone, columns transmute into inclined struts that are stabilized by horizontal V-braces where they again return to the vertical. Although modulating the surfaces from which they protrude, the columns and struts contribute aesthetically in other ways as well. The struts visually connect the tower enlargement to its stem. Their fineness and skeletal qualities also confer a spatial ornamental quality that softens an otherwise abrupt transition. Those nearest to the corners of the tower angle outwards towards the corners above, lessening the visual severity of the overhang in that area. In modulating the tower's exterior surfaces the columns and struts also contribute depth and texture, two surface qualities discussed in the following section.

Depth and texture

Although structure can modulate the surfaces around it by means of its distinguishing colour or materiality, in most buildings, including those just visited, structural depth is a prerequisite for and a major contributor to modulation. Variation of surface depth relieves plainness, and in conjunction with natural and artificial light, creates opportunities for contrasting bright and shadowed areas that visually enliven a façade. Until the emergence of Modern Architecture in the early 1900s with its flat and thin exterior skins, façades possessed reasonable depth, although that was often achieved through the use of decorative structural elements. The Gothic period is unique for the degree of structural depth associated

▲ **4.8** Cathédrale Nôtre Dame, Paris, France, 1260. Deep perimeter structure surrounds the chevet.



▲ **4.9** Dulles International Airport, Washington, DC, USA, Saarinen (Eero) and Associates, 1962. Piers create deep bays along the façade.

with its architecture, and in particular its cathedrals, whose walls are flanked by massive exterior structure. Buttresses topped by pinnacles and supporting flying buttresses contribute an extraordinary depth and texture as a by-product of structural necessity (Fig. 4.8).

Modern structural systems usually do not require nearly as much depth, but architects often welcome whatever depth is available for the aesthetic value it brings to a building exterior. For example, deep perimeter structure juts out from Dulles International Airport terminal, Washington, DC. Unlike Gothic buttresses that resist compression thrusts originating from masonry roof vaults, the terminal's piers resist tension forces arising from a reinforced concrete catenary roof (see Fig. 3.10). The piers are very substantial even though an outward inclination reduces the bending moments they must resist. Their elegant taper reflects both structural actions and the architect's desire to express 'the movement and excitement of modern travel by air'.[4]

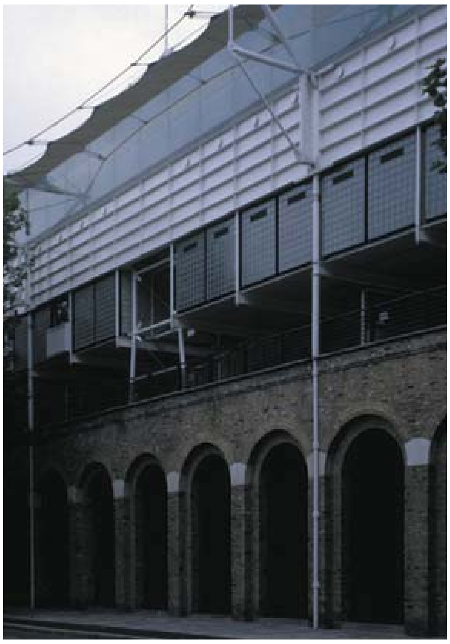
From most viewpoints the piers visually dominate the exterior of the terminal. They provide depth and rhythm to the front façade (Fig. 4.9). Even though fully glazed walls butt into the sides of piers and limit the extent of their exposure, by curving the glazed walls in-plan into the building, additional façade depth is gained. This masterful design move simultaneously dissipates the possible visual severity of planar outward-sloping surfaces, echoes the profile of the curved canopy above, and also accentuates both points of entry and bays between the piers for people to meet and wait in. The curved walls also allow for wind face-loads to be resisted by horizontal arch or catenary action depending on the wind direction, reducing considerably wall framing member dimensions and maximizing transparency.

Although designers usually provide structural depth to façades using ribbed or discrete elements, as in the previous example, continuous structure like an undulating wall presents other possibilities. If folded or curved in plan, the structural depth and the stability and strength normal to the plane of a wall increase. Such a wall can therefore be understood as a vertically cantilevered folded-plate when resisting face loads. In the context of this chapter, shaping a wall in plan presents opportunities for architectural enrichment, as illustrated at the Mönchengladbach Museum. Highly regarded for the qualities of its interior spaces and urban setting, an exterior gallery wall undulates (Fig. 4.10). The sinuous wall imbues one gallery interior with special character and outside, the wall's serpentine geometry appears as a natural extension of the curvilinear paths and brick walls that lead up the hillside to the museum. The gently curving wall possesses an attractive softness and naturalness.

▲ **4.10** Mönchengladbach Museum, Germany, Hans Hollein, 1982. Curved exterior gallery walls respond to the site contours.

