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The aesthetics of gravity

Beyond taste or fashion, there exists a lasting and common consensus for a perception of beauty linked to weight or weightlessness. This essay attempts to develop an understanding of different approaches to the issue of weight and weightlessness in architecture and civil engineering. In complex urban and programmatic settings, however, the question of gravity has to be integrated with many other issues, as exemplified by Albini and Helg's La Rinascente department store in Rome.

Before even learning how to speak, an infant experiences and plays with gravity. To let objects fall, to build and then destroy the tower of blocks, or to be puzzled by a hovering mobile as well as its own struggle to sit upright, demonstrates that gravity is of our primary certainties. Growing up, we interiorize nature's extraordinary inventiveness to come to grips with gravity. Trees, wheat, mushrooms, and animals all have formal structures that bear the imprints of gravity. We see gravity in action, as with waterfalls and sleigh riding. The balloon escaping the child's hand may be a first traumatic experience of the infinite universe, and 'anti-gravity'. The balloon is joining the stars. The child dreams of flying like a bird that carries with it the illusion of weightlessness and of overcoming the apparently unavoidable burden of gravity.

As Starobinski (1970) states in his essay *The dazzle of lightness or the clowns' triumph*, 'the circus may well offer some of beauty's highlights'. The dexterity, the lightness, the taking wing of the clown inspirits miraculous achievements. He quotes Gautier commenting on the clown Auriol's performance: ' ... the clown completely ignores the laws of gravity: he walks up varnished walls like a fly, he would walk on the ceiling if he wanted to. If he does not fly it must be for mere vanity ... there exists nothing more aerial, lighter and of more graceful risk'. The clown's body challenges gravity [Fig. 1]. His make-believe that gravity can be overcome, or no longer exists, is turned into a programme for an aesthetic experience.

Formal structures, relating to gravity and to anti-gravity, are thus so deeply embedded in our minds that they most likely influence, if not our sense of beauty, which is cultural to an extent, then at least our sense of propriety. There are basically four ways in which architects and engineers deal with this issue of weight or weightlessness:

- making solidity 'manifest'
- achieving stability through an elegant performance minimizing material use
- creating imbalance in order to re-balance
- referring to gravity as a compositional theme rather than a structural reality

Each of these four approaches is explored below.

Making solidity manifest

This quality can be achieved by weight and sometimes by over-sizing. Beams and vaults are sturdy and rely on solid walls or columns; buttresses are plain rather than flying; jambs and lintels of openings are apparent rather than hidden. This approach can be recognized throughout antiquity from Egyptian to Mycenean, and in Hellenic [Fig. 2] and Roman architecture.

This interpretation of gravity, if applied to architectural aesthetics, leads us back to Schopenhauer's (1818) radical position in favour of Classical antiquity with a clear articulation of support and beam, vertical and horizontal, column and entablature. Architecture does not imitate nature but works in the spirit of nature, expressing and distinguishing without detour or mannerisms that which carries from that which is being carried. Schopenhauer's arguments clearly offered Neo-

Classicism a philosophical foundation at the beginning of the nineteenth century.

Very few twentieth-century architects chose to express the evidence of solidity through massivity. With new technologies this was not considered to be 'in the mood of the time'. Yet the work of Louis Kahn, which is largely based on simulating solidity, enjoys worldwide recognition. His contemporary thin walls fold and refold in order to sustain the *impression* of massivity. The resulting cavities are then 'inhabited'.

Achieving stability through elegant performance, minimizing materials

This can be achieved by breaking down the forces into a filigree structure not unlike the tree leading the forces from its tiny overhanging branches down to the stem and roots. Other examples are thin shells. Gothic cathedrals with their ribs, shafts and flying buttresses may be considered mankind's most elegant achievement of this approach in stone. With iron, steel, reinforced concrete and more recently cables and sophisticated wood or glass technology, the nineteenth and particularly the twentieth century excelled in producing elegant and often rather biomorphic structures.

Auguste Perret's church in Raincy, Pier Luigi Nervi's and Robert Maillart's ribbed slabs, domes and mushrooms, Buckminster Fuller's geodesic domes, John Foster's 'umbrellas', Felix Candela's and Eladio Dieste's shells [Fig. 3], Marc Mimram's steel constructions and Julius Natterer's filigree wood constructions are all examples of the search for minimizing materials with a maximum contribution to strength.

