5 Building function

Introduction

In its exploration of the relationships between structure and building functionality this chapter begins by considering how structure located on the perimeter of a building maximizes spatial planning freedom. A common approach for achieving large structure-free floor areas is to locate primary structure either outside or just inside the building envelope. Next, structure is observed subdividing interior space; first, where the subdivided spaces accommodate similar functions and are perceived as being part of a larger space, and secondly, where structure separates different building functions, like circulation and gallery spaces, from each other. This leads on to a section that examines how structure's physical presence, including its directional qualities, defines and enhances circulation. Finally, examples illustrate structure disrupting function, both deliberately and unintentionally.

Numerous architectural texts acknowledge the need for thoughtful integration of structure with building function. At an essentially pragmatic level, Schodek explains the concept of 'critical functional dimensions.'[1] This approach requires a designer to determine the minimum structure-free plan dimensions for a given space or series of spaces. Once these dimensions are decided upon, 'basic functional modules' can be drawn in plan. Spaces between the modules then determine where vertical structure can be located without intruding upon function. Minimum clear spans across modules can then be readily identified and, together with module shapes, can suggest suitable structural systems such as load-bearing walls or moment-resisting frames in conjunction with one- or two-way floor or roof horizontal spanning systems.

Different-sized modules are often required within one building. For example, the office-sized structural module above ground floor level in the Hôtel du Département, Marseilles, is doubled in size through the use of the X-columns in order to accommodate basement level car parking (see Fig. 3.47). Schodek also discusses briefly the spatial implications of various structural systems, noting the different degrees of directionality they impose upon the spaces they enclose.

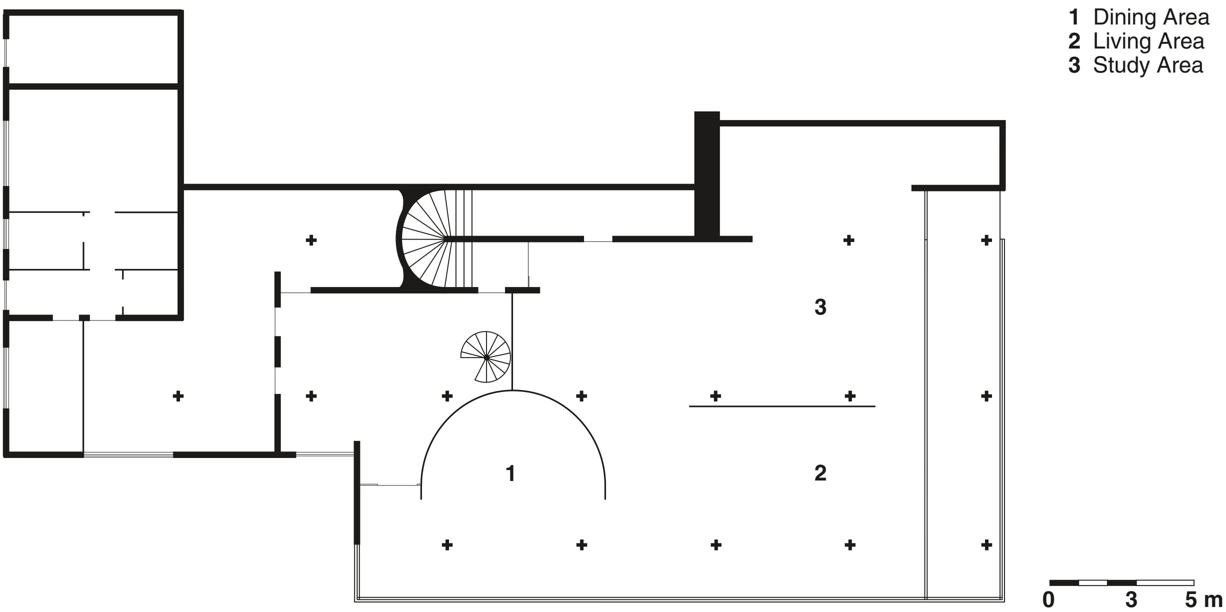
Krier takes a broader architectural approach when discussing structure and function. He emphasizes the spatial qualities of different structural systems and insists upon structure and function being integrated: 'Construction is closely related to function. A clearly defined concept of spatial organization demands an appropriate structural solution. The more harmonious this unity, the closer one comes to the architectonic end product.'[2] He categorizes structure which he primarily perceives as a spatial organizer, into three different types: solid wall, skeletal construction, and mixed construction comprising both walls and skeletal structure. Each type possesses a different architectural character. For example, solid walled construction with its introverted and more intimate character contrasts with skeletal structures that are more open and adaptable. Mixed systems, on the other hand, present opportunities for a hierarchy of interior spaces, greater spatial complexity and 'differentiated tectonic character'.

Whereas Krier emphasizes how interior structure, by virtue of its layout and detailing affects spatial character, and therefore function, this chapter concerns itself more directly with the relationship between structure and the physical or practical aspects of building function. The aesthetic impact of structure upon interior space and the inevitability with which it affects function to some lesser extent, is discussed in Chapter 6.

Maximizing functional flexibility

Freedom from structural constraints results in maximum flexibility of space planning and building function. A space clear of interior structure can then be ordered by other architectural elements such as partition walls or screens, if necessary. Clearly, maximum interior architectural flexibility is achieved by positioning primary structure outside the building envelope. Unfortunately, this strategy is often not easily implemented due to possibly excessive structural depths and other architectural implications like cost that are associated with spanning across the whole width of a building. A far more common and realistic approach to achieve a high degree of planning freedom involves adopting the 'free plan' – that integration of structure with interior space inherited from the Modern Movement. Spaces that once would have been enclosed by load-bearing walls now flow almost completely unimpeded around and between columns that are usually located on an orthogonal grid.