No doubt the texture of brickwork also enhances one's enjoyment of this small section of the museum. Texture implies variation of surface depth and is linked to materiality. Each material possesses a unique texture depending on how it is fabricated, formed or finished. For example, before the introduction of metal arc welding the texture of steel-plated structural connections arose from overlapping plates and single or multiple rows of rivets. Since the advent of welding, plates can be butt-welded together and the weld ground flush, forming an almost invisible connection and reducing the surface texture. Other steel textures have not changed over time, especially the ribs and stiffening plate sections that prevent large areas of thin steel plate from buckling. At Mound Stand, London, this texture contributes significantly to the exterior surfaces (Fig. 4.11).

Due to the planning and construction constraints arising from placing a new stand over one already existing, some unusual structural solutions were called for. Along the rear and the side-walls of the stand, gravity loads are resisted and transferred to supporting members by one-storey-deep steel plate-girders. From a distance they appear as walls, but upon closer inspection one recognizes vertical and horizontal stiffening plates, the unmistakable language of thin steel-plate construction. This texture not only conveys a strong sense of materiality and speaks of the deep member's structural responsibilities, but it also enriches the surface qualities of the building, better known for its tension-membrane roof structure.



▲ **4.11** Mound Stand, Lord's Cricket Ground, London, England, Michael Hopkins & Partners, 1987. Horizontal and vertical stiffening plates texture a steel beam-wall along the rear of the stand just below the tension-membrane roof.

Structural texture is even more strongly associated with timber construction. Consider, for example, a traditional timber roof with its hierarchical construction. Beginning with primary members, say beams, successively shallower members like rafters and purlins and then sarking progressively build up the structural depth as they overlay each other at right-angles.

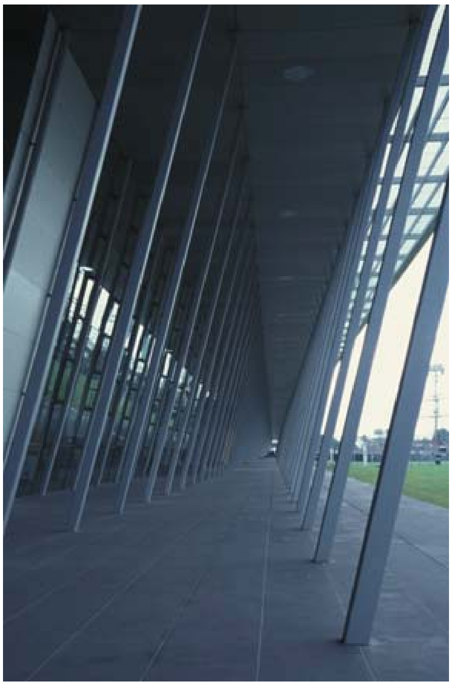
With a structural form far more sophisticated than for most timber structures, the World Exhibition Centre Canopy, Hanover, also possesses a much admired hierarchical structural texture. Although the main members, the masts and cantilevering ribs are themselves textured, the fine ribbed-shell structure spanning between the cantilevers and covered by a timber lattice and a white water-proof membrane appeals to the eye (Fig. 4.12).

Screening and filtering

Depending on its depth, density in plan and elevation, and its spatial relationship to a building envelope, exterior structure can be read as a screen or filter, contributing yet another set of aesthetic qualities to a façade.

▲ **4.12** Canopy structure, World Exhibition Centre, Hanover, Germany, Herzog + Partner, 1999. Attractive textured soffit surfaces.

▲ **4.13** Exhibition Centre, Melbourne, Australia, Denton Corker Marshall, 1996. Verandah posts visually soften the façade.



▲ **4.14** A view along the verandah.

The main façade of the Melbourne Exhibition Centre that faces the Yarra River illustrates clearly how exterior structure screens and filters. A multitude of slender steel posts on a close 3 m by 3 m grid support a wide verandah that slopes away from the main building (Fig. 4.13). The posts, two bays deep, tilt away from the building to maintain orthogonality with the verandah roof. Their rotation from the vertical introduces a sense of movement that explains why, when viewed from a distance, the posts are likened to reeds along a riverbank. From that same view, it is difficult to discern the building envelope beyond them. It fades into the background behind the sheer numbers of posts that screen and soften it. From inside the Centre, one appreciates the extent to which the posts diffuse natural light and filter views toward the river. A promenade along the building edge through the posts yields a final delight – their slenderness, close spacing and uniform tilt recalls walking through saplings of a windblown forest (Fig. 4.14).

At Library Square, Vancouver, an exterior structural frame curves around the main rectilinear library block, wrapping and screening it (Fig. 4.15). In two locations, where the frame almost touches corners of the library, gaps open in the frame, allowing glimpses of the library behind. Appearing as trabeated construction longitudinally and vaulted construction transversely, the frame's single-bay deep structure explicitly references the Colosseum in Rome. An open and arcaded ground floor structure repeats at roof level as an open framework and floors at other levels accommodate reading galleries. The openness of the framework provides plenty of natural light for perimeter reading areas and filters light entering the main library.

