Technologies in Comparison. Glass Tube Production, Project and Implementation: from the SC Johnson & Son's Research Laboratory Tower by Wright to Today's Experimentations

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Architecture, as the art of building in reference to the structure and performance of the building components, as well as the specific technologies of the chosen material, emphasizes a typically organic connotation that crosses over the traditional gap between architecture and engineering. In fact the various solutions to a construction problem, that is the way to propose and face each problem, are permeated with the evolutive significance and with the essence of the constructive system, by making choices appropriate to the use of materials that – even if considered unusual or inappropriate till only yesterday – today reveal building capabilities compatible with the object composition. This in reference to the cohesion system that amongst numerous adequate solutions – in dialectics between natural environment, planned space and users – recalls the contingency of static-constructive, performance related, formal-aesthetical type of issues and, hence representative of the image, as a consequence of the economical and financial aspect involved. The final connotation qualifies itself as an adequate solution in the standardization of the approach, as if adapting itself to a distinctive – let say this, by using modern terminology, even if often overused – *minimalist* form, characteristic of an approach consequential to a balanced application of industrial design.

It does not seem useful now to go into the consequent predictable issues that arise from the architectonic methodology and language in the specialized literature that, capable of marking the procedural approach taken in today's building practice, evoke the exclusive essence of the work without resorting to masks and embellishments, by using technical-constructive details until they reach the image of a whole with a proportional passage of scale (fig. 1). Instead, the intention is to identify those expressive terms that, chosen amongst today's available constructive systems, give rise to minimum elements meaning the work on which the approach is carried out and, with it, the intervention of preservation and maintenance, that is materiality, form and performance. It is an approach amongst many, it's obvious, but it seems interesting to investigate and to provide adequate food for thought that, above all else in the modern application of techniques and technologies direct to the preservation of the architectural asset, to pursue the objective of considering as *constructive material* not only the elements implemented in order to give shape to the preservative approach, but the asset itself.

The same contextual reporting, semantics or material – used in many of the recent architectural experiences, in particular from the 1990s to today – has produced a distinction amongst the forms of languages that, through the signs used and the materials implemented, enhances, amongst different approaches, the modalities of a typically minimal tech. In this, constructing in adhesion to the vocabulary adopted, the planning solution derived appears, anyway, to fall into line with a *contextual casualness* for whoever adapts the system of relations and circumstances of the place and also, for whoever argues the approach in an aprioristic way with respect to the space and time contingency. Both of them, in fact, consciously plan a reproducible prototype, even if not standardized, adaptable to the case and user demands (fig. 2). Not a univocal solution, but contingent and temporary.

Figure 1. Kaisersaal, Berlin. When in 1996 the Esplanade Hotel was demolished, the Kaisersaal was moved to Sony Center, arranging for its complete restoration. (Photo: Gian Piero Cossu)

The same planning solutions, impersonally expressed with algorithms of analytical structure, bring out revised theoretical forms typical of the technique – useful for the testing of every planning progress – which are also gathered from the biological, physical and chemical world, permeating the results with experimental applications that cry out to the planner and his team for competence, intuition and sensitivity. This completes the initial scientific-mathematical knowledge – directing the project – through processes of elaboration of the intuitive-experimental character and, therefore, of checking the object with respect to a functional definite system, discerning the difference between the team, the essence of the form, the individual performance and the spatial balance.

By proceeding this way the actual mutation of the whole architectural system is carried out through innovative forms with regards to the introduction and application of new solutions, systems and standards, and also by resorting to the transformation of objects, materials, equipments and services adapted to new ways of use. The impact, then, on the market of such innovative products with an adaptive character, prevails in comparison to the slow establishment of dynamic novelties in the construction industry. But the innovation concerns – in the two cases – the planning idea that adapts conformation and performance, costs and consumption of the object that, by qualifying itself as a building, allows the technological apposition to a univocal reference but also to a sphere of the architecture that deals with renovations and not only with salvage and restoration.

Figure 2. I. Mendaro Corsini, *Cultural Center Temple of San Marcos*, Toledo. (Photo: © Lluis Casals)

This, therefore, requires the more adequate and coherent use of certain materials that, traditionally, are experimentally capable – in consideration of their chemical-physical specifications – of fulfilling a vital role to the stability of the whole, also collaborating with materials which have always been faithful to the principal functions of balance. On the other hand, the range of performance characteristics of traditional materials grows, also by resorting to sophisticated technologies which allow high structural performance, indispensable for the adoption of building procedures that guarantee a certain grade of transitoriness and transformation of the architectural object, typical of a method of construction sustainable and desirable in the practice of an updated conservative form.

We will not get into the consequences of a debate that sees the intervention for protection and preservation as an added value to the good to be safeguarded, which is a necessary but also false enhancement. It is preferable to discuss into constructive techniques and practices.

Once acquired, amongst the competences of the team, the capacity to discern what is deducible from the typical efficiency of the natural structures, by referring to such a functional performance to the resistance of the materials at stake, as well as the way to conceive the cooperation between the one chosen and the conformation of the supporting structure; the methodological outline identifies the significant terms of geometrical character of the morphological asset, in order to induce the processing of a general mechanical principle from which to obtain form and structure with a satisfying applicability as a consequence of its grade of adaptability (fig. 3).

From the grade of resistance acquired by the structure one arrives at specific formal qualities capable of safeguarding the balanced asset of the object subjected to preservation, in respect of the stylistic autonomy that, through an inductive course, involves material, components, structure and strain. It is about representing the mutual influence between material and structure, by giving expression to the couple structure-natural space to pick up the most appropriate references to the construction of the artificial world.

The material is the first element of the induction of planning necessary to catch the *techne* of the architecture itself. Here we speak about glass and the experimental investigation carried out which highlights that the use of materials comes close to high technology, characterizing the synthesis of the process adopted. This happened even before the technological progress that allowed the adoption of the term – *high-tech* – defining a planning approach common to numerous interventions.