Creating imbalance to re-balance

This is what comes closest to Starobinski's 'triumph of the clown'. The building turns into a performance

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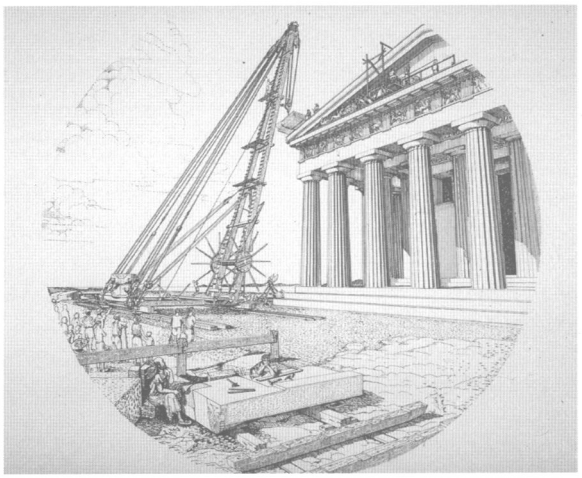

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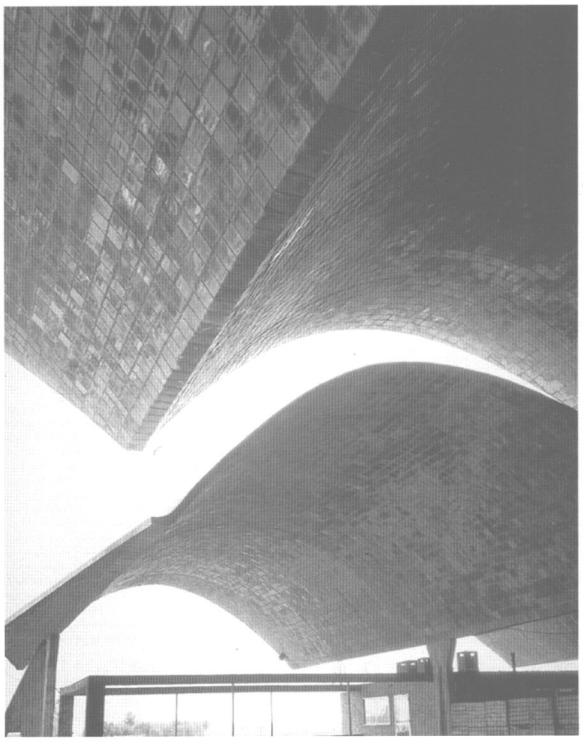

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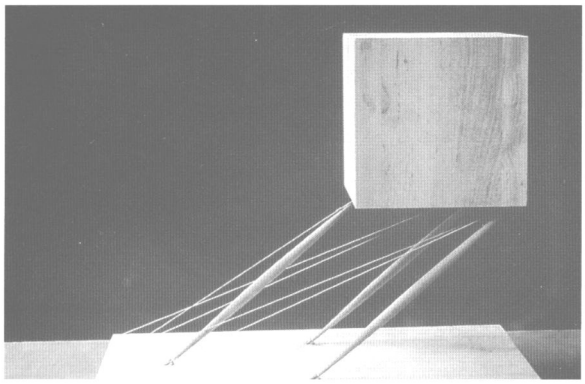
1 The clown challenges the laws of gravity: his make-believe is a programme for an aesthetic experience

2 Solidity made manifest. The Parthenon under construction, drawing by Manolis Korres

3 Stability through elegant performance. Eladio Dieste's precompressed free-standing shells for Massaro Agroindustries (Uruguay, 1978) have a cantilever of 16.4m and a thickness of 100mm of which 73mm is perforated brick



4 Re-balancing imbalance. This sculpture by Santiago Calatrava produces the same kind of dynamic effect as some of his bridges

through the interplay of weight and counterweight, of tipping over and retention, of cantilever and embedding. Sometimes part of the magical game is hidden to produce a sensation of surprise.

The platform for Lenin by El Lissitzky may be the twentieth-century prototypical example of this kind of 'dynamic' effect. Similarly Calatrava's sculptures [Fig. 4] and some of his bridges, such as the Alamillo bridge in Seville with its oblique suspension post, only resist collapse thanks to an invisible counterweight at the top of the mast. One may even say that creating imbalance in order to re-balance is the basic characteristic of Calatrava's slightly mannerist work with its 'hardly believable stability'. This kind of performance is clearly linked to modern technology and computer calculation. We therefore seldom find such figures in nature or in the architecture of the past.