▲ **4.15** Library Square, Vancouver, Canada, Moshe Safdie and Associates Inc., 1995. A gap reveals the cross-section of the screening frame and a glimpse of the main library block behind.

▲ **4.16** Getty Center, Los Angeles, USA, Richard Meier & Partners, 1997. Exterior structure deepens the rear of the Rotunda.

While less overt at the Getty Center, Los Angeles, structural elements play important screening roles in many locations around the museum complex. In some cases by varying the relative positions of structure and skin in plan, structure projects beyond the building enclosure to contribute depth and to some extent screen the façades. This strategy can be observed where the Rotunda backs onto the Museum Courtyard (Fig. 4.16). The exterior columns of many buildings are exposed and act as counterpoints to adjacent walls. In other areas, exterior colonnades that support canopies or walkways enrich the experience of walking beside the buildings (Fig. 4.17). This layering of structure in front of the façades deepens them and effectively screens them, successfully reducing the undesirable visual dominance of potentially large areas of bare wall.

▲ **4.17** A colonnade supporting an elevated walkway alongside an external wall.

Compared to the relatively deep structural screens at the Melbourne Exhibition Centre, Library Square, and to a lesser extent the Getty Center, most screening structure on the main façade of the Centre Pompidou, Paris, lies within a vertical plane (Fig. 4.18). Located in front of the building envelope a distance almost equal to the length of a gerberette,[5] the screen consists of slender horizontal tubes and vertical and diagonal tension rods. The exterior structure, mainly resisting tension forces, is so fine it risks being misread as scaffolding. Although ineffective as a screen or filter for natural light, the large number of members and

▲ **4.18** Centre Pompidou, Paris, France, Piano and Rogers, 1977. Screening effect of structure on the main façade.

▲ **4.19** Mexican Embassy, Berlin, Germany, González de León and Serrano, 2000. Dynamic columned-walls.

their light colour create a fine mesh-like screen that lessens the visual impact of the exposed columns and wall cladding behind it. From a functional perspective, the horizontal separation of the screen from the envelope provides width for circulation routes along the front façade, and space for exposed services at the rear.

The main façade of the Mexican Embassy, Berlin, is the final example of exterior structure functioning as a screen (Fig. 4.19). Forty closely spaced and over-structured concrete mullions-cum-columns, necessitated by neither gravity nor wind loads, satisfy security and aesthetic requirements. By virtue of their depth and close spacing the columns achieve a reasonable degree of physical and visual security. Although pedestrians can see through the glass panes between columns when standing directly in front of them, from oblique angles the columned-wall becomes opaque.

The architects' goal 'to create a building that possessed an unmistakable image' necessitated a creative approach to configuring the façade.[6] Several subtle geometric manipulations of the 17 m high columns transform a potentially repetitive façade into one comprising two columned planes, both angled inwards and one warped to achieve a dynamic visual effect.

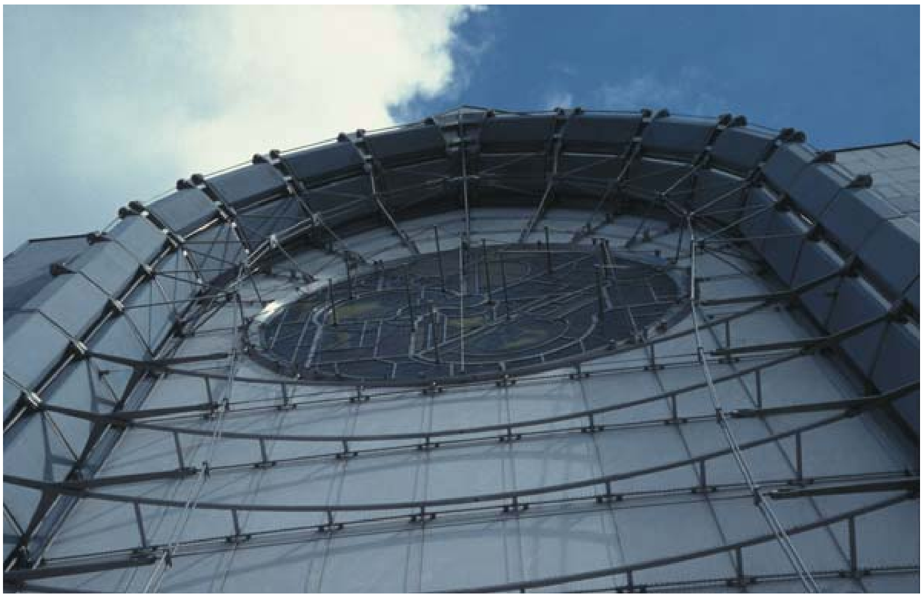
Beginning at the left-hand side of the embassy as seen from the street, vertical columns step back progressively from the pavement towards the entrance. To the right of the entrance, column bases lie on a straight-line between it and the corner of the building. However, the set-out line for the tops of the columns does not parallel the set-out line for their bases. From the right-hand corner of the building as seen from the street, the upper set-out line angles away from the column-base line below towards the street so that the top of the column closest to the entrance is located approximately 3 m in front of its base. This simple geometric variation between top and bottom set-out lines creates a warped surface, affecting the visual impact of the columns profoundly. As the eye moves relative to the columns, they also appear to move. An exquisite rough-chiseled finish to the white concrete columns completes the structure's positive visual contribution and reflects the embassy's high quality design and construction.