A widespread perception exists of the spatial neutrality of structure that enables the 'free plan'. That is, the impact upon interior architecture by structure, perhaps in the form of columns or short walls, whether assessed by its effect upon function or aesthetics, is considered minimal. However, such structure is far from being spatially neutral. Where located within a building envelope it reduces the net usable area as well as restricting space-use in its vicinity. These detrimental effects have been quantified for office buildings. Space loss not only includes the area



▲ **5.1** Tugendhat House, Brno, Czech Republic, Mies van de Rohe, 1930. A simplified ground floor plan.

of the structural footprint itself, but also adjacent neutralized areas that are inconvenient for furniture and screen arrangements.[3]

More profound disturbances to building function from so-called 'free plan' structure also arise. Consider, for example, the oft studied Tugendhat House designed by Mies van der Rohe (Fig. 5.1). One reviewer suggests rather uncritically how the architect 'used the columns to help identify places: two of the columns, together with the curved screen wall, frame the dining area; two others help define the living area; and another column suggests the boundary of the study area at the top right on the plan'.[4] However, an alternative reading could view that identification of places as being so unconvincing as to verge on the unintentional. Moreover, after observing the columns positioned close to walls but playing no particular spatially defining architectural roles, and other columns located awkwardly in secondary spaces, one could conclude that the interior architecture would be much improved if the existing walls were to become load-bearing and as many of the non-perimeter columns as possible were removed!

As already mentioned, maximum planning freedom occurs where vertical structure is located on a building's perimeter. This option suits single-storey construction better than multi-storey buildings for two reasons. First, perimeter structure inevitably results in long spans necessitating relatively deep structure and subsequent large inter-storey heights. A deep or high roof structure of a single-storey building does not usually have such severe consequences upon building height as do several layers

▲ **5.2** Oxford Ice Rink, England, Nicholas Grimshaw & Partners, 1985. Exterior masts and projecting horizontal spine beam.

▲ **5.3** Financial Times printing works, London, England, Nicholas Grimshaw & Partners, 1988. Exterior columns along the main façade.

of deep floor structure. Secondly, roofs generally weigh far less than suspended floors so they can span greater distances more easily.

Categories of perimeter structure include exoskeletal structures where all structural members lie outside the building envelope, and others, where to differing degrees structure impinges upon interior space. In the second set of buildings, structure either potentially disrupts function around the perimeter of the floor plan, or else it is well integrated with occupancy. Examples of various types of perimeter structure are given below.

According to its architect, a need to reduce building bulk was one of the main reasons for choosing a mast structure for the Oxford Ice Rink, Oxford (Fig. 5.2). Primary structure, in the form of two masts, tension rods and a central spine-beam, carry over 50 per cent of the roof weight. As a consequence of the substantial overall structural depth, equal to the mast height less that of the roof, and the 15 m intervals between supporting tension-rods along its length, the depth of the 72 m long spine-beam is shallow enough to allow the beam to be located under the roofing. Continuous roof beams that span the rink transversely and rest upon the spine-beam at their mid-spans, are supported on slender props located along each eaves line of the main form.

The exterior structure of the Financial Times printing works, London, also facilitates function and allows for flexibility in the future. Perimeter columns line sections of the north and south façades (Fig. 5.3). Their location outside the glass skin they support removes from the approximately 100 m long press-hall any internal structure which could otherwise disturb movement of personnel or paper within the space. Interior structure defining an internal spine-zone parallel to and behind the press

▲ **5.4** Toscana Thermal Pools, Bad Sulza, Germany, Ollertz & Ollertz, 1999. Timber shell structures.

▲ **5.5** Open structure-free space under the shell roofs.

▲ **5.6** Timber Showroom, Hergatz, Germany, Baumschlager-Eberle, 1995. Timber columns project into the showroom.

hall is also walled-off to avoid any structural protrusions into the hall. As well as its functional suitability, this structure-and-skin combination has won over critics by its elegance of detail and sheer transparency. The nightly drama of printing is now highly visible from a nearby road.

By their very nature, shell structures are supported at their perimeters. Although any associated structural elements, such as the ribs that might increase the strength of a shell are usually constructed inside the exterior skin, their structural depths are so shallow as to not reduce space usage significantly. The Toscana Thermal Pools, Bad Sulza, enclosed by glue-laminated timber ribbed-shells, benefit from planning freedom unconstrained by structure (Figs 5.4 and 5.5). Free-flowing interior spaces surround the main pools. As well as providing openness in plan, the shells' ribbed interior surfaces contribute to the attractive interior ambience.

The interior portal frames of the Timber Showroom, Hergatz, are representative of most interior perimeter structures whose vertical members intrude into the building plan (Fig. 5.6). Sometimes, floor plan edge-zones whose widths equal the structural depths can be incorporated unobtrusively into the overall building function. Take Gothic churches, for example, where numerous side chapels slot between deep internal buttresses adjacent to the aisles. At Hergatz, it is of little consequence that structure does not integrate with an edge-zone function. The glue-laminated timber columns are quite shallow, and the exposed frames possess an unusual attractiveness. Here, a conventional engineering system, often relegated to light-industrial buildings, is transformed into one with intrinsic beauty by virtue of its detailing quality. Curves soften the appearance of the frames and invite new architectural interpretations of their

▲ **5.7** Sainsbury Centre for Visual Arts, Norwich, England, Foster Associates, 1977. The vertical wall structure that is visible on the end elevations houses support functions.

▲ **5.8** Frankfurt Messenhalle 3, Frankfurt, Germany, Nicholas Grimshaw & Partners, 2001. Buttressing struts and ties for the arched roof structure penetrate the services and circulation zones located along the sides of the hall.

form. Member tapering bestows a lightness and elegance, while unobtrusive connections, such as at the eaves joints, avoid any discordant notes.

At the Sainsbury Centre, Norwich, the perimeter structure lies completely inside the skin (Fig. 5.7). Tubular-steel triangular trusses span between columns of identical cross-section. Although the 2.5 m thick structural walls are unusually bulky, mechanical services, storage and service areas fully occupy all of the space within them. The location and integration of all these secondary functions within the structural depth allows the remainder of the interior to function as a public space free of both vertical structure and 'servant spaces'.