Referring to gravity as a compositional theme

For the majority of architects the central issue is not that of expressing the structural reality of the flow of forces. They are more often interested in referring to gravity by consciously structuring a volume according to the distribution of *visual weight*. As Arnheim (1997) points out, 'there can be no assurance that the physical formula automatically corresponds to the visual effect, that is *that the load looks the way it is*'. He rightly suggests that three factors govern the visual perception of weight:

- *distance* from the ground and from surrounding objects
- *load*, the weight of visual mass as distributed from the top to the ground
- *potential energy*, the possible acceleration 'if that element was falling down to the ground'

On the basis of Arnheim's observations it is possible to understand the emotion created by certain settings. Let us look at three very different ways of dealing with visual weight distribution.

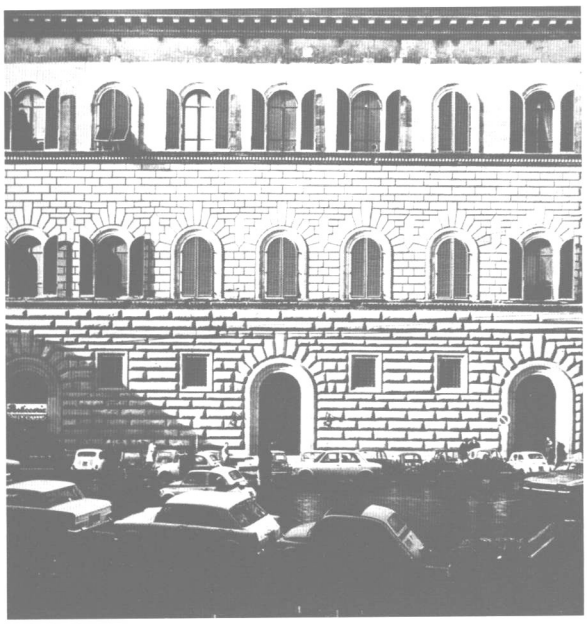
Since antiquity, Classical architecture has been governed by the principle of *tripartition* which implies that every element should articulate a beginning, a middle and an end as shown in Serlio's treatise of the sixteenth century (1537). For the vertical division of a facade this means that there should be a base, related to the earth, the upper floor(s) and finally the top floor and cornice that concludes the composition towards the sky. The base carries the weight of the volume. During the Renaissance, the base was expressed in larger and rougher stone and small openings, with the exception of the door; the piano nobile was more refined and the concluding top was even smoother and finished off with a delicate cornice [Fig. 5a].

Our second example, more specifically related to the twentieth century, relies on the *inversion of weight distribution* by means of pilotis in steel or reinforced concrete. The 'heaviest' element is lifted up way above the ground. The Doge's Palace in Venice is among the very few pre-industrial examples of such weight distribution. Le Corbusier's Villa Savoie and, even more so, his monastery of La Tourette [Fig. 5b] illustrate this 'dangerous' inversion producing what Arnheim calls potential energy.

The third example involves the idea of *floating*, a theme cherished by several twentieth-century architects. It generates either apparently free-floating, superimposed prisms with significant overhangs such as in Frank Lloyd Wright's Falling Water or, as in his Robie house, and in Mies van der Rohe's Barcelona pavilion, a roof which is autonomous without reference to vertical elements of the building below. The latter belongs to the ground. The 'hovering-syndrome' as Adolf Max Vogt calls it in his remarkable essay (1989) can be achieved not only by literally detaching the floating roof but also, as in the case of the Barcelona pavilion, by abstracting the load-bearing elements (chromed reflective column casings and the mirrors of polished marble).

More recently, the gigantic, infinitely thin floating roof of Jean Nouvel's concert hall in Lucerne not only shelters the building. It also hovers at an urban scale including the square, the quay and the lake. The supporting structure cannot be seen from the ground, which adds a magic dimension to its visual perception. Much the same is true of Ragnar Östberg's hovering ceiling over the central court of his Stockholm town hall [Fig. 5c].