Structural scale

Structural scale strongly influences how exterior structure contributes aesthetically to a façade. The dimensions of structural members can lie anywhere on a continuum between the extremes of mesh-like fineness and massive monumentality. Several buildings, beginning with those utilizing small-scale structure, illustrate varied approaches to structural scale.

Where steel is used most efficiently, in tension, members invariably fall into the category of small scale – a consequence of sufficient strength gained from minimal cross-sectional area. At the Cathédrale Nôtre Dame de la Treille, Lille, a stainless steel rod-and-tube structure, reminiscent of a spider's web, supports a new exterior nave wall (Figs 4.20 and 4.21). This diaphanous steelwork contrasts with both the new post-tensioned stone arch needed to equilibrate the tension within the exposed steelwork, and the cathedral's original masonry structural elements. In this project, the dimensions of the exterior steel members were deliberately minimized by pre-tensioning the steel.[7] Shadows from large structural members

▲ **4.20** Cathédrale Nôtre Dame de la Treille, Lille, France, Pierre-Louis Carlier architecte, 1997. A steel filigree structure supports the nave wall.



▲ **4.21** Horizontal steel structure spans between columns of a prestressed stone arch.

▲ **4.22** Hotel de las Artes, Barcelona, Spain, Skidmore Owings & Merrill, 1992. Structural bracing appears frail in relation to the building elements behind.

would have detracted from the interior visual appearance of the translucent top-hung wall comprising only 30 mm thick marble sheets.

The combination of the primary arch with the secondary fine steel structure also illustrates variations in structural scale, usually associated with an expression of structural hierarchy, in a rather extreme manner. As in most situations displaying structural hierarchy, such as the World Exhibition Centre canopy discussed previously, primary structural member dimensions exceed those of secondary structure and so on.

Although not an issue at the Cathédrale Nôtre Dame de la Treille, where one witnesses a celebration of structure's filigree quality, small diameter tension members often belie their critical structural importance. Where exposed on a building façade perfectly adequate primary tension-only cross-bracing can appear too flimsy or insubstantial. These bracing members are likely to be far smaller than their neighbouring elements such as columns or cladding panels. Designers must decide whether or not to expose structure in these situations. If the scale of structure as compared to that of adjacent architectural elements or spaces might lead to unintended readings, such as the flimsiness mentioned above, perhaps the structure should be either enlarged or concealed if this reading is to be suppressed.

This issue of structural scale arises at the Hotel de las Artes, Barcelona. Its lateral load-resisting system consists of exoskeletal braced frames that wrap around each corner of the building (Fig. 4.22). Frame members, considerably smaller than the cladding panels behind them, appear rather

▲ 4.23 Cité des Sciences et de l'Industrie, Paris, France, Adrien Fainsilber, 1986. Scaled-up columns relate to building scale and truss dimensions.

▲ 4.24 Law Courts, Bordeaux, France, Richard Rogers Partnership, 1998. Human-scale rather than monumental columns.

frail. Given a darker and monochromic background the structure might be read more positively – perhaps perceived as a protecting mesh or a net with an attractive fineness, rather than its current ambiguous reading of being neither too strong nor too fragile.

The widespread practice of increasing the visual mass of columns, particularly in multi-storey buildings, seeks to avoid similar ambivalent reactions to structural scale. This strategy was adopted at the Cité des Sciences et de l'Industrie, Paris (Fig. 4.23). During its conversion from abattoirs to a museum of technology, reinforced concrete columns were considered under-scaled relative to the long-span roof trusses above them and the overall scale of the building. They were subsequently sheathed by masonry walls to bulk them out and create more suitable monumental 'structure'.

At the new Law Courts, Bordeaux, exterior structure typifies structure at human scale (Fig. 4.24). Exposed five-storey high columns are relatively slender given their height and the size of the building behind them. Their modest diameter acknowledges the light loads from the delicate steel trusses they support and their independence from suspended floors supported by interior columns. On the façades, as in the interior public spaces, structural scale avoids monumentality, consistent with an architectural goal of creating a transparent and non-intimidating environment.

Connecting the exterior to the interior

In contemporary architecture, structure that is exposed on an exterior elevation sometimes bears some resemblance to the interior structure. This may be a consequence of a design process that begins by attending

▲ **4.25** Stansted Airport terminal, Essex, England, Foster Associates, 1991. Portico 'trees' are an extension of the interior structure.