With regards to the use of glass in construction one cannot stop the basic necessity for air, light and protection. It is not only a matter of being able to involve the effects of reflection and refraction capable of modifying the perception of the image, by skilfully using the constituent relations that link space and light, volumes and shadows, dividers and screens. It isn't only about altering the traditional space, characterized by the mass and the opening, getting to a simple representation of an extreme space, to a bilateral transparency that, without apparent obstacles, connects the inside with the outside, or allowing the immediate identification of the perceptible to sight.

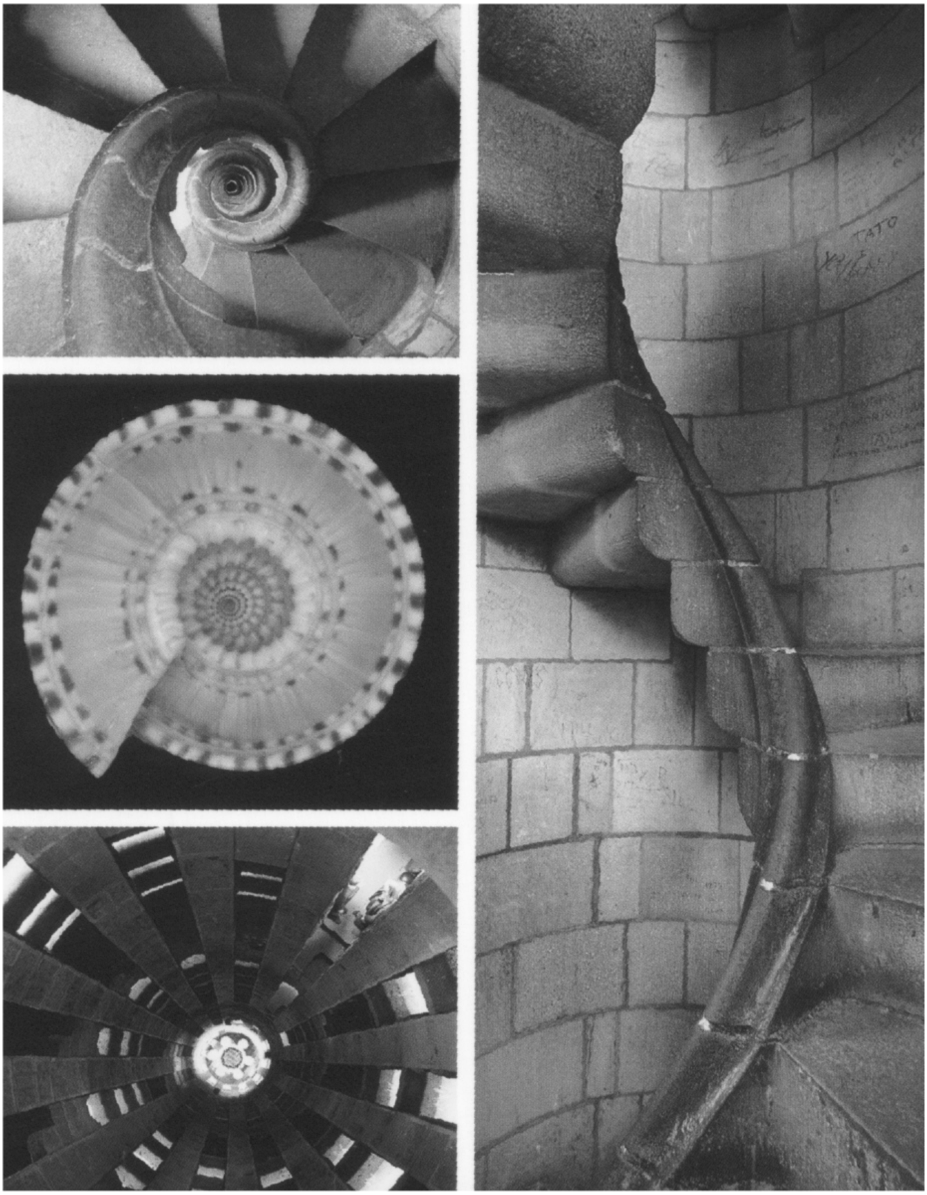

Figure 3. A. Gaudì, *Sagrada Familia*, Barcelona. Details of curve of the spiral staircase to comparison with a shell. (Photo: © Pere Vivas)

As purchasers, designers and consumers today we all participate in a dematerialization process of a horizontal or vertical closure, like an internal partition and its supporting frame, consequent to a progressive abandonment of the necessity to assign to a further structure the function of sustaining the glass system, in favour of a project where all the elements fulfil function and performance (fig. 4).

Only subsequently to the technical and technological adjustment, through the understanding of the physical and structural characteristics of the material – now of the glass – it is possible to hypothesize not only about the comprehensiveness of the static system at stake, and, therefore, the cooperation with other materials, but also the adoption of innovative contents to express new meanings. Sometimes these are ambiguous for unlikely spatial conformations that turn up side down the intention of making perceptible what appears beyond the wall, the screen, behind the structure; also making confusing suggestions or expressing the more and more refined necessity for comfort.