Gravity, although omnipresent is, in the great majority of constructions, a minor determinant for expression. There are plenty of other issues, such as site, programme and meaning, able to 'carry' a design. But there are some buildings where the expression of how gravity has been overcome becomes typically a major factor, demonstrating how forces (weight and thrust) work in underground



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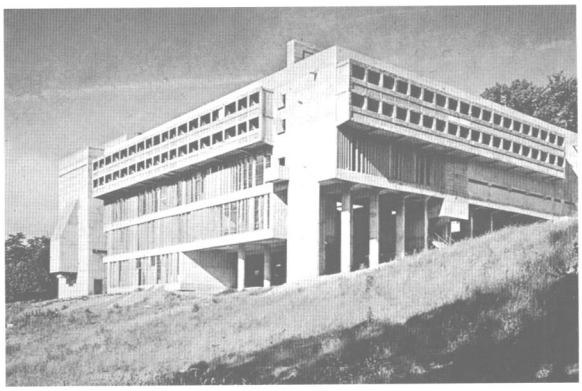

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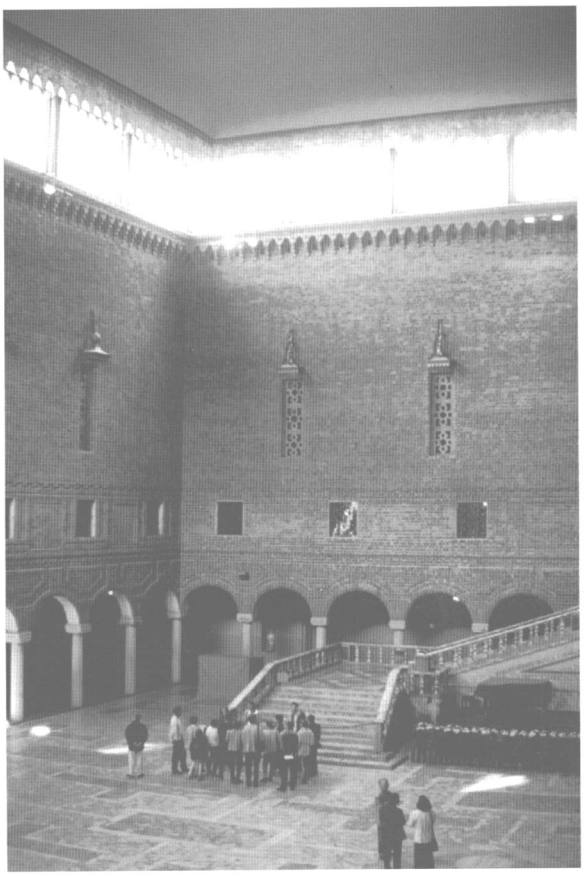


5c

5 Gravity as a compositional theme
a Giuliano da Sangallo, Palazzo Gondi, Florence, 1490: Classical tripartition from heavy base to light cornice, earth to sky
b Le Corbusier, La Tourette, 1957/60: inversion of visual weight with the heaviest element lifted above the ground
c Ragnar Östberg, Town Hall, Stockhom, 1916: the use of a hovering ceiling to convey the impression of an exterior piazza

spaces or large single-storey volumes with wide spans – such as churches, concert halls, markets, stations, exhibition buildings, airports and, of course, bridges.

In addition, there are, as we have already pointed out, some architects and engineers for whom the expression of the flow of forces is a matter of ideology irrespective of the type of building designed (Nervi, Perret, Foster and others). Their work benefits from worldwide attention, not merely by peers, but particularly by the public at large. As we suggested before, expressing the flow of forces presents a chance for connecting the perception of the built environment to people's basic bodily experience with gravity, thus awakening our sense of the sublime.

Gravity and the teaching of design

Teaching implies consciousness of issues and methods. Our classification of these in four categories helps to give a clearer picture of how to communicate and to discuss a particular aspect of an architect's, an engineer's or a student's approach to the issue of designing with or for gravity. How this occurs and how it is integrated with our critical thinking, deserves further discussion. In order to be more explicit we shall examine the particular question of designing the exterior envelopes of buildings, especially their relation to gravity. The reason for this particular selection of one issue among many was clearly explained by Frampton (1995) when he wrote that, '... the presencing of a work is inseparable from the manner of its foundation in the ground and the ascendancy of its structure through the interplay of support, span, seam and joint – the rhythm of its revetement and the modulation of its fenestration'.

The economic and ideological forces which

currently govern the relations between techniques and their physical expression in industrialized countries are complex and often contradictory in terms of exterior appearance. This raises a number of difficulties:

- an antagonism between artistic expression and constructive reality
- the fact that saving labour is more cost-effective than minimizing materials
- the need to package buildings into a 'Thermos' or insulated container in order to achieve better energy management
- the growing importance of the facade in accommodating complex regulating and distributive mechanisms

We shall briefly examine these four conditions.