Exhibition Hall 3, Frankfurt, also exemplifies the instance of perimeter structure located within the building envelope well that is integrated with building function (Fig. 5.8). Over the upper exhibition level, tubular-steel arched roof beams span 160 m between triangulated buttresses that are expressed on the end elevations. The buttress depths on each side of the building accommodate the main concourse areas, both horizontal and vertical circulation systems, and service areas. As at the Sainsbury Centre, the entire distance between these perimeter structural zones where measured across the building can be used for exhibition purposes. The first floor structure consists of pairs of storey-deep steel trusses spaced a corridor-width apart in plan, and overlain by beams and a concrete slab. The 32 m spacing between ground floor columns results in a structural grid that also provides a high degree of flexibility for exhibition layouts.

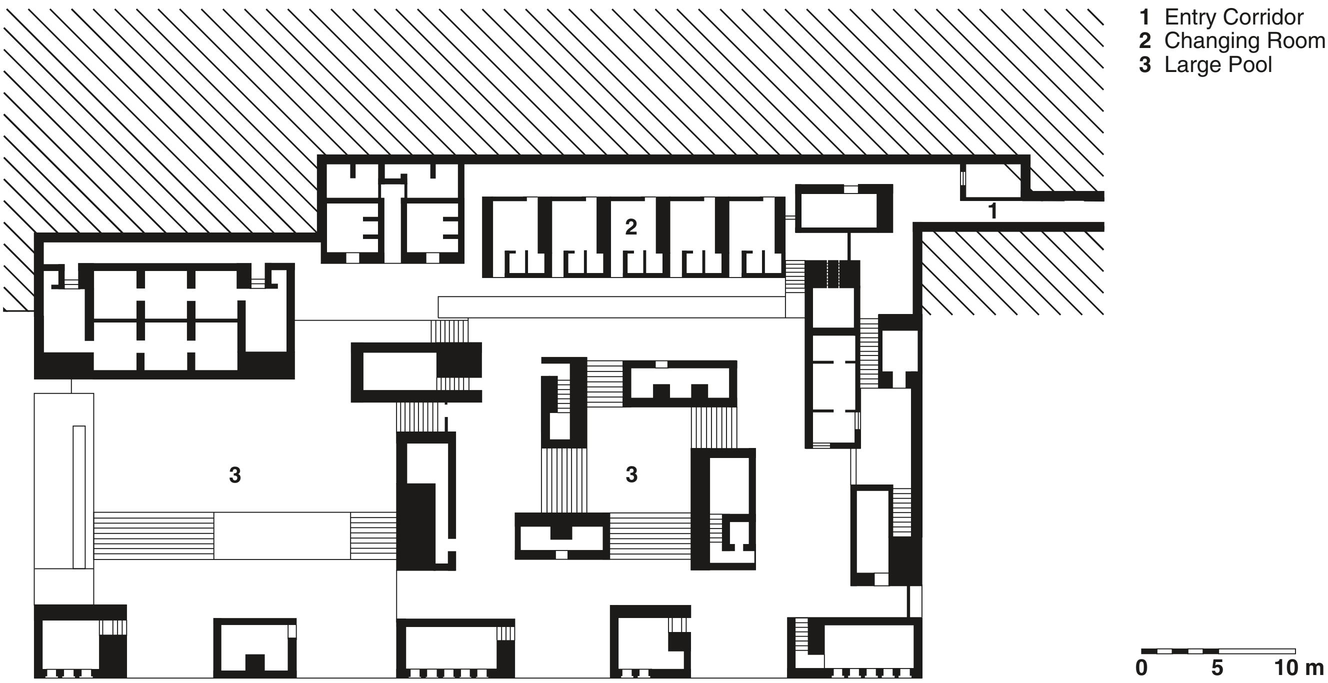
▲ **5.9** Museum of Roman Art, Merida, Spain, Rafael Moneo, 1985. A view along the nave.

▲ **5.10** Floor slabs divide the space vertically.

Subdividing space

Since antiquity, load-bearing walls have divided building plans into separate spaces. However, since the introduction of metal skeletal-frames in the nineteenth century, non-structural partition walls have provided an expedient alternative. Yet, as observed in contemporary works of architecture, structure still subdivides space. First, several buildings are considered where the interior structural layout within a single large volume creates numerous smaller spaces with similar functions. Further examples then illustrate how interior structure can be configured to create spaces with different functions.

Structure plays significant spatial organizational roles at the Museum of Roman Art, Merida (Figs 5.9 and 5.10). Nine cross-walls subdivide the main space horizontally into separate galleries. A nave, defined by almost full-height arched openings and itself a gallery, forms the main circulation space with smaller galleries off to each side. In the same manner as the brick-clad concrete walls slice through the plan, thin walkways and gallery floors divide the space vertically. A limited structural vocabulary – walls, arches and slabs – transform the potentially empty shell into a series of special architectural spaces that facilitate circulation and the display of artifacts. As well as introducing spatial variety, the combination of structural walls, their rhythm and the hierarchy of different sized arches, greatly enriches if not becomes the interior architecture. Arches range in scale from the prominent nave arches through to those of a more human-scale between the upper galleries, through which only one or two people at a time can pass.



▲ **5.11** Thermal Baths, Vals, Switzerland, Atelier Peter Zumthor, 1996. Simplified ground floor plan.