▲ **4.26** Mont-Cenis Academy, Herne, Germany, Jourda & Perraudin, 1999. The front canopy structure is almost identical to that of the interior.

to the interior structure and then letting those decisions in conjunction with other ideals like transparency, inform the exterior design. However, correspondence between exterior and interior structure may also have deeper roots. There may be a conscious reaction against the practice of façadism where a façade bears little relationship to the rest of the building, or a concern for a holistic and integrated architecture with a demonstrable relatedness between exterior and interior. An outside/inside connection need not be literal but might entail external expression of the interior structural qualities, rather than the exposure of actual members and details.

High-Tech architects usually make the interior/exterior connection explicit, as exemplified by the Hong Kong and Shanghai Bank. At Stansted Airport Terminal, Essex, also designed by Foster Associates, the structural 'trees' that dominate the terminal's interior extend from behind the glazed front wall to support a full-length portico (Fig. 4.25 and see Fig. 9.8).

The Mont-Cenis Academy, Herne (Figs 3.26 and 4.26) also gives similar advanced notice of its interior structure on the exterior. Timber posts and roof structure that support a full-width entrance canopy are a pure extension of the structure inside the building envelope. Although the exterior posts are as naturally detailed as all others, they have required slight structural modification. Due to the canopy roof span lengths being longer than elsewhere, steel rod composite-action has been added to supplement the vertical load-bearing capacity of the posts. This is not the only time composite-action appears in the building. It is similar to the system used throughout the roof structure to extend the span of the timber purlins without increasing their dimensions.

Clearly expressed composite timber and steel construction also connects exterior and interior at the Wilkhahn Factory, Bad Münder (Fig. 4.27). Here the choice of structural materials is well suited to the furniture-maker owner. The roof structure, comprising steel rods that greatly extend the structural capacity of the timber roof beams, spans between steel-braced timber masts. The structural system is repeated four times across the width of the building. Unfortunately, densely clustered hanging light-fittings limit the extent to which the interior structure can be appreciated.

In each of the buildings considered above, the whole interior structural system repeats on the exterior. A more subtle approach, perhaps suited to a wider range of architectural styles, entails the exposure of just one structural element that reflects the interior structural qualities of the building. Two large columns with haunched capitals that designate entry

▲ **4.27** Wilkhahn Factory, Bad Münder, Germany, Herzog with Bernd Steigerwald, 1993. Longitudinal structural form is exposed.

▲ **4.28** Public University of Navarra, Pamplona, Spain, Sáenzde Oiza Arquitectos, 1993. The pair of exterior columns are precursors to columnar interior architecture.

to the central block of the Public University of Navarra, Pamplona, exemplify this approach (Fig. 4.28). Without literally reproducing the interior columns they set the scene for an almost overwhelming display of columnar interior architecture. Their conical capitals, circular stems and concrete materiality make an unambiguous connection (see Fig. 5.16). At each end of the building, two levels of colonnades set within exterior walls connect to the interior structure even more explicitly.

▲ **4.29** Millennium Stadium, Cardiff, Wales, The Lobb Partnership (now HOK Sports), 2000. Main entry is under the beam between the mast legs.

Entry

Provision and articulation of entry, very important aspects of architectural design, provide endless opportunities for structural participation. At a basic level, structure might contribute little more than the support of an entry canopy. Yet in another building, structure might function as the architectural element that creates a sense of entry, its expression and celebration. The columns framing the main entrance to the Public University of Navarra above, fall into this category, and the following examples also illustrate structure playing significant roles in marking and defining entry. Each entrance's structural form is totally different, relating either to the structural layout of its own building, or in the final example, to that of its neighbouring structures.

Eighty-metre-high masts located at its four corners define the main entry points to the Millennium Stadium, Cardiff. Spectators enter under structural frames at the bases of the masts supporting outriggers that cantilever inside the stadium to carry the primary 220 m long roof trusses that retractable roof units move along (Fig. 4.29). The role of signifying entry, that canopies usually play, is amply fulfilled by structural elements. Multiple horizontal and inclined structural booms and ties project outwards in a grand welcoming gesture while the huge beam and mast legs above ground level articulate the entry area.

These impressive tubular-steel mast structures required significant design modifications in order to accommodate entry. The cross-bracing extending down the mast is interrupted above ground level by the deep beam. Together with the mast legs it forms a single-storey moment-resisting frame that avoids the need for ground level bracing and simultaneously creates an entry portal. The massiveness of this structural threshold appropriately prepares spectators for the huge enclosure that lies beyond it.