Artistic expression versus constructive reality

Modern technology offers a fabulous liberation from structural constraints, opening the way to free spatial composition exemplified in the work of van Doesburg, Le Corbusier and early Mies van der Rohe. Slightly closer to our time we find the work of Eisenman, Libeskind, Hadid and others operating on a basis of appearing to have been 'liberated' from constructive constraints. Architecture apparently adopts painting's freedom to decide on grammar, form, texture and image. Sometimes reality catches up with, or works against imagination, as in the case with Zaha Hadid's first actual building, the Vitra fire station near Basle: the heroic canopy apparently 'forgot' that it was made out of reinforced concrete and not of cardboard – it already sags more than 200mm. Jean Nouvel, similarly striving for glorious effects, at least knows that in such cases one needs an invisible but real and permanent false work.

The twentieth century has, no doubt, produced the most 'illogical' structural forms of all time thanks to its sophisticated technologies, 'which appear to be capable of anything'. The buildings of contemporary designers attract public attention and criticism, as in the case of Gehry's Bilbao Guggenheim museum. The buildings of the Baroque did the same during the seventeenth and eighteenth centuries. The difference is that the historic Baroque interiors were non-structural stage sets while the 'contemporary baroque' relies on technologies capable of integrating structure and decor into a single and unique composite element.

Economy of labour versus economy of materials

Currently, the most fundamental change is the dominance of computer technology combined with the effects of rationalization – in which the economy of expensive labour competes with the lower cost of materials. Achieving structural 'presence' demands a rationale which may be unfavourable in terms of the expression of the flow of forces from top to ground. Reinforced concrete, particularly the art of pre-tensioning, and the fact that rigid connections are capable of producing forms close in appearance to the abstraction of cardboard models, often obscures structural expression. Maillart's expressive mushrooms [Fig. 6a] are replaced by Geilinger's efficient 'mushrooms' hidden within the thickness of the slab [Fig. 6b].

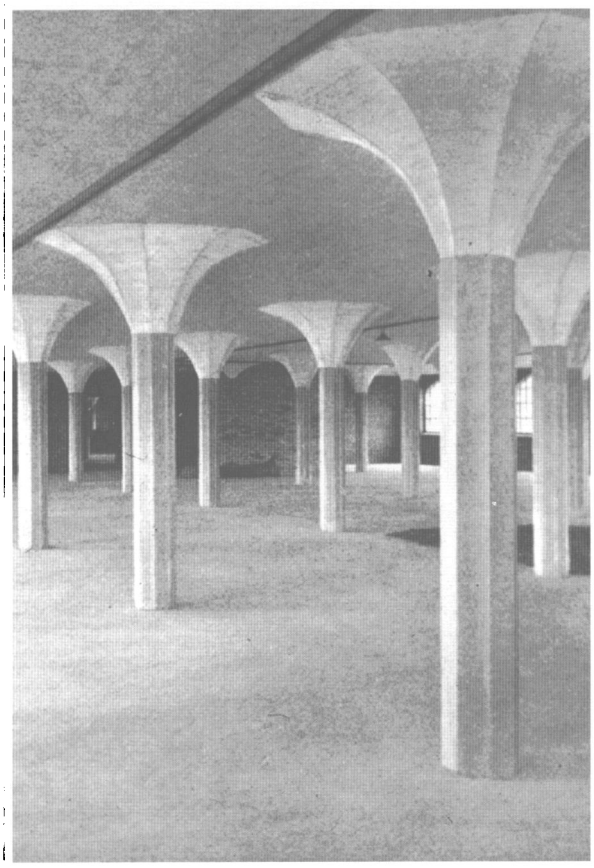
Bridges tend to obscure or distort their primary effort of spanning thanks to hidden pre-tensioned cables. Pre-tensioning is what reduces structural configurations to the 'primitive cardboard model', with simplified and economic formwork. As Pier Luigi Nervi wrote (1955): 'In spite of having been used for over a century, the potential of concrete is still unrealized. The main reason is practicality: the fabrication of form work in wood. This implies using the logic of wood construction and not of concrete ... We are building prismatic forms merely for a temporary reason' [Fig. 6c]. Most engineers' rationale remains focused on strength and economics; the idea of *showing* strength and the flow of forces does not seem to be a priority. Nervi's work is an exception [Fig. 6d].