Structural walls at the Thermal Baths, Vals, are also the means by which the architect introduces spatial variety. In this building, partially embedded into a hillside slope, narrow light-slots separate turf-covered concrete roof slabs in plan. Vertical support to the roof may be thought of conceptually as a series of large blocks, typically 3 m by 5 m in plan (Fig. 5.11). Constructed from load-bearing composite layered stone with an interior reinforced concrete core, the blocks organize spaces for bathing, circulation and resting. However, as well as defining individual spaces within the main volume of the baths, the blocks themselves are hollowed out. Within each, a bath, unique by virtue of its temperature, lighting or some other quality, or another facility like a massage room, may be discovered. Bathers therefore enjoy extremely varied spatial experiences – from public pools partially enclosed and screened by walls washed by light passing through slots above (Fig. 5.12), to more intimate spaces that are tucked away deep inside the structural blocks.

The Némausus Apartments, Nîmes, is the final example of structure subdividing spaces that accommodate similar functions. Ship-like in form, the apartment building 'floats' on approximately two-hundred relatively slender columns dispersed over a lowered ground floor (Fig. 5.13). Two rudder-shaped shear walls project from its 'stern' to anchor the building longitudinally both physically and conceptually. The structural layout is the major determinant of space usage. At the upper levels, the apartment

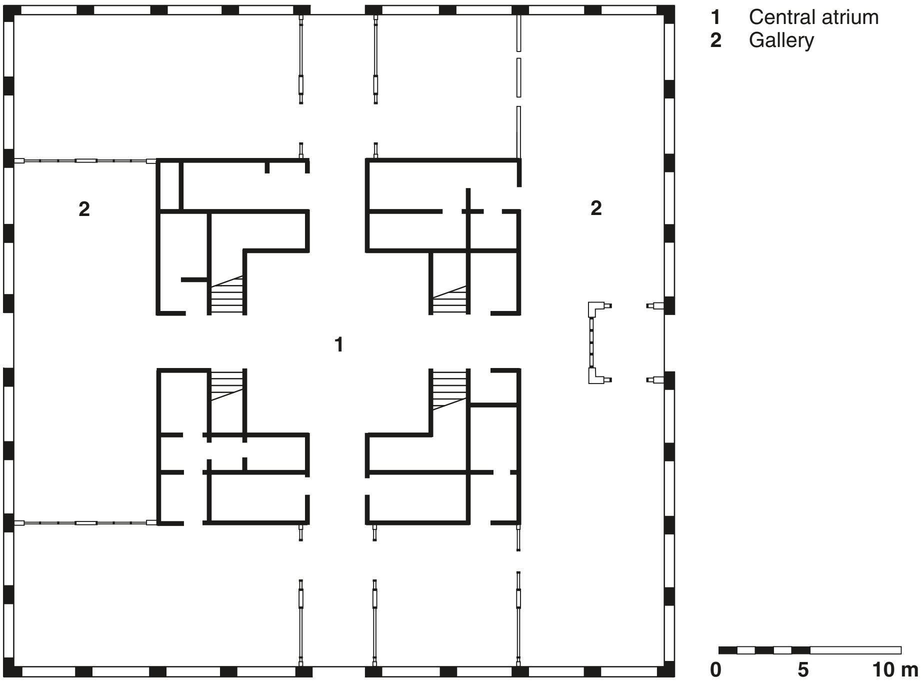
▲ **5.12** Main interior pool, partially surrounded by walls. (Courtesy H. P. Schultz.)

▲ **5.13** Némausus Apartments, Nîmes, France, Jean Nouvel et Associés, 1988. Columns define car parking and their spacing reflects the widths of the apartments above.

widths are defined by regularly spaced transverse concrete walls which transform into columns at ground level. Car parking occupies this space. Along each side of the building, columns define spaces for pairs of car parks. Although lacking the poetics of the previous two examples, the structure here creates parking bays while maintaining an openness that is conducive to the security of people and vehicles. At first floor and above, structure demarcates individual apartments.

Several buildings now illustrate how structure subdivides space in such a way as to separate quite different functions within it. Like the Thermal Baths, structural ordering of the Contemporary Art Wing, Hamburg, is best appreciated in plan (Figs 5.14 and 5.15). Moving outwards from the central atrium that rises the entire building height, three concentric structural layers are penetrated before entering the galleries. First, two walls define a narrow annulus dedicated to vertical circulation. The next outer zone, also sandwiched between walls, predominately houses service areas. Finally, galleries occupy the majority of space between the third ring of walls around the atrium and the perimeter wall-cum-frame. While structural walls and their space-dividing roles are clear in plan, one of the fascinations of this building is that the walls, even though exposed, are not perceived as structure. All wall surfaces are planar and painted white, evoking a sense of simplicity and purity. Such an emphasis upon surface that leaves visitors without any clues hinting at the materiality or the structural significance of walls, avoids any potential architectural distractions in the vicinity of the exhibited art-works.

▲ **5.14** Contemporary Art Wing, Hamburg, Germany, O. M. Ungers, 1996. Building exterior.



▲ **5.15** Simplified ground floor plan.

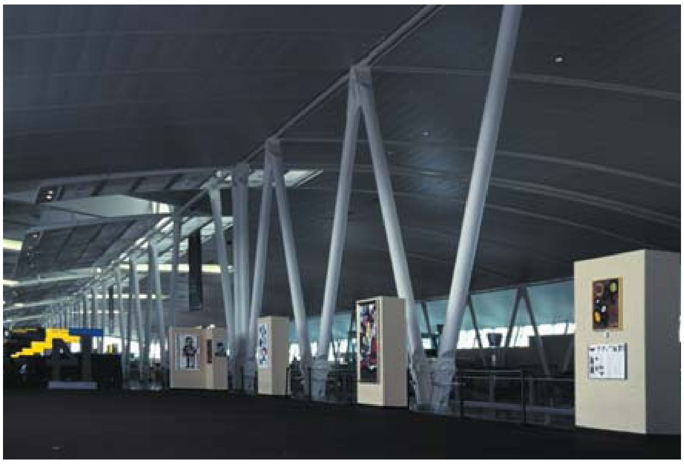
The famous Renaissance architect Alberti perceived a colonnade as a virtual wall: 'a row of columns is indeed nothing but a wall, open and discontinued in several places'.[5] Such a reading can be appreciated when observing the interior columns at the Public University of Navarra, Pamplona. In the main building, columns separate spaces with different functions (Fig. 5.16). A row of closely spaced columns runs the length of the two main corridors, dividing each into two unequal widths. Column spacing of only 1.5 m contributes to a powerful colonnade experience. Where corridors pass an interior lobby or a waiting area, an extra row of columns separates and screens the two spaces from each other.

