The Phillips Pavilion 1958 - Iannis Xenakis and Le Corbusier

Audio-Visual Fabrication Of A Space In Architecture

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Abstract:

The Phillips pavilion may be a unexpected flash in design and a stimulating story that ought to not be forgotten. The layout of the pavilion with its hyperbolic paraboloid shells was vibrant. Xenakis collaborated on sophisticated short-lived sunlight and sound event architectures. What's special to Xenakis is that his technique has transmitted shapes in countless areas from engineering to music, from art to architecture and social activities from one sector to another. This experience of working at a moment and implementing identical buildings in various areas has opened up the technique for following the transfer of mathematical-scientific structure into practice (partially backed by the universal pc tool). In this sense Xenakis pleads for a "General Morphology" case, a quest for the knowledge of the kind and its generation. The' material' fine arts works of Xenakis can be seen in continuity with its music and light architectures.

Keywords: Hybrid space, media art, acoustics, music, sound, experience, remark, interior, audio-visual

1. The story behind the pavilion

When Philips electronics requested Le Corbusier for the pavilion's initial commission at Expo 1958 (World Fair) held in Brussels, Belgium.
"I won't make you a pavilion, I'll make you a poème électronique and a vessel containing the parts of the poem: first light, second color, third image, fourth rhythm and fifth sound — rejoined into a comprehensible synthesis for the public, demonstrating the possibilities of Philips' products." Le Corbusier answered, "while in India on a lengthy journey to Chandigarh, I shall create a compilation for the audience that demonstrates the opportunities of Philips ' goods." The complete display is to be executed automatically via a complicated control system which switches on and off video projectors and speakers caused by the overall score. Thus the first multimedia architecture in the emerging electronic age was realized, and was, among other things, one of Le Corbusier's most remarkable' poetic objects.' (Giovannardi, 2015)

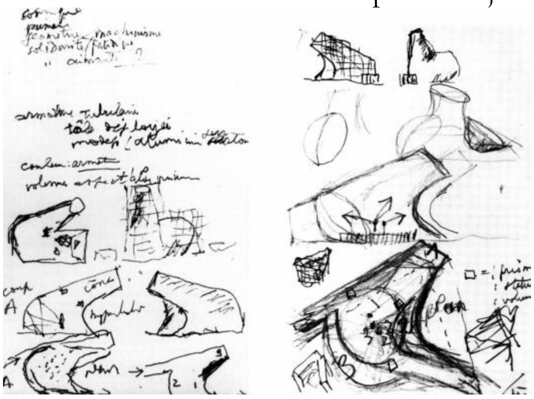


Figure 1 Le Corbusier, design sketches for the Philips Pavilion, September–October, 1956 (# 2012 Artists Rights Society (ARS), New York / ADAGP, Paris / FLC).

Le Corbusier, son of a musician and brother to a composer, showed little delight in the selection of Philips and completely opposed Britten's participation. He requested that the Philips Pavilion be the primary layout arbiter and urged composer Edgard Varèse to take up the music. The notion of use Varèse was nevertheless not received with excitement and twice in October 1956 and again in December 1957, Kalff (Philips Consultant and Architect) attempted to exclude him from the project and substitute him with a more traditional composer such as Henk Tomasi, ordered to compose an alternative work' in the reserve.' Kalff did not make a sign of his worry, justified by the reality that Varèse was not well recognized, and that his music, regarded by many as a "sound cacophony," did not satisfy the present public taste. Le Corbusier was stubborn and victorious and won the argument. (Xenakis I. , 1959)

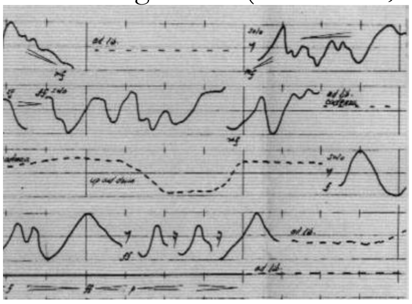


Figure 2 E. Varèse: drawings for the realization of the Poème électronique

2. The architecture / Space

The sketch given to Xenakis showed something shaped like the stomach of a cow, with an entrance and an exit, and an interior that had to hold at least 400/500 people and all the equipment for video, lights and sound. (Clarke, 2012)

"According to Le Corbusier, the building had to be a 'bottle' containing the 'nectar of the show and the music'." Xenakis

More specifically, to realize the projections, Le Corbusier wanted flat, vertical surfaces; for the spatial effects, he wanted the top of the neck of a bottle that would 'lose' the projected images; for the associated color effects, however, he wanted concave and convex surfaces. For the rear of the pavilion, he asked for a simple convex surface that would not overly affect the view of the gardens and lawns surrounding the buildings. (Clarke, 2012)

The Exterior // Interior Architectural Considerations

The original architectural concept of Le Corbusier coincides with his understanding of the Pavilion as a container for this show. At first he proposed that the interior was nothing more than a cover, a complete negation of architectural shape, potentially a textile layer such as his 1937 Pavilion des Temps Nouveaux. He quickly left this concept, which would provide insufficient acoustic separation, and instead suggested a curved scheme intended to effectively perform crowds of individuals in and out, as in the abdomen (Fig. 3).