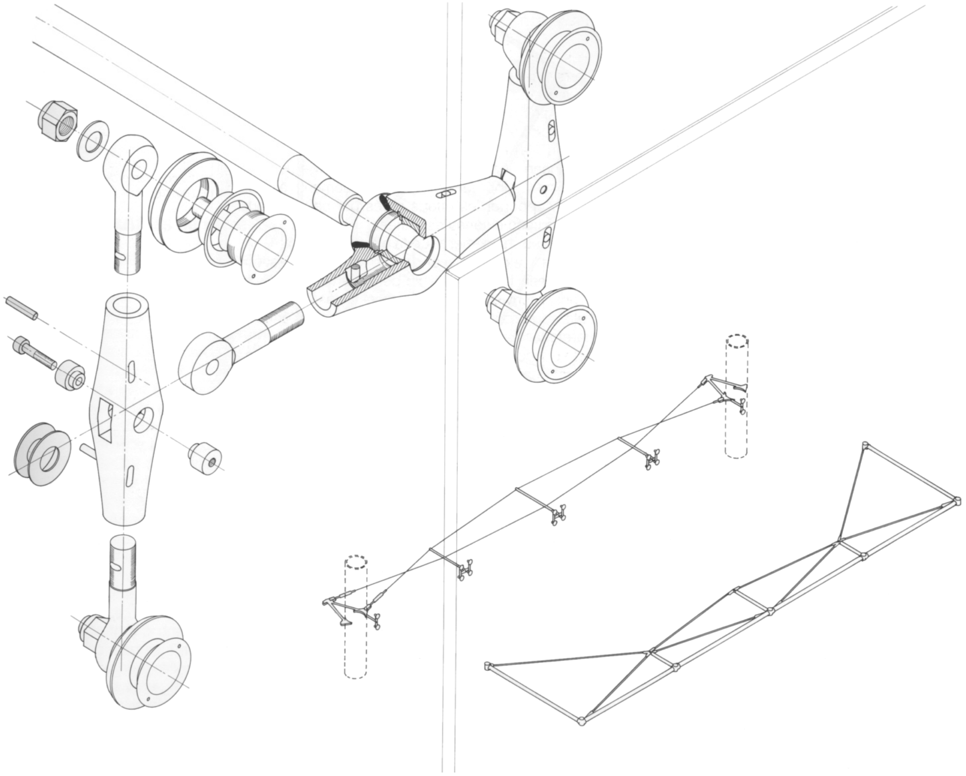

Figure 4. A. Fainsilber, R.F.R., H. Dutton, *The Greenhouses of Villette*, Paris, 1986. System of fixing of the glazing plan. (Rice 1995, pp. 30-31)

This is not the place to linger over the fragility of glass, but it seems useful to stress its essentiality based upon the valuation of actions and distortions, as well as the further causes of alteration and adaptation, by dissolving every doubt about the functioning of the plan. This is a form of expectation of glass behaviour, as of any other material, that does not seem to be acquired in the immediacy of the construction process, but that the experience characterizes distinctively in the architectural historical process, as sign of a component and technical progress carried out for the renewed instrumental asset.

The reference is, in particular, to the borosilicate glass tubes: the evolution of the material and of the performances that it is able to grant, have been progressing for less than a century and I believe it is useful to propose a reading that highlights, in the period mentioned, a continuous growth that today seems appropriate to consider in the practice of protection and preservation (fig. 5).

The sodic-calcic glass is a material composed by sodium, magnesium and aluminium oxide. Other substances can be taken into consideration to alter its characteristics and aspect. This is the case of the borosilicate glass that contains an addition of boron oxide, which permits the reduction of the expansivity. In comparison to a float or sheet glass – of the same chemical composition and physical behaviour – it permits greater resistance to sudden changes in temperature, as well as to leaching and to the attack by some acids. This makes it preferable to other glasses in certain circumstances, such as when dealing with fire resistant glass, products for the kitchen or laboratory samples. It presents a breaking behaviour similar to the one of the float; the borosilicate glass is manufactured like the float glass and sheet glass, as well as the laminated glass of ornamental type, with variable thickness from 3 to 15 millimetres. Here it highlights, though, the applications with regards to tubes, that is – with reference to the factory elements of a construction object, then to the hierarchic system of a supporting structure or of a closure – linear poles stressed only axially by a perpendicular action to their transversal section.

The Architectonical exam taken highlights that with the use of borosilicate glass tubes in F. L. Wright's experience in the Johnson Wax buildings, in Racine, (fig. 6), represents an evolution determined by the technological progress, made possible after the adoption of a central core structure in conglomerate reinforced concrete into which the overhanging floors interlock, in such a way that the skin of the building is completely lightened of the loads, making it possible to implement it using framed glass tubes.

It is, then, simply a façade, innovative though in the adoption of tubes, not only for the implications that the system allows to deepen our understanding in terms of planning of the working space, of relation between interior/exterior, of artificial or natural lighting, but most of all – after that Willis Polk at the beginning of the 1900 had already completed the first high rise curtain wall building, the Hallidie Building in San Francisco - for the necessity of reaching with the technologies available at the time a level of architectural experimentation adequate to the material requirements.

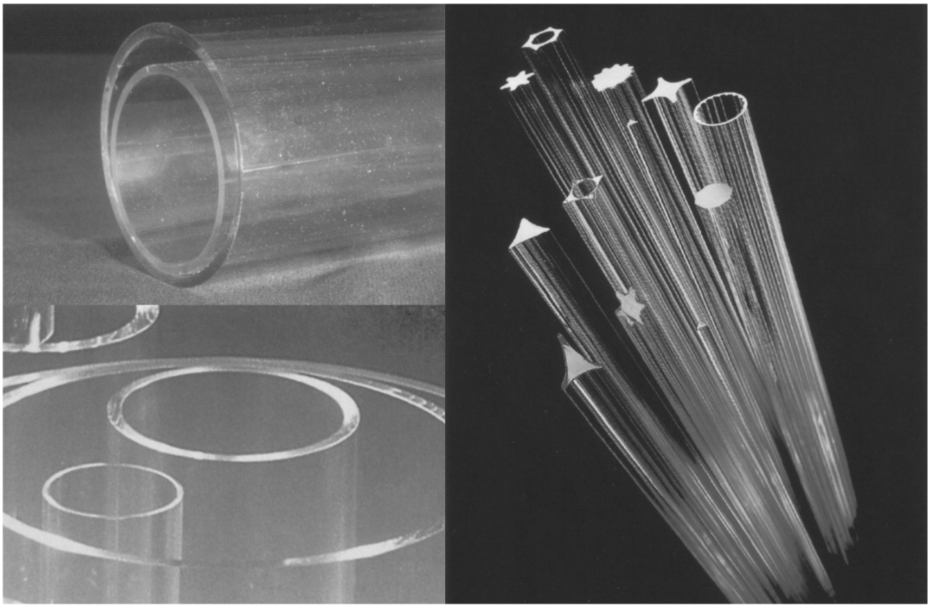

Figure 5. Left: borosilicate glass tubes. Right: *glass profile of Program Conturax* by Schott (Achilles 2003, pp. 124, 127)