▲ **5.16** Public University of Navarra, Pamplona, Spain, Sáenzde Oiza Arquitectos, 1993. Columns to the left run along the corridor length and those to the right define the corridor width in the absence of side walls.

Structure plays a similar screening role and separates different uses of space at JFK Airport Terminal 4, New York. Immediately inside the main doors to Departures, structure creates an entry zone en route to the ticketing areas (Fig. 5.17). Longitudinal anchor braces that stabilize the whole terminal and a series of slightly inclined and the inverted chevron braces that provide full three-dimensional triangulation, define the zone's length. It is unusual to see braces with such a low angle of inclination that potentially reduces the amount of usable space beneath them, but most of the suspended floor beneath the braces is voided to create a spacious double-storey Arrivals area beneath. A row of vertical V-struts signals completion of the ticketing process (Fig. 5.18). Stairs lead down to a forecourt and retail outlets and departure gates. On the upper level, bridges span towards another permeable structural wall and the airline club lounges beyond. Structure thus delineates the extent of entry in plan and then separates the bulk of the terminal space into three different functions.

At the Education Centre, Newport, structure also separates spaces with different functions by screening them off from each other. In this case a gently curved row of timber paired-poles separates a teaching

▲ **5.17** JFK Airport Terminal 4, New York, USA, Skidmore Owings & Merrill, 2001. Structure occupies the entry zone with the entrances to the left.



▲ **5.18** V-struts separate ticketing areas to the left from a circulation area and retail outlets on the floor beneath.

▲ **5.19** Education Centre, Newport, Wales, Niall Phillips Architects, 1993. The front of the Centre.

▲ **5.20** A teaching space is separated from the corridor to the right by pairs of columns.

▲ **5.21** Library, Delft Technical University, The Netherlands, Mecanoo Architekten, 1997. A view towards the main entrance.

▲ **5.22** The circulation desk beneath the cone is surrounded by steel struts.

space from an adjacent circulation area behind it (Figs 5.19 and 5.20). The sense of functional separation is accentuated by both the close 2 m spacing between poles, and their pairing which increases the structural density and reflects the repeated paired-poles on the building exterior.

A large cone emerges from the turf roof of the Delft Technical University Library, Delft, which appears to be embedded within a hill (Fig. 5.21). The exposed structure is more than just a virtual projection of the cone surface towards its apex. Near-vertical tension rods support areas of annulus-shaped suspended floors within the cone. The ground floor area beneath the cone is therefore left free of structure. Splayed steel tubes around its circumference surround the circulation desk area, defining it yet distinguishing it from the other library functions within the main hall (Fig. 5.22).

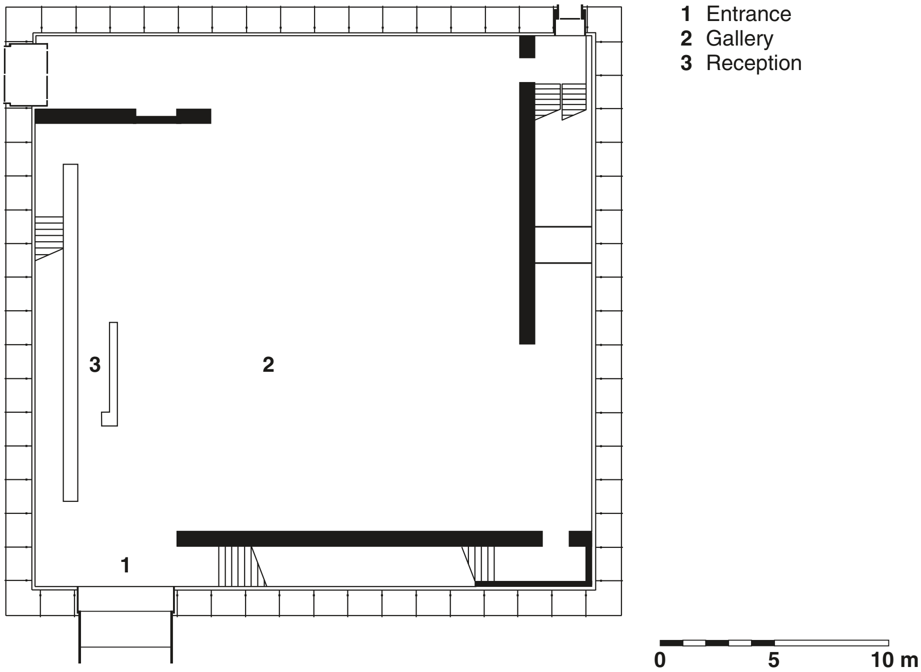
Returning to the Law Courts, Bordeaux, but instead of revisiting the main façade, attention this time focuses upon the public side entrance.

▲ **5.23** Law Courts, Bordeaux, France, Richard Rogers Partnership, 1998. A waiting area under a courtroom pod.

Initially, one is confronted by a timber-clad conical pod outside the glazed skin of the main building, and soon one becomes aware of six others lined up inside. Inclined struts elevate the pods, each housing a courtroom, above concourse level. As well as their structural roles, the struts define informal waiting and meeting areas and separate them from the main circulation route (Fig. 5.23). Eight sloping precast-concrete struts under each pod introduce an informal quality to the spaces. From some vantage points any sense of visual order disappears completely. The struts appear to be assembled chaotically, rejecting any aspirations of a formal interior architecture that alienates some sectors of society. Structure can be read as an informal and perhaps visually confused setting that empathizes with the states-of-mind of those unfortunate enough to visit the courts.