Structure also defines entry to the elevated departures area at Terminal 2F, Charles de Gaulle Airport, Paris (Figs 4.30 and 4.31). In this case, pedestrians enter between structural members rather than underneath them. The entrance locations along the building frontage correspond to the structural organization of the concourse roof – a system of paired primary steel ribs carrying secondary structure that supports the impressive concrete ceiling slabs. V-shaped struts project down from the ribs and bear upon greatly enlarged vertical concrete columns, semi-circular in cross-section. The column orientation and its form suggest a dramatic reading. An original single circular column appears to have been split in half and both halves then moved apart to create an entrance.

▲ **4.30** Charles de Gaulle Airport: Terminal 2F, Paris, France, Aéroports de Paris, 1999. Semi-circular columns signal entry.

▲ **4.31** A 'split-column' viewed from inside.

Entry between these columns is particularly memorable. As seen from the footpath, the columns clearly signify entry by projecting outside the cladding line rhythmically in step with the roof structure. Although it seems perverse to enter through a massing of concrete when the whole wall cladding is otherwise glazed, upon entry one enjoys pondering the immense physical force required to 'split' and 'move' the concrete semi-circles apart. Given the apparent effort required for its construction the entrance therefore has special significance. After the experience of passing between the columns one discovers that their shapes and materiality complement other curved and exposed concrete surfaces throughout the terminal.

The pitched entrance canopy structure of the Dome Leisure Centre, Doncaster, also marks entry quite unambiguously and introduces visitors to the interior structure (Fig. 4.32). Inside the building, identical interior triangulated structure defines and modulates the pedestrian mall leading to the heart of the complex, the dome. Exterior structure is therefore an extension of the interior structure, displaying a structural language consistently spoken throughout the centre, namely, perforated steel I-sections and steel tubes.

Like the Terminal 2F entrances (Fig. 4.30), the Leisure Centre entry canopy is over-structured. While its visual severity arising from the use of large members is reduced by their generous circular penetrations and tapered sections that introduce additional liveliness, one wonders to what extent this grey-coloured structural display helps realize the architect's intent 'to embody the exuberant spirit of leisure'.[8] However, the structure certainly defines entry clearly, and an absence of orthogonality

▲ **4.32** Dome Leisure Centre, Doncaster, England, FaulknerBrowns Architects, 1989. Structure articulates entry.

▲ **4.33** Cité de la Musique, Paris, France, Christian de Portzamparc, 1995. Entrance structure.

with its connotations of formality no doubt encourages a more relaxed attitude in building visitors.

The Cité de la Musique, Paris, provides the final example of structure articulating entry. An open rectangular framework designates entry (Fig. 4.33). Its four closely spaced two-storey-plus red frames reference the nearby Parc de la Villette follies, less than a hundred metres away. Therefore, rather than reflecting interior structure which in this building is not particularly evident, the entrance responds to external influences. Unlike the open frameworks that inspired the canopy design, Portzamparc's entry folly bears load from two trusses forming an elongated wedge. The trusses, visible through the glazed walls of the wedge that defines a linear circulation spine, visually tie the entrance framework to the main building. Since the trusses bear on the first storey beams, the structural members above that level are essentially gestural. The open frames of the Cité de la Musique entry structure successfully fulfil common architectural expectations by marking entry and encouraging it.

Expressive roles

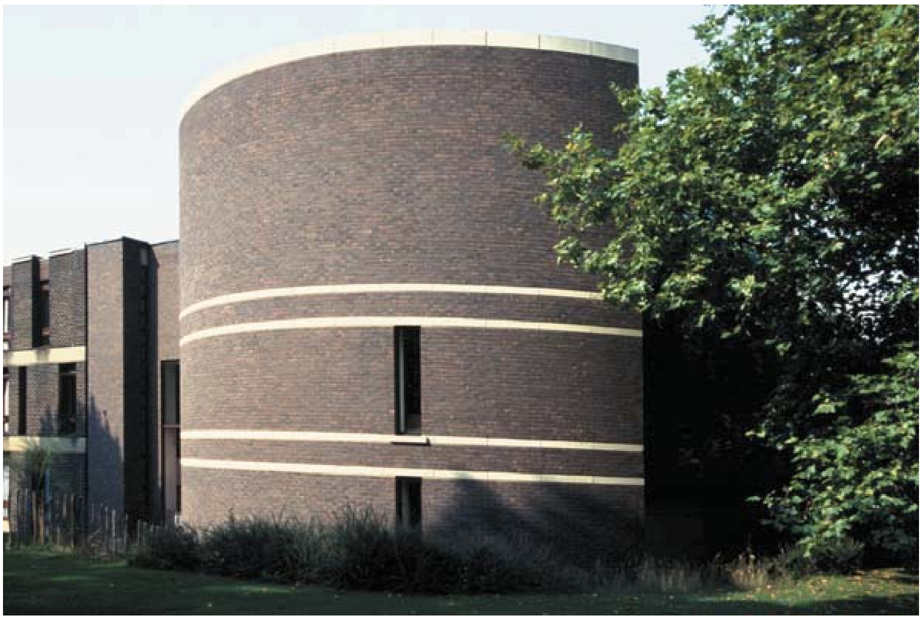
Exterior structure has a long tradition of playing expressive roles. Consider Gothic cathedrals. Their pinnacles, flying-buttresses and buttresses express how the horizontal thrusts from masonry roof vaults are resisted and transferred to the ground (see Fig. 4.8). Load paths become legible through a combination of structural layout, shape and scale. On the other hand, Renaissance exterior structure, such as at S. Giorgio Maggiore, Venice, expresses aspects other than the Romanesque interior or its structural actions. Four giant attached-columns dominate the façade (Fig. 4.34). They appear to be supporting a section of pediment thrust up