Packaging versus the expression of structure

The majority of high-rise buildings are supported by a steel or concrete frame and protected by a non-load-bearing curtain wall. In recent decades, the management of energy resources has become a major issue, which in turn has reinforced the move towards an uninterrupted and highly insulating envelope. This excludes the possibility of literally showing the frame. There exist basically two 'packaging traditions': one where the organization of the skin reflects or gives some clues to the load-bearing structure it protects, and the other which is totally independent thereof.

Louis Sullivan was among the first architects to experiment with brick and ceramic claddings: these related to the Chicago frame without expressing it literally. Some years later, Auguste Perret applied Alexandre Bigot's ceramic tiles in 25 bis rue Franklin (1903). This closely reflected the organization of the concrete frame behind, although Perret took some minor liberties where these enabled a more elegant solution. As Joseph Abram wrote (1986), 'for Perret the cladding inevitably conceals and it is therefore necessary to prove its protecting role. In order not to appear as an arbitrary decor it has to reveal the way in which the stability of the building is achieved'.

Many recent buildings emphasize the idea of continuous uniform and insulated packaging rather than referring to the supporting frame. The stillness of a more abstract volume or global image takes precedence as can be seen in some of Zumthor's, Herzog & de Meuron's [Fig. 7a] and Nouvel's buildings. There will, nevertheless, be major changes in the next two decades. Thanks to entirely new composite building materials such as glass fibre and carbon fibre products, glued structural profiles and even structural cladding will be very lightweight, insulating and non-corrosive – and perform at least as well as steel [Fig. 7b]. This in turn will reduce the multi-layered complexity of facades. It opens once more the possibility of expressing structure internally and externally. The revolution in building techniques will echo the revolution that occurred with the invention of steel and of reinforced concrete.



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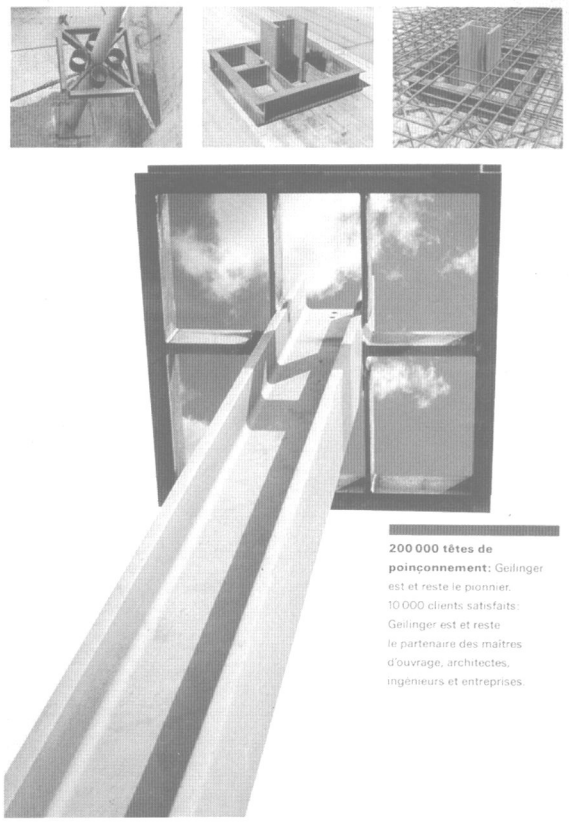

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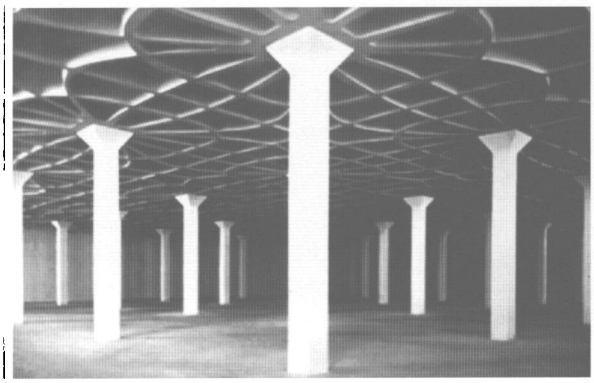