Figure 6. Wright Frank Lloyd, *Johnson Wax Buildings*. (Hertzberg 2004, p. 51)

What better close examination can be interesting, then, if not the fact that over the years borosilicate glass tubes have acquired a structural function, fulfilling those functions of framework of the skeleton structure mentioned above? Once the possibility of resorting to toughening processes has been verified, the borosilicate glass tubes can in fact generate the composition of a reticulated structure stressed only by compression or traction, or else depending on the ending of the joints, also by flexion and, therefore by cutting, with the consequences that entail, in addition, the eventual combination with other materials.

We will see, in fact, that the use of tubes through processes of *centric hardening*, allows a section of glass subjected to pressure to transmit the traction strain axially with the elimination of the prestressed strain. We talk, in fact, of *externally pre-strained glass*: the glass is compressed through an external system of rods and cables, without resorting to processes of physical or chemical hardening. The fact that it is subjected to *external* actions refers to the presence of another material to be stressed, for example by applying the axial action on steel rods inside a glass cylinder. Although externally pre-strained glass is not very common because it performs better under compression, there are numerous examples to be taken into consideration. Amongst the many (fig. 7) is the column made in 1997 with layers of glass discs for the Conservatory in South London that, based on a project by Bere Associated, provides for a steel pole to penetrate the glass discs to guarantee the connection between them.

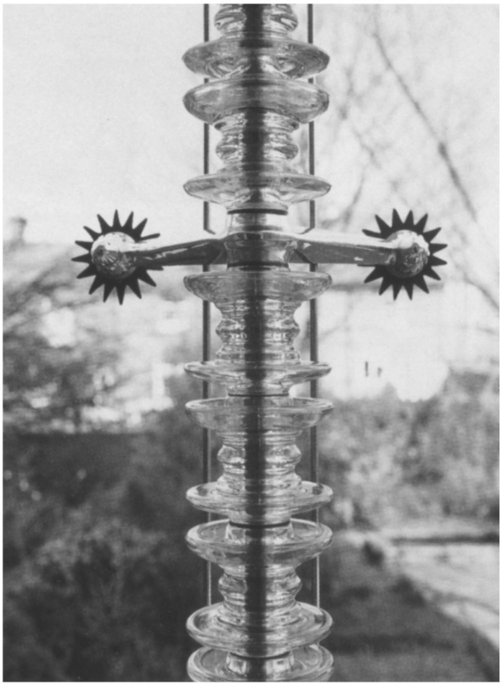

Figure 7. Bere Associates, Glass column at South London Conservatory. (I.S.E. 1999, p. 97)

1. Frank Lloyd Wright, Johnson Wax Buildings, Racine, Wisconsin, U.S.A., 1936-1950.

In the Administration Building (fig. 8), Wright's planning reaches the essence of the architectural shape by implementing innovative dendriform columns in conglomerate reinforced concrete and glass tube grids. Of these technologies of the beginning of the last century, the course taken regarding borosilicate glass tubes and the efficiency of the entire structural system imagined has to be analysed. In the Administration Building it is a rigid, hinged at the foot structural system of a continuous accurate support of the loads of the project. Clerestories of about 1.5 meters wide are considered a partial *curtain wall* and utilized instead as a closure of the building, settling on the irregular contour.

Figure 8. Above: The Great Workroom; Administration Building and Research Tower. (Hertzberg 2004, pp. 56, 59). Below: Pyrex tubes in Great Workroom skylights. (Lipman 2003, pp. 78-80, fig. 79, 82).

The continuous translucent screen controls the permeability of the surrounding environment, also in the attempt to modular the diffusion of the light transmitted by the tubes. After a year of experimentation Wright gave up on the use of sheet glass in the lanterns and then in the clerestories, and decided to use ridged glass that provides for an assemblage in the form of a bunch of large tubes – initially 3" in diameter, then reduced for economic reasons to 2" – sealed at the base. (fig. 9).