▲ **4.34** S. Giorgio Maggiore, Venice, Italy, Palladio, 1610. The Classical façade does not relate to the Romanesque interior within.

from one that previously spanned the entire width of the church. Framing the main entrance, they express monumentality and the importance of the nave in relation to the aisles.

Contemporary exterior structure continues this expressive tradition by communicating a diverse range of ideas, architectural qualities and actions. Exterior structure can to some degree express any architectural idea. The clarity with which such an idea might be communicated is quite another matter. That certainly depends on an architect's skill. In the following four examples, structure expresses quite different ideas.

The exterior of Fitzwilliam College Chapel, Cambridge, differentiates itself from adjoining architectural forms to express ideas of protection and enclosure (Fig. 4.35). The chapel's distinctive circular geometry sets it apart from the surrounding rectilinear blocks. As an extension to a 1960s linear accommodation wing, the chapel adopts the same width as the existing construction where it connects. Then, after provision of a circulation area several metres long, perimeter walls begin to form a cylinder, increasing the building width and partially encircling the chapel inside. Like embracing arms, in an understated and simple manner, they protect and enclose, metaphorically as well as physically. As at the Mönchengladbach Museum (see Fig. 4.10), the act of curving walls in plan increases their strength and stability against horizontal loads. The



▲ **4.35** Fitzwilliam College Chapel, Cambridge, England, Richard MacCormac, 1991. A chapel side-wall with an accommodation block to the left.

walls, equally likely to be read as non-load-bearing cladding as structure, contrast with the explicitly exposed structure at the Licorne stadium, Amiens, that similarly engenders perceptions of protection and enclosure (see Fig. 3.13).

The exterior structure of the Öhringen Business School represents the antithesis of the symmetry and calmness of the Fitzwilliam College Chapel. Outside the main entrance the exterior structure breaks long established traditions of structural order and rationality (Fig. 4.36). In front of a glazed wall, three cross-braced buttresses appear to be quite haphazardly orientated – their alignment neither relating to the building envelope nor to the interior structure. A similarly unusual relationship exists between the buttresses and the thin steel girts they support. The normal hierarchy of mullions supported by girts that are in turn supported by buttresses is subverted. A girt passes through a buttress without being able to transfer its loads to it (Fig. 4.37).

Exterior structure in this area of the school appears ad hoc and crude. Blundell-Jones notes that this aesthetic is in fact carefully developed and a 'confident use of a vocabulary elaborated over decades'.[9] The architect, Behnisch, is well known for his colliding geometries, layered spaces and careening volumes. Upon entering the atrium, a fragmented and layered structural language contributes to a light and lively, if not exciting, interior space.

▲ **4.36** Business School, Öhringen, Germany, Gunter Behnisch & Partner, 1993. The main entrance and the haphazardly orientated buttresses.

▲ **4.37** A horizontal plate passes through the buttress without making contact.

▲ **4.38** Olympic Archery Complex, Barcelona, Spain, Miralles and Pinos, 1991. Aimlessly directed columns support slabs passing over the retaining wall.

The 1992 Olympic Archery Complex, Barcelona, also disregards an ordered and rational view of design and building. Where seen from the original archery training fields, the buildings that now function as football changing-rooms exhibit haphazardly orientated roof planes and exposed structural members (Fig. 4.38). Depending on their function, the training field facilities comprise several different architectural forms. For example, spectators shelter under irregularly tilted and cantilevered concrete slabs, while changing-rooms and other facilities are enclosed. The buildings are mostly embedded within the bank they retain.

▲ **4.39** Parc Güell, Barcelona, Spain, Antonio Gaudí, 1914. The retaining structure elegantly expresses resistance to the soil pressure acting upon it.