Primary structure at the Kunsthaus, Bregenz, separates vertical circulation from other space usage, in this case, galleries (Fig. 5.24). Best appreciated in plan, the vertical structure consists of only three structural walls, the bare minimum to resist lateral loads in orthogonal directions without the building suffering torsional instability (Fig. 5.25). The asymmetrical layout of the walls presents a challenge for the suspended floors that must span most of the building width. From a view-point located in the middle of any of the four galleries stacked one above the other, structural walls screen off areas of vertical circulation and the grey concrete walls, detailed and constructed with the utmost precision, become the backdrop on which to display art. Visitors remain

▲ **5.24** Kunsthaus, Bregenz, Austria, Atelier Peter Zumthor, 1997. The building with the main entrance to the left.



▲ **5.25** Simplified ground floor plan.

completely unaware of another enhancement the structure contributes to the function of the Kunsthaus – kilometers of piping filled with circulating water are embedded within the concrete structure, enabling it to act as an environmental modifier.

In this last example of structure subdividing space to facilitate separate functions, concern for the well-being of office-workers led to the dominant interior structure of the Centraal Beheer Office Building, Apeldoorn (Fig. 5.26). The structural layout provides workers with opportunities to create their own places and feel at home. Within a regular structural grid, spaces or cells 9 m by 9 m in plan, connect via short corridors or bridges and are flanked by voids. The layout offers a wealth of three-dimensional spatial variation and experience. Cells merge and interweave together. Column-pairs articulate thresholds between cells and circulation between them. Each cell, square in plan, is supported by two columns at the third-points along each side with the clear span between them little more than 2 m. It is the combination of close spacing between columns and their reasonably large dimensions enabling them to act as screens that introduces a domestic and relatively intimate feel to the spaces. The structure also enhances privacy and the ability for individuality to be expressed and respected. Building users gain a strong impression of inhabiting the structure and of engaging with it regularly in contrast to the occasional structural encounter experienced in typical open-plan office accommodation. Even though the building is over thirty

▲ **5.26** Centraal Beheer Office Building, Apeldoorn, The Netherlands, Herman Hertzberber with Lucas & Niemeijer Architects, 1972. Columns subdivide the cafeteria into more intimate spaces.

years old, according to one staff member, office workers really enjoy working in it.

Articulating circulation

Structure has a long tradition of articulating circulation. Arcades and colonnades have defined circulation for thousands of years. Due to its ability to provide order to a plan, structure often functions as the spine that inevitably defines the primary circulation route. As Cook writes: 'Where ceremony is not involved, a central row of columns or a spine wall is a highly satisfactory way of generating built form. This spine can be formed by a corridor and we then have a brilliantly forceful generator, the spine being the route, the operational generator and also the focus of the structure from which all other parts of the system develop. Stretch the diagram and you have the Gothic nave.'[6]

By virtue of their physical presence, columns, walls or other structural members can literally and virtually restrict movement to along a single axis. The way the walls within the Contemporary Art Wing, Hamburg, confine and direct movement has already been discussed (see pages 87–8). Structure can also play less directive roles by merely suggesting a circulation route. Often these more subtle roles are played by horizontal structure, such as beams, that exhibit a directional quality. Both of these contributions of structure to circulation are examined, beginning with examples where structure defines circulation.

The first floor of Colegio Teresiano, a Barcelona convent school, provides a most memorable example of structure defining a corridor. The

▲ **5.27** Colegio Teresiano, Barcelona, Spain, Antonio Gaudí, 1889. The first floor arched corridor.

ground floor plan consists of two spine-walls that create a central corridor with classrooms off either side. At first floor, the load-bearing walls that would be expected above those below are replaced by parabolic arches (Fig. 5.27). The combination of a simple repetitive rhythm arising from their close 1.2 m spacing, their roundedness and whiteness, and the quality of light filtering through from central light-wells conveys a remarkable sense of softness and tranquility.

Although the entrance colonnade to the San Cataldo Cemetery, Modena, is equally as strongly articulated by structure, its aesthetic qualities contrast greatly with those of Colegio Teresiano. Two storeys high and supporting a single storey columbarium above, concrete wall-like arcade columns are very narrow for their height. They create a processional route, extending the entire length of the building (Fig. 5.28). The experience of passing each pair of columns that flank the corridor emphasizes progress along the route which stretches far into the distance. Unless a deliberate turn-of-the-head reveals views between the columns, the perspective along the main axis is framed by what seems like an infinite number of receding walls. While one reviewer refers to the colonnade's 'haunted' quality, it certainly fosters impressions of formality, rawness and joylessness.

The final example where structure defines circulation are the far less sombre, even exuberant, entry canopies to the Bilbao Metro (Fig. 5.29). A transparent skin sheaths eleven tubular-steel arched frames. As well as articulating circulation, other aspects of their design provide a great

▲ **5.28** San Cataldo Cemetery, Modena, Italy, Aldo Rossi, 1984. Walls delineating the entrance colonnade recede into the distance.

▲ **5.29** Bilbao Metro, Bilbao, Spain, Foster and Partners, 1996. Rounded frames express movement to and from an underground station.

deal of architectural enrichment. Note, for example, how the front frame leans slightly outwards over the threshold in a subtle but effective welcoming gesture. While the second frame is orientated vertically, those that follow it lean over incrementally in the other direction until they align normal to the slope of the escalator or stairs inside. Due to their changing orientation from the vertical, the frames invite entry and then graphically indicate in elevation the transition from horizontal to downwards movement. They therefore both express and respond to movements within, and even their roundedness echoes the forms of the underground tunnels and platform areas to which they lead.