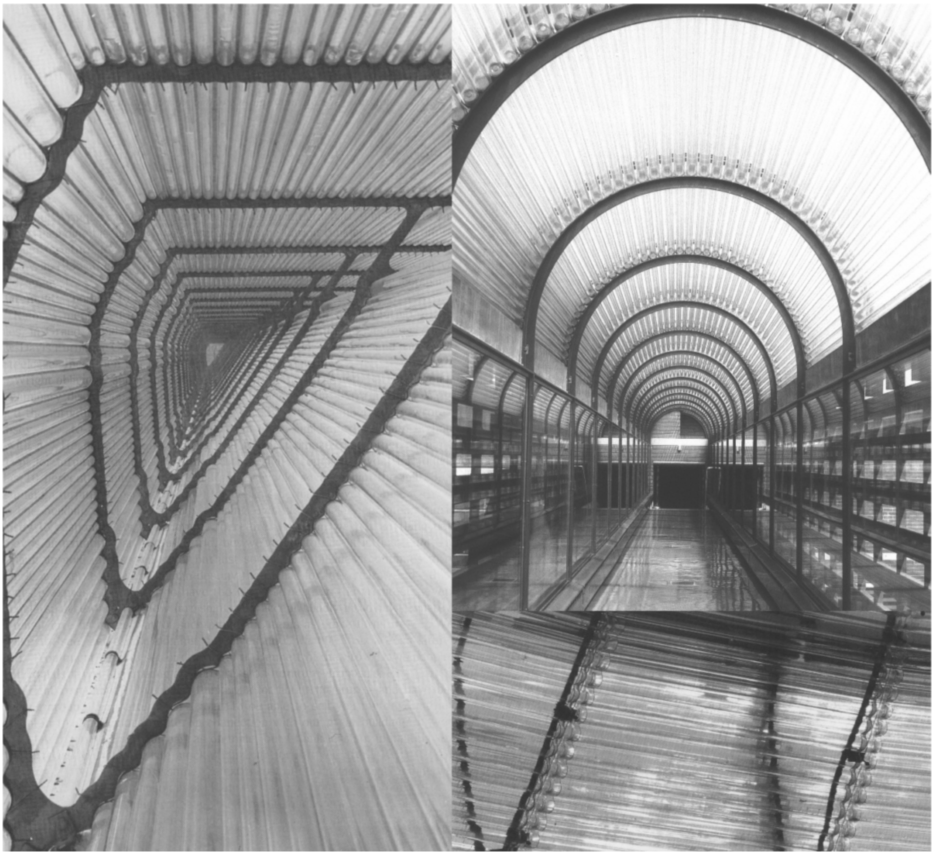

Figure 9. Left: two inner rows of Pyrex tubes in upper clerestory, wired to aluminium racks. (Lipman 2003, p. 69, fig. 74) Right: glazed bridge, (Weston 2003, p. 85). Below: the system of the pipes in Pyrex (Hertzberg 2004, p. 60).

Corning Glass by Corning (N.Y., U.S.A.) produces them using a formula of borosilicate glass improved under the *Pyrex*© trademark that, patented in 1915 by E.C. Sullivan and W.C. Taylor, has to be used for durable glass products; though at the time it was only used for kitchen products and for small sample tubes used in experimental applications typical of industrial cycles.

In the case of the Administration Building the Pyrex glass, because of its reduced expansivity, provided resistance to sudden changes in temperature, as well as to the corrosive action of atmospheric agents, adapting itself to the curvatures of the building in a component asset of alternating strips of light and shade with the joints. This was preferable compared to the flat screens that, for the technology available at that time, would have been more difficult to manipulate during the moulding and making process. Although in 1938 the government office assigned to Wright seven patents on the details of the Pyrex glass tubes, the particularity of the tubes represents an advanced technological application, implemented but not refined yet, especially in the joints of the clerestories tubes where the rainwaters which are not appropriately transported away, are channelled and flood the working areas. (fig. 10).

Figure 10. Workman caulking Pyrex tubing, skylight on roof Great Workroom. (Lipman 2003, p. 80, fig. 81)

This is also a curtain wall, a glass wall stretched on a frame with aluminium borders stabilized with dentil shaped elements, so that each engraving accommodates the glass tubes, tightened by a wire with a loop knot at 1 millimetre from the frame, on a length of over 1 meter, sealing the horizontal joint with a mastic of well known sealing capability produced by *Vulcanite*, as well as using tubes of a smaller size by the head joint. Furthermore, despite himself, Wright hides some *Lumiline* bulbs amongst the double layers of clerestory and lantern tubes, increasing the natural illumination with an artificial one.

It is during the administration period of the Company that the problems of a technology still not perfected are soon discovered: in particular, on the clerestories. Not only with regards to the above mentioned seepage of rain water, and for the hooking of the tube to the rack, but also for the maintenance of the artificial illumination system, forcing wires and bulbs to be replace, by using high and bulky machinery to dismantle the first layer of tubes. Before Wright died (1959), the higher tubes of the clerestories were replaced with an aluminium system in which flat modules in glass fibre were fitted in order to resolve the problem of seepage. As these interfered with the natural light, it forced the adaptation of the artificial system, with new lighting bodies; while adequately shaped acrylic material modules, especially in Plexiglas, replaced the lower tubes, copying the profile and using dark colouring to obtain the original shadow lines on the joints of the tubes.

It is in the Johnson Research Laboratory Tower, instead, that the use of Pyrex tubes had to be deepened. (fig. 11). The research system had the objective of creating a modern scientific laboratory for 75 chemists and 75 different laboratories with related extensions equivalent to a natural social model that, revising the *dendriform* column, takes shape inside a core tower. It reflects the *organicism* of a lymphatic system, where structure, form and function seem to coexist, arranged in a configuration more symbolic than functional in comparison to the laboratory typology. It recognised the creative and innovative business spirit of the Company and most of all of its research team, as well as the publicity purposes.

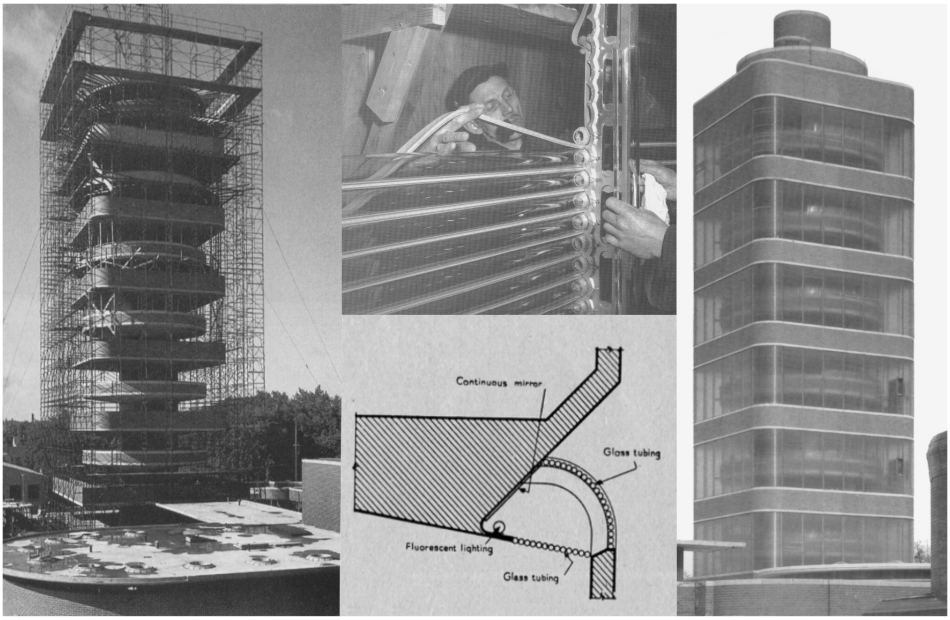

Figure 11. At the extremities, the Research Tower. Center. Above: workman installs Koroseal gasket. (Lipman 2003, pp. 129, 158, 154, fig. 123, 142, 139). Below: detail of Guggenheim Museum. (Wright 1959b, pp. 19-28)