Their irregular and dynamic architectural and structural forms appear to be expressive, but of what? First, one notes that although the building functions as a retaining wall its structural layout and detailing does not respond to the reality of horizontal soil pressure. Casually inclined columns are no match for slipping soil, stabilized in this case by stone-filled wire cages, and contrast starkly with a nearby construction that also combines retaining and shelter – for at Barcelona's Park Güell, Gaudí exemplifies structure expressing its soil-retaining function clearly and gracefully (Fig. 4.39). Perhaps the forms express aspects of archery? Such a reading seems reasonable. The linearity and random orientation of exposed structure, as well as its dynamic qualities could well refer to arrows in flight or their quivering upon striking a target. However, as one reviewer reports, any expressive qualities primarily express the design process. He writes: 'Let's . . . get straight on to what Miralles likes to remember as being essential to this project. In a nutshell, he reminds us, the project grew out of "rubbing" over other projects and out of the possibilities offered by the need to carry out earth retaining work.'[10] It therefore appears the design process itself is being expressed!

Expressive qualities of the exterior structure at Bracken House, London, an insertion between the end wings of a central demolished block, have clearer and more obvious origins. Structural members are not immediately recognizable from a distance due to their relatively fine scale, made possible by the close proximity of the primary columns, just four metres

▲ **4.40** Bracken House, London, England, Michael Hopkins and Partners, 1991. Main façade.

▲ **4.41** Metal columns, a cantilever bracket and a stainless steel rod behind a stone pier.

behind the façade (Fig. 4.40). The exposed structure includes slender secondary columns, mullion-columns on the exterior bay window corners and ground floor piers supporting the columns (Fig. 4.41).

If an exploration of structural expression begins by considering the slender gun-metal columns, one notes their similarity to the bronze columns of the old building. The scale of both old and new columns and their fineness recalls Gothic attached-shafts. At first floor level where the columns meet their base-brackets, short cantilevers express structural actions. Tapered arms reflect internal bending moments, and a stainless steel rod with its enlarged end connection detail expresses its tensile role in preventing the bracket from over-turning. Solid stone piers carry and express compression, the dominant structural action.

The truss framing the main entrance and supporting the roof canopy also expresses structural actions, and like the columnar structure displays equally high levels of craft and design elegance (see Fig. 7.39). Individually cast and highly refined, its elements exude a sense of quality. Such a high standard of design is consistent with the client's expectation that the building 'shall offer respect to the great architectural achievements of the past, dominate this century and realize the vision of the next'.[11] Quite a demanding brief!

Any discussion on the expressive roles of exterior structure must consider the expression of another important architectural issue – the relationship between a building and its foundations, or in other words, how

▲ **4.42** Church in Porta, Brissago, Switzerland, Raffaele Cavadini, 1997. Front elevation with a visible gap under the beam.

▲ **4.43** Splash Leisure Centre, Sheringham, England, Alsop & Lyall, 1988. Wall-to-foundation detailing conveys a lack of grounding.

a building is grounded. At one end of the spectrum an architect might seek to express a strong sense of grounding where a building is read as being rooted to its foundations and growing from them, but other design concepts, as illustrated by the following two examples, express floating or hovering.

At the Porta church, Brissago, ground floor beams that would normally be partially embedded like typical foundation beams are elevated above the ground, creating a 100 mm gap (Fig. 4.42). By visually separating the tiny cube-like church from its foundations the architect conveys a sense of the building 'touching the ground lightly'. This perception of the superstructure being not *of* the site, but rather built *over* it, respects the site's previous occupant; a medieval chapel whose demolition caused considerable controversy.

The lack of any visible structure at the base of the Splash Leisure Centre, Sheringham, conveys the even more extreme impression of the building being transportable (Fig. 4.43). This perception arises from a simple construction detail. The double-layered plywood cladding overhangs and partially conceals a conventional concrete foundation whose edge sits flush with the inner layer of plywood.

By way of contrast, an effective method to express strong connectivity between a building and its site involves exposing foundations that emerge from the ground and then seamlessly form the superstructure. The Welsh Wildlife Centre, Cardigan, illustrates such an approach using stone blocks (Fig. 4.44). They form a solid plinth that suggests a strong connection between the substructure and the superstructure. Although expressed far less intensely, that same sense of a building being grounded or grafted to

▲ **4.44** Welsh Wildlife Centre, Cardigan, Wales, Niall Phillips Architects, 1994. Stone plinths visually anchor the building to its site.

its site is observed in two previously discussed buildings, at 88 Wood Street, London (Fig. 4.4), and at the RAC Control Centre, Bristol (Fig. 4.5).

Summary

This chapter illustrates exposed structure enriching the exterior visual qualities of buildings. After over-viewing some of the many contributions exterior structure can make to façades by focusing upon the Hong Kong and Shanghai Bank (Fig. 4.1), the chapter examines the aesthetic impact of exterior structure. Case studies illustrate how structure modulates surfaces and provides a means for introducing often much-desired depth and texture. Structure also screens façades and filters light and views. The importance of suitable structure scale is noted where structure plays any of these roles.

Two sections then explore how structure connects exterior and interior architecture and how it marks and articulates entry into a building. Finally, the chapter provides precedents of structure playing expressive roles. Based on the variety of expression evident in the few examples presented, it would seem that exposed structure is capable, to some degree at least, of expressing any architectural idea or quality.

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