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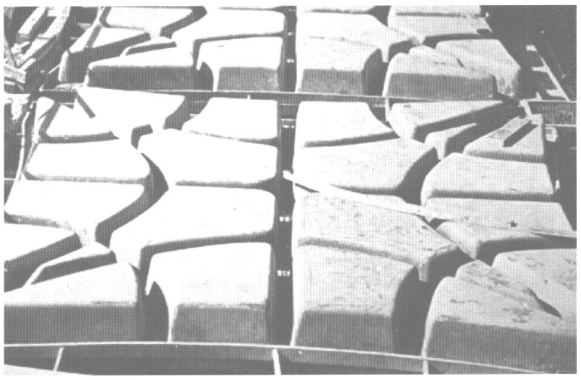


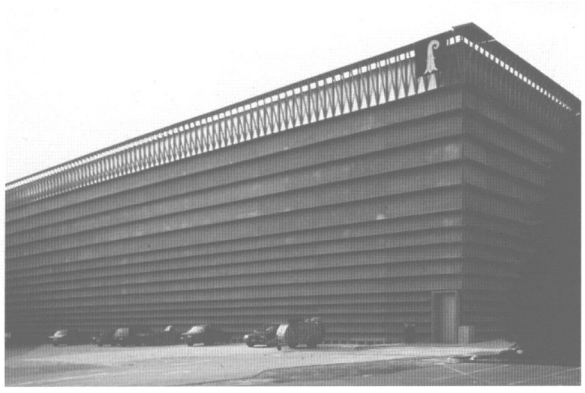
6d

6 The economy of materials or labour
a Robert Maillart, warehouse in Zurich, 1910: the expressive mushrooms can be compared with ...
b ... Geilinger's steel 'mushrooms' which are simply concealed *in the slab thickness*
c Pier Luigi Nervi, Gatti wool processing plant in Rome, 1951-53: ribs follow the flow of forces ...
d ... but can only be constructed with the aid of temporary *formwork*

The facade as *complex machinery*

Architecture has come a long way since the building facade's role was merely that of carrying loads, of climatic protection and of the natural lighting and ventilation of interiors. The modern commercial building's facade has to accommodate thermal inertia, ducts and directing devices for ventilation or air-conditioning, heating, electricity, telephone, electronic distribution, artificial light fittings, sprinklers, other liquids and so on ... and almost subsidiarily: the structure with its fire protection.

Without wishing to advocate high-tech expressionism, one might have expected that the need to integrate such complex machinery into a coherent whole would, by now, have produced a new language where structure might or might not continue to play a formal role. In reality, the harsh division of labour in industry – in terms of production as well as for design competences –



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7 Packaging versus structural expression
a Herzog and de Meuron, storage building Ricola in Laufen, Switzerland, 1986-91: the 'elegant dress' says something about the weight of storage rather than structure
b Thomas Keller, lightweight demountable footbridge in Pontresina, Switzerland, 1997: the profiles are made from Isophtalacid-polyester reinforced with glass-fibre nets. This material is weather resistant, insulating and is of equal strength but four times lighter than steel

seldom permits this. The complex facade looks rather like the front of the car: there is the (architect-designed) smooth and styled hood; opening it, one discovers an incredible bricolage of more or less interconnected sub-systems offered by the various engineering subcontractors. While this may be appropriate for cars which are not bound to a locus or place, and whose aerodynamic performance may indeed require the smoothing out of its exterior form, one may question the same styling principle applied to buildings.

Rome's still unequalled 40 year old La Rinascente department store by Franco Albini and Franca Helg [Figs. 8a-d] illustrates this point. Of course, it is a bricolage as well and, given the time of its construction, a bricolage largely based on craftsmanship rather than industry. But in spirit it remains a fabulous prototype for rethinking the facade as a complex piece of machinery, yet remaining perfectly respectful of its programme and specific urban context.

A fabulous prototype

Albini and Helg's task was to build a typical department store, which meant a blind multi-storey container, usually unfit for historic urban settings. The clue to the successful structuring of the facade's scale, proportions, texture, colour, light and shadow can be found in its dependence on the understanding of the components and the consideration of their performance from different perspectives: technical, architectural and urban. Taken individually, none of the technical sub-systems represent in themselves the most economic and rational solution. But together they provide a successful combination of internal comfort and good urban appearance, which produces the impression that the *building has always been in that place on Piazza Fiume in Rome.* In our time, where the language of 'High-Tech' is too often verbose, it is worthwhile recalling Franca Helg's (1982) explanation of the ethical foundation of their approach.

'What we set out to do in this dense urban environment was to give the building a status which was not necessarily monumental but was neither dull nor insignificant. It was to have an architectural character and dignity of its own, and at the same time respect the existing norms, the building requirements, the demands for internal flexibility and so on.