Beginning with the Canary Wharf Underground Station, London, several examples illustrate how the *directionality* of exposed structure articulates and enhances circulation. The station's ticket hall, a cathedral-like volume, is visually dominated by a central row of elliptical concrete columns that register its length like marker posts (Fig. 5.30). Although the columns restrict the width of the linear circulation path slightly, their shape and orientation parallel to the flow of commuters minimizes this effect and reinforces the primary axis of movement. A substantial longitudinal spine-beam further accentuates directionality. Its attractively rounded soffit that bears upon sliding-bearings on top of the columns, leads people both into and out of the station via escalators. Ribs cantilever transversely from the spine-beam, hovering like outstretched wings and modulating the vast ceiling. Their relatively small dimensions and transverse orientation do not detract from the linearity imposed on the space by the spine-beam.

Roof structure at the Terminal 3 departure hall, Hamburg Airport, also contributes to circulation by a clear expression of its directionality (Fig. 5.31). Since the roof dimension in the direction of passenger

▲ **5.30** Canary Wharf Underground Station, London, England, Foster and Partners, 1999. The ticket hall with its central columns and spine beam.

▲ **5.31** Terminal 3, Hamburg Airport, Germany, von Gerkan • Marg + Partner, 1991. Roof trusses emphasize the direction of movement on the departures level.

▲ **5.32** Museo di Castelvecchio, Verona, Italy, Carlo Scarpa, 1964. A central beam under the ceiling helps to articulate the linear circulation route.

movement is considerably greater than the building width, 101 m verses 75 m, one would expect primary structure to span the shorter distance. However, at Terminal 3, twelve curved-trusses span from terminal landside to airside. They are supported on two rows of concrete piers spaced 61 m apart and cantilever beyond them at each end to enclose the full roof length. Breaking with convention again, the trusses run *between* rather than above the piers, signalling the direction of circulation between the structural members. Pairs of elegantly detailed steel struts rise from the piers to triangulate the roof structure both parallel to and normal to the trusses, framing the entry thresholds created by the piers. Departing travellers who approach the terminal by car or on foot from a car parking building across the road, are greeted by the ends of the trusses that protrude through the landside glazed wall. Then, in a gentle curve, the trusses rise up and over the departure hall with its three levels of shops and restaurants towards the airside. The introduction of natural light through glazed strips directly above the trusses intensifies their directionality.

Immediately after entering the Museo di Castelvecchio, Verona, visitors pass through six inter-linked galleries aligned in a row. Thick walls subdividing the elongated space are penetrated by arched openings that provide and clearly articulate a linear circulation route (Fig. 5.32). The axis of movement is further enhanced by the exposed ceiling structure. Exquisite riveted steel beams that bear on the cross-walls, run the length of the galleries. Beam support points are recessed into the walls to suggest that the beams are continuous and pass through the walls rather than being supported by them. An elaborate steel bearing located at the mid-span of each beam, and therefore at the centre of the gallery, vertically separates the beam from the ceiling. It supports two shallow concrete beams cast integrally with the ceiling slab that are orthogonal in plan and cross at that point. The steel beam differentiated by its materiality and richness of detailing from the surrounding construction introduces another structural layer that enhances the experience of circulation considerably.

Disrupting function

Occasionally, structure disrupts some aspect of the function of a building. In a few cases an architect may cause this disruption quite deliberately. More often though, functional disruption is like a side-effect from medication, unwelcome, but accepted as the cost of achieving a certain architectural objective. This situation has already been encountered at the Baumschulenweg Crematorium. ‘Randomly’ positioned columns prevent direct circulation through the condolence hall, but it would be

▲ **5.33** Research Centre, Seibersdof, Austria, Coop Himmelb(1)au, 1995. The office block and its irregular columns.

▲ **5.34** A column dominates the 'thinking room'.

churlish to complain given the space's wonderful architectural qualities (see Fig. 2.13).

Hale discusses how some buildings, while of expressive architectural form, function poorly. He gives specific examples of how deliberate structural disruptions, such as columns that are placed in the middle of a house dinning room and in the middle of a lecture theatre, can be read as a means of functional or historical critique.[7]

Similar but less severe disruption occurs at the Research Centre, Seibersdof. Primary exterior structural elements supporting the building appear to be positioned and orientated randomly, but with sufficient order to allow the building to span the road (Fig. 5.33). Interior structure on or near the building perimeter also exhibits disorderly behaviour with respect to other elements. Diagonal braces cut across most windows, but the most disruptive structure is found in the tiny 'thinking room'. A centrally located column not only dominates the room but severely restricts how it can be used (Fig. 5.34). One reviewer describes the room as 'the one truly challenging space' that is consonant with the architects' expressed desire for 'untamed, dangerous architecture'.[8]

It is debatable whether the realization of architectural ideas at the Convent of La Tourette, Eveux, justify such a high degree of disruption to the use of its interior spaces. The strategy of avoiding perimeter columns by placing them several metres into the building has achieved

▲ **5.35** Convent of La Tourette, Eveux, France, Le Courbusier, 1959. The western façade and three levels of irregularly-spaced mullions.

▲ **5.36** Two columns on the right are set-in from the exterior wall and intrude upon a teaching space.

▲ **5.37** Pizza Express Restaurant façade, 125 Alban Gate, London, England, Bere Associates, 1996. Deep window mullions limit the café seating layout.

the dual aims of 'floating' the building and freeing-up the façade. Apart from the concrete-walled chapel, the remaining blocks 'touch the ground lightly', and as viewed from the west the complex rhythmical composition of window mullions appear to today's viewers like typical barcode patterns (Fig. 5.35). Unfortunately, while the building exterior is freed from structure, the spatial functionality of the interior suffers considerably. Circular concrete columns severely limit how seating and furniture can be deployed in many of the rooms (Fig. 5.36).

Disruption can also be completely unintended during the design process but evident when a building is completed. Two unrelated examples of disruptive structure are encountered at 125 Alban Gate, London. In the first, deep window mullions intrude upon a first-floor restaurant space. Face-loads on the two-storey-high glazed walls are resisted by mullions in the form of innovatively designed vertical trusses. The truss chords consist of stainless steel rods threaded through glass electrical insulators (Fig. 5.37). The combination of the spacing between these mullions and their depth affects the table layout detrimentally. Unfortunately, the mullion spacing is overly generous for one table, but too close for two, raising the question as to whether the mullions' aesthetic impact justifies the loss of significant usable space.