Referring to the Japanese experience (1917-1922), which adopted a vertical and central rigid nucleus for the Imperial Hotel, Wright initially forecast eighteen floors for Johnson, then reduced it to fifteen for economic reasons. He saw an interwoven tower of 50 metres in height, with a central nucleus structure of about 18-20 centimetres, into which the overhanging floors interlock and extend for about 7 metres, so that the external casing can be completely relieved from the loads and it can be built in any light and thin material, instead of glass, as well as adopting a Cherokee-red brick covering that had already been used for the Administration Building, which acted as a formwork.

Although the structural calculations seem complex, as no guide could assimilate the cases common to the novelties represented by that building, the project does not reach the structural limits of the natural constructive principle adopted and of its technology.

Around the shaft floors made of alternating square elements of 144 m^2 overlap and extend beyond the circular ones of approximately 102 m^2. A luminous armour with a double wall of hollow glass tubes extends around the perimeter, for approximately 70% of the façade, in luminous contrast to the overhanging floors. Nothing new was involved in the approach, giving preference to experience, also by implementing the details of glass tubing originally planned for the Guggenheim Museum in New York – which is piled up vertically, as it seems to be the easiest configuration to be made watertight, more than the clerestories and lanterns of the Administration.

By the end of 1943, Wright had already found four possible glass tube systems: (fig. 12): 1°) In the first, a series of tubes would be accommodated inside an aluminium-perforated rack, similarly to the Administration Building. By adhering the superior and inferior border of each tube to the rack, the tubes would be separated by approximately 6 millimetres from each other by the perforated lodging. 2°) A more expensive system provided for tubes with two grooves of approximately 3 millimetres on opposite sides: in this way a metal sheet would seal the system, conveniently fitted between the grooves of adjoining tubes and screwed to the rack. Although this solution was soon abandoned. 3°) A single line of solid adjoining tubes of approximately 5 centimetres diameter, without any sealant, represented a further solution which also required a line of glass sheets hanging from the inside so as to make cleaning easier. Nevertheless this system was abandoned immediately because it was the most expensive, and also because of the dust that would reach the tubes and the condensation that would form, limiting cleaning and, therefore, reducing the grade of illumination required. 4°) On the other hand, the last solution provided for the replacement of solid tubes with hollow ones, in order to guarantee the lighting effect desired. This would be the chosen solution, by installing 28 000 meters of glass tubes to the rack with a wire fixed by a loop knot, similarly to the Administration Building. Once in place a flat glass module would be installed in front of the glass tubes.

As a sealant Corning Glass, with Wright’s approval, resorting to a single layer of Koroseal with an aerial cells structure, separated by a lining, waterproofed, easily mouldable by adhering it to the tube, both longitudinally and as a ring on the externally head joints. However the joint would be subjected to further polishing. In fact by becoming excessively distorted because of the weight of the overhanging tubes and by contracting on the glass surface, it became necessary to use plastic wedges to take the weight of the tubes. Furthermore having to adjust to the effective variability of the tubes diameter, the *Koroseal* forced refined measuring instruments to be used.

The practice of laboratory activities inside the Tower, on their own, would have immediately highlighted the limits of the innovative technology adopted. Subjected to the obvious greenhouse effect, it was necessary to adequately screen the sun's radiation coming through the full-length glass windows on the West side, in order to guarantee adequate working conditions. But amongst all the problems noticed, despite Wright's optimism, there were immediate seepages and leakages in the curtain wall, because of the splitting of the lining that expanded during the good season and contracted in winter. New flexible linings, with a synthetic rubber base, which in 1958 consisted of a rubber with a waterproof silicon composition, were immediately provided.

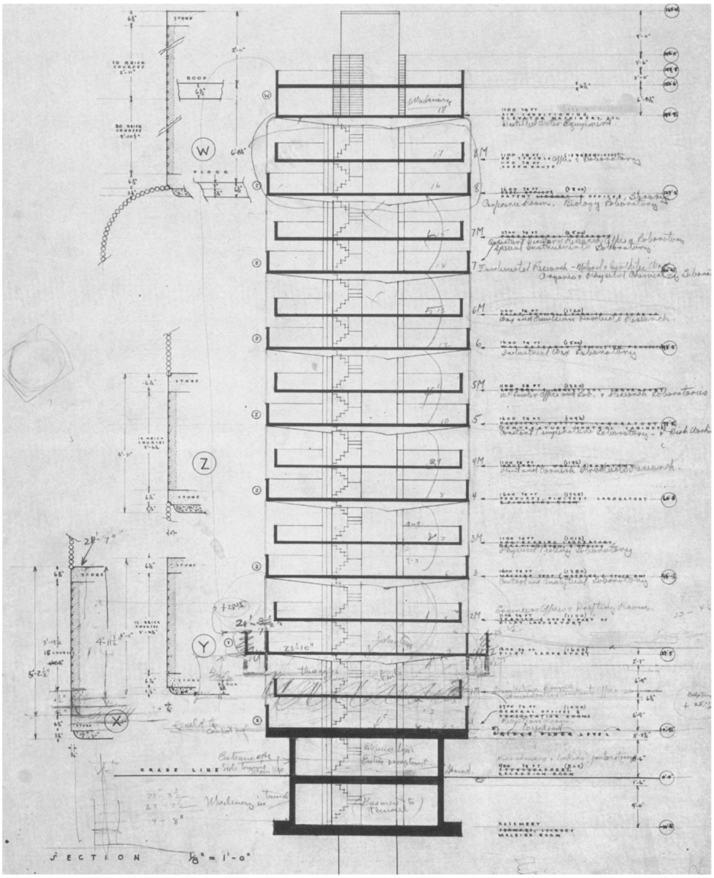

Figure 12. Preliminary section through the Research Tower, with detail sections.
(Lipman 2003, pp. 152, fig. 138)