'All the component parts – the structural ones, the technical fittings, the outer walls, the windows, the roof, the materials, the colours – are reciprocally interrelated throughout. In the long patient repetitive design work we analyzed the possible alternatives for the use and design of individual components and investigated details in relation to the overall composition. The Rinascente Building brings Via Salaria to an end, and it completes the square of Piazza Fiume. The structural division of the building is a technical choice and at the same time an architectural one of proportions that display a quiet rhythm.

'The lines of the steel girders, attractive in themselves, serve as architectural cornices; the heads of the secondary braces, which are exposed, increase the general effect of crushing the shadows and giving emphasis to the dimensions. The panels, which swell where they contain the installation pipes, represent a technical solution; by their

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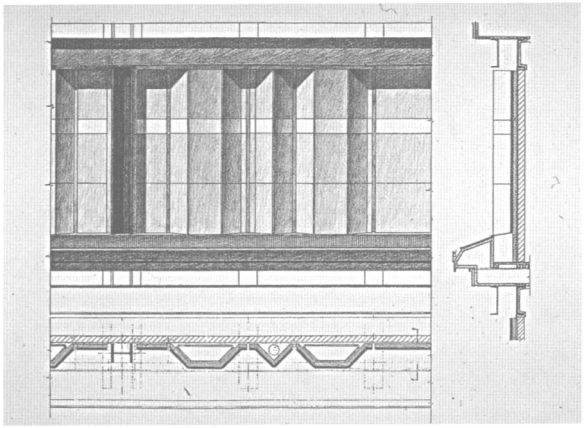

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8 Franco Albini and Franca Helg, department store La Rinascente, Rome, 1959.
The integration of structure, HVAC and other services including maintenance in the facade helped in determining an appropriate urban scale and expression
a The store in its setting. The need for a blind facade is compensated for by the care with which it has been designed as a synthesis of technological and formal solutions
b End elevation. The attic or cornice level contains the HVAC plant rooms
c Detail. The prefabricated cladding has a lively grain and colour and changes in appearance with the play of sunlight
d Elevation study showing the vertical ducts concealed in the corrugations

position around the circumference, the pipes give a lot more inside space and at the same time provide a formal solution full of 'chiaroscuro' effects. The variation in the corrugated surfaces of the outer walls, which changes in its intensity from top to bottom, corresponds to the narrowing of the air-conditioning pipes; closer near the street, wider towards the square, it also helps to break the uniformity. The rail for the maintenance and cleaning of the facade is specially designed for the truck and its crane arm, but it matches the top of the neighbouring houses.

'Baroque memories, or memories of bourgeois architecture at the turn of the century? I don't know. When discussing some of the solutions adopted by our group there has often been talk of "irony" and there may be some who have used this word also for the "mocked-up cornice". But I never felt that there was any irony in it. The architectural elements – though free, we feel, from norms and regulations – certainly stem from specific building requirements and are part of our visual memory. A building of such size, with its horizontal and vertical divisions, needed a crowning cornice to finish it off if it was to fit into its immediate surroundings.

'Finally, why that colour? Why that material? The Memorial to the Unknown Soldier in Piazza Venezia is in white marble, well suited for fountains in Brescia but livid and inert in the luminosity of Rome, whereas the bricks of the ruins of S. Sabina and S. Giovanni in Laterano are rich with light.

'The material of the curtain wall of the new building had to be prefabricated with a lively grain and colour, though not too bright; it had to be as resistant to the city atmosphere like the cements that were used at the beginning of the century.

'For us, the analysis and study both of the details and of the whole were based on a "how shall we do it?" approach, and at the same time were closely linked with the question "how do we see it?". The details, the technological and formal solutions were drawn into a synthesis and their many elements into a unitary order. Things that have been created and made by others, both ancient and modern, are all within our experience, they form part of us, and in our designs emerge as a heritage which belongs to the architectural culture of all of us.'

Beyond the rationale of pure technique

Teaching engineering to architects, or architecture to engineers ought to focus precisely on the realm of integration so eloquently and appropriately achieved by Albini and Helg. We have to learn to go beyond the rationale of pure technique and economics, of particular sub-systems, as well as that of technical expressionism or 'pure' form for its own sake. This has nothing to do with art. Art has little need to refer to gravity or urban settings, but human existence on earth must do so.

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