The second example serves as a reminder of how diagonal members pose a danger to the public. It recalls the full-scale mockups undertaken during the Hong Kong and Shanghai Bank design. During development of a 'chevron' structural scheme, eventually rejected by the client, Foster and Associates placed a polystyrene full-scale diagonal member in their office to assess its danger to passers-by.[9] On the first floor of 125 Alban

▲ **5.38** 125 Alban Gate, London, England, Terry Farrell, 1992. A transfer-truss diagonal member poses a potential danger to passers-by.

▲ **5.39** California College of the Arts, San Francisco, USA, Tanner Leddy Mantum Stacy, 1999. Light steel frames prevent injuries from the 'Nave' brace members.

▲ **5.40** Staatsgalerie, Stuttgart, Germany, Stirling and Wilford, 1984. Columns form a visual barrier around the information desk.

Gate, five one-storey deep transfer-trusses enable the building to span across a road (Fig. 5.38). Truss diagonal tension members, encased in stainless steel tubes, intrude into the public space. To prevent people from injuring their heads, the designers positioned seats and planters to create a safety-zone in the vicinity of the structure.

At the Montgomery Campus, California College of the Arts, San Francisco, the architects provide a more permanent solution to prevent structure-induced injuries. The College occupies a former bus maintenance garage constructed in the 1950s that required seismic retrofitting. Steel chevron frames brace the building in both orthogonal directions. Those orientated transversely define a central interior street (Fig. 5.39). Known as 'The Nave' it has become a successful venue for exhibitions and other events. Light steel frames protrude below waist level from the inclined steel tube braces to prevent any accidents, but just in case these frames are not noticed, rubbish bins are strategically placed alongside.

To conclude this chapter, two buildings illustrate how structure affects building users in unanticipated ways. Within an entry foyer at the Staatsgalerie, Stuttgart, a circular colonnade rings an information desk (Fig. 5.40). Due to the large column sizes and their close spacing they visually form a cylindrical wall that reads more like an attempt to restrict access than to encourage it, and this reduces accessibility to the desk.

A final rather quirky example reiterates the potential danger to people from diagonal structure positioned below head-height. At the Scottish Exhibition Centre, Glasgow, the main concourse passes under a series of pitched portal frames supporting a glazed skin. The portals are

▲ 5.41 Scottish Exhibition Centre, Glasgow, Scotland, Parr Partnership, 1985. Knee pads on truss-columns.

triangular-sectioned tubular steel trusses with clearly expressed pin bases (Fig. 5.41). An elegant convergence of the three chord members onto a chamfered cylindrical base can not redeem the unfortunate situation where people sitting in a café area strike their heads against the structure. A more elegant solution than the protective-pads might have been the creative deployment of planters, as observed elsewhere in the building.

Summary

In order to explore how structure contributes to and enhances building functionality this chapter begins by reviewing two design strategies to achieve building functionality – one based on identifying and applying 'critical functional dimensions', and a second more general architectural approach. The question of how to maximize functional flexibility is addressed with reference to the 'free plan'. Examples then illustrate how perimeter structures with diverse spatial relationships to their building envelopes allow the most flexible planning and usage of interior spaces.

Two groups of buildings illustrate how structure also contributes to building function by subdividing space. In the first group, the spatial subdivision of a large volume enables similar functions to occur in each small space. Several of the buildings are notable for the diversity of spatial experience and architectural qualities they provide. In the second group, interior subdivision leads to a different space-use in each of the subdivided areas. Typical examples include the structure separating circulation from other spaces such as waiting areas and galleries.

Circulation is a necessary function of any building and is frequently defined or articulated by structural elements such as arcades and frames. Depending on numerous factors including structural spacing, scale, materiality and detailing, structurally defined routes can be read and experienced very differently. For example, while one corridor exudes tranquility, another conveys impressions of rawness and joylessness. Even if the physical presence of structure is insufficiently strong to define circulation, it can enhance it by conveying a sense of directionality.

The concluding section considers works of architecture where structure disrupts function. In most of these cases where structure frustrates building users, architects have given greater priority to the realization of other architectural objectives. Examples illustrate that causes of disruptive structure range from completely intentional to purely accidental reasons.

This chapter illustrates the profound influence structure can have upon building function. By virtue of its permanence, structure both defines and limits the activities within a building. The degree of subtlety with which this is achieved depends upon the extent of the structure's physical presence both in plan and section. Whether it is maximizing functional flexibility or disrupting it, subdividing space or articulating function, structure must be thoroughly integrated both with the design concept and the functional requirements of the building.

REFERENCES AND NOTES

1 Schodek, D. L. (2001). *Structures*, 4th edn. Prentice Hall, p. 468.
2 Krier, R. (1988). *Architectural Composition*. Academy Editions, Rizzoli, p. 27.
3 Davis, G., Thatcher, C. and Blair, L. (1993). *Serviceability Tools Volume 1: Methods for Setting Occupant Requirements and Rating Buildings*. The International Centre for Facilities, Ottawa.
4 Unwin, S. (1997). *Analysing Architecture*. Routledge, p. 137.
5 Quoted in an extensive analysis of architectural form in Ching, F. D. D. (1996). *Architecture: Form, Space & Order*, 2nd edn. Van Nostrand Reinhold, p. 14.
6 Cook, P. (1996). *Primer.* Academy Editions, p. 84.
7 Hale, J. A. (2000). *Building Ideas*. John Wiley & Sons, pp. 87–8.
8 Steel, C. (1996). Tame at heart. *Blueprint*, 127, pp. 3–6.
9 Williams, S. (1989). *Hong Kong Bank: The Building of Norman Foster's Masterpiece*. Jonathan Cape, p. 105.

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