2. Enginius Ingegneri Associati, Bridge on the river Tiber in Rome and Walkway at Via Lapi in Faenze, Italy, 1999-2003.

Since 1999, the Enginius Studio has been interested in the close examination of the bearing structure in glass giving the research and experimentation essential elements for an advanced project. With reference to the already presented project received for the contest for the new bridge on the river Tiber in Rome and the new walkway at Via Lapi in Faenze (fig. 13), the experimental calculated route evidenced the need to adapt to a highly advanced material to resolve problems of insertion and of contextual balancing, and of course in the conservation and preservation of the surroundings.

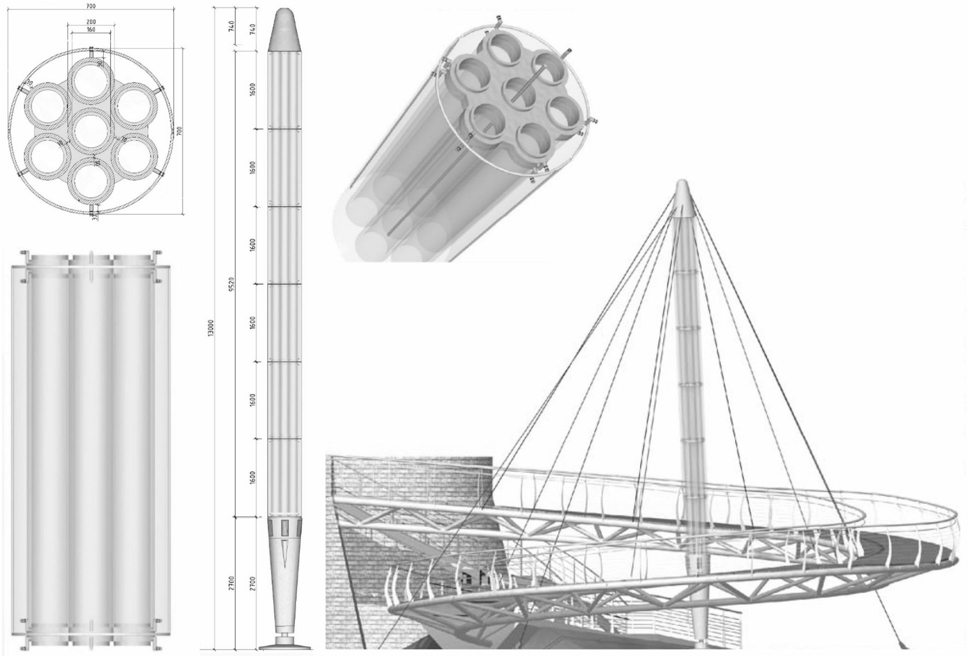

Figure 13. Enginius Ingegneri Associati, *Walkway at Via Lapi in Faenze*. (Designer: Marco Peroni)

Proceeding in the experimentation of these proposed materials, with reference to the examples of renowned design engineers who have shown advanced indications, interventions of great importance have been realized. The project for the pedestrian bridge, eventually suitable for vehicles, resorts to having only one main-stay arch on the inferior level with geometric and material characteristics – not only scenographical but also with an internal lighting system – useful for the parabolic conformation, which rests on the framework, consenting the glass structure, bearing in mind that the resulting compression of the loads must be distributed vertically. This allowed the elaboration of the particulars, distinguishing the causes of the dissymmetry of the arch and the varying agents on the framework which glass cannot support.

The accomplished arch didn't have just one glass tube but 68 cables composed of a double wall of curved tempered and stratified glass, which created an air chamber, between the two curved sheets, of 25 centimetres for the positioning of post-tension cables and radial stiffening ashlar, the whole realized in vertically ribbed stratified glass sheets.

Each ashlar is therefore the result of an assembly designed to transmit in a uniform manner the forces resulting from the stress compression of its sections. It deals with two semicircular elements, 60 millimetres wide, joined in the centre by two circular crowns placed at opposing ends, in addition to tight veins of radial cables corresponding to the rigid section – with the aim of balancing the flexions, and directing the resulting loads towards the resistant section – and with the backup of structural resin. The ashlars are connected to each other thanks to the above-mentioned rigid metal slabs, necessary to guarantee an adequate distribution of the tension. It is this design solution that determined the dimensions of the glass ashlars following structural verification of the materials, bearing in mind the proper attention needed in the production phase of the semi-ashlars, as well as the moulds and the kilns used.

Progress was made over the years using research that was available on the building market – elaborating on the idea and referring to the new walkway in Via Lapi in Faenze. It was possible because of the available technology of laminated glass tubes, through which a layer of PVB is attached. More over experimentation applied maximum compression and tension of 400 Newton/ square metres (400 kilogramme/square centimetre). The project forecasted the realization of a central pylon for the support of the forestays of a suspended helicoidal ramp. Dealing with a structural element that for its kind of restraints forecasted stress only under compression. It was foreseen that the realization was a glass structure. Even in this case it was known that one glass tube wasn't sufficient, and for reasons of instability it needed at least seven cylindrical tubes each of 200 millimetre in diameter, all of which were independent but collaborating through a steel connection put between them. It was necessary to transmit through the ashlars the tensions resulting from the cut deriving from the flexion caused by warping phenomena and partial breakage. This solution increased the safety coefficient of the whole system, allowing the consideration of a potential collapse of two out of seven of the planned tubes, even if it means the necessity of replacing the broken ashlars, and therefore the temporary closure of the structure for repairs.

3. Gose Stefan and Teuffel Patrick, *Tensegrity sculpture*, University Stuttgart, Glass technology live, Düsseldorf, Germany, 1996.

According to R. Buckminster Fuller (1895-1983), the Tensegrity (fig. 14) represents the innovative evolution of the glazing structural system. With a volume of a 5 metres cube, the system of bound tight and unbound compressed elements is built up with pretensioned steel cables of *Pfeifer Group* and with borosilicate glass tubes, 3-4 meters long, built by *Schott AG*.

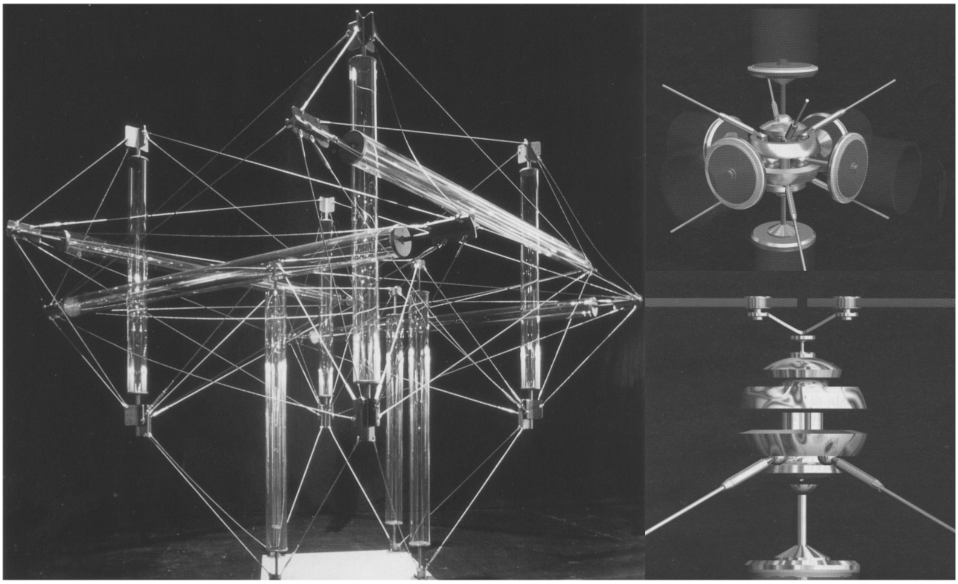

Figure 14. Left: Gose S. and Teuffel P., *Tensegrity sculpture*. (Behling 1999, pp. 116-117). Right: the connection patented by University of Florence. (Inzitari 2005, pp. 57-58)

From the design to calculation, through the dimensioning and the stabilizing of the system, the choice of glass as structural material conditions the applications of the Tensegrity, although the use of the principle derives from the brittle and undeformable characteristics of glass. As a matter of fact the glass breaks suddenly according to the stress capacity. After calculating the strengths and the deformations of glass and forecasting the reactions of the system, we measure the compressive high-strength – 1000 megaPascal – which does not limit the applications and the low resistance to tensile stress – 40 megaPascal about, that is conditioned by breaking. Besides the glass has reduced capacity of resistance to punctiform loads, so we can use only tempered glass.

So the Tensegrity uses glass tubes to bear up the compressive stress and bound steel cables to bear up the tensile strain. In assembling the first Tensegrity, we use glass tubes to measure – 12 tubes: four of the principle ring (135 millimetres outside diameter, 6 millimetres width, 3.50 meters long), and horizontal and vertical height (135 millimetres outside diameter, 6 millimetres width, 2.00 meters long) – and pretensioned cables at first put in the main ring and after in the horizontal and vertical tubes, they are bound with pretensioned cables. After binding the cables to the connections and the Tensegrity, we regulate the cable tensioners, so we obtain the resistant geometric configuration. Tensegrity is composed of modular elements made generally in workshop with milling machines CNC (computer numerical control). This structure is easily transportable and has great stability owing to the geometrical array (expressed with elaborate algorithms) and to the transfer of the action to the connections, with a system of assembly, characterized by versatility, image and by the chosen technique and the technological procedure of the working process.

Now we analyze the connection. The connection is marked out by experimental requirements and must be shaped for some movements. Owing to the imposed loads, the continuity among the members could cause cutting actions and bending moments. So we use the ball joint that reduces the actions on the members only to normal force, allowing the rotation around the axis of the components of the frame, of either the compressed tubes and the pretensioned cables, or both. This ball joint is comparable to a space rolling bearing, without caulk weld, but with one bolt. The connection is made with two equal rings shaped a frustum of cone placed symmetrically on the central hinge bolt. These rings act as self-centering fifth wheel, supporting the hinge bolt, with two symmetric equal elements, put on and under the previous rings, with special elements. So we can shape the cap, putting a self-centering fifth wheel and the necessary members, without contrasting the rotation and the connection with the skin. In this way the forces on each member are directed towards the central axis of hinge bolt, without any eccentricity.

The prototype in aluminium is a simple system of joint, compatible with the building. Up to day, the production and the building use of Tensegrity consider the structural feasibility – studied in Italy by Mechanical and Industrial Technologic Department in the University of Florence – and high costs of production.

As we have said before, we can point out the logic of an architectonic method of the material, which is over the stress analysis, guaranteeing the continuous redevelopment of the research of these architectures of the detail, aiming to the final result.

We point out the structural and technical capacities of the material, using the information know-how and the industrial design, with a craft method, without standardizing the production, but moulding the structural components which are the symbols of the architectural configuration.
The final result is a work of vanguard which interest the conservation of the building property, adapting the project to the instability and to the space-time fragmentation. With this process we can face the material respectful interventions. We find this process in the project of *Schloss Juval* (Robert Danz, South Tyrol, 1996) (fig. 15).

We think this approach useful in order to understand this technological method to reach the finding consistent with the conservation.

Figure 15. Danz R., *Schloss Juval*, South Tyrol, 1996. (Schittich 2000, pp. 298-299)

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