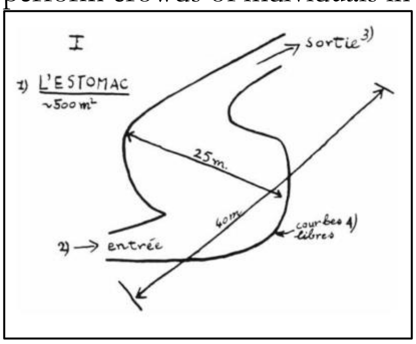


Figure 3 I. Xenakis drawing of Le Corbusier's 'stomach plan: originally published in Philip Technical Review, 20: (1958/1959); (courtes Philips Electronics).

Visitors were to be ingested, forcefully churned and decomposed by the Poeme's digestive enzy me, and excreted back to the fairground. His early drawings illustrate a vaguely organic, free-form structure with convex walls and a cylindrical protrusion. (Hamburger, 1985)

This system would have achieved the stomach plan's official intention, if Le Corbusier had enough time to create it. It appears that Le Corbusier was prepared to give his colleague the artistic direction due to the distinctive experiential disconnection between the pavilion interior and exterior, one of its only totally opaque buildings. From outside, the curved forms of Xenakis would give no hint of what lay inside, while the darkened interior would not allow a clear view of the shape of the building illuminated by Corbusier's projections alone.

The original sketches of the two architects for the pavilion show different types of architectural thinking. Hyperbolic paraboloids had more acoustical significance than the original idea of Le Corbusier for a completely convex envelope, which had concentrated sounds instead of spatially spreading them, but the structure is hardly functionally oriented. The method of Xenakis would be more accurate to look at as a predecessor to the present parametric design: the composer adopted the stomach plan as a pre-determined limit, established an architectural grammar of controlled surroundings and then iteratively configured the shape with structural, acoustic and esthetic criteria.

a. The first design:

The pavilion's floor plan was simply set out, guided by the demands of the "Electronic Poem." Each demonstration lasted between 8 and 10 minutes and was witnessed by some 600 or 700 people evenly agitated over the entire pavilion floor area. A more or less circular scheme with an area of 400 to 500 m2 and two broad spots as entry and exit canals was therefore required. (Xenakis I. , 1959)

To generate different wonderful impacts, color changes locally, changes of light and shade, etc., in the projection of images or color maps on the walls; or portion of them at least; they must have bent surfaces to obtain the light from divergent perspectives. Even the uniformity of the curvature discovered in the spherical and cylindrical vaults must be prevented. This resulted to the concept that there were surfaces with distinct curvature radii. These surfaces are also appropriate for acoustic requirements. To allow full flexibility to create with the help of loud speakers a range of unique impressions. The objective was to prevent uncontrolled acoustic inputs because of wall waves which are heard either as isolated echoes or as reverberations, as far as feasible. It is recognized that in this regard parallel lead is hazardous due to repeated reflection; sections of the spherical surfaces are similarly inadequate, as they may lead to localized echoes. (Sterken, 2004)

Xenakis transformed his ideas into surfaces with very different radii of curvature, which obviously caused Xenakis to consider saddle surfaces and especially the restricted surfaces in this category. The architect knew about simple controlled surfaces, such as the hyper-bolic paraboloid and the conoid, through the work of Laffaille and other pioneers in this field. The conoid is achieved by allowing a straight line (a generator) to move along two non-intersecting rows, one a Straight line and the other an arbitrary curve, to keep it parallel to that plane.

The pavilion of Philips offered to the architect a special opportunity to construct a structure entirely from these ruled surfaces and to build a homogenous 3-dimensional envelope that would allow the three dimensions to play an autonomous role as opposed to conventional architecture, which usually still manifests the form of the ground plane in all parts of the building.

However, the elaboration of this new architectural concept was generally a method incorporating creative curiosity and a sense of shape rather than a matter of logic. The series of illustrations, Table 1, enable the architect to demonstrate his initial layout.

This layout (Fig. 12) has a conoid E, a flooring composed principally of two conoids F and D, two hyperbolic paraboloids K and G, a cono L connection and two open triangles as entry and exit. The two peaks from the oblique straight rows from one channel (Fig. 8, Table 1) are counterbalanced by a third peak projected above the channel.

Fig. 13 demonstrates the first construction template, the ribs in which the layers are crossed. The spokes of flat wire form in this model, and the curved ends are placed in a concrete foundation. The surfaces are made by stretching strings between the ribs. (Xenakis I. , 2003)

Figs. 4-6: Development of the ground-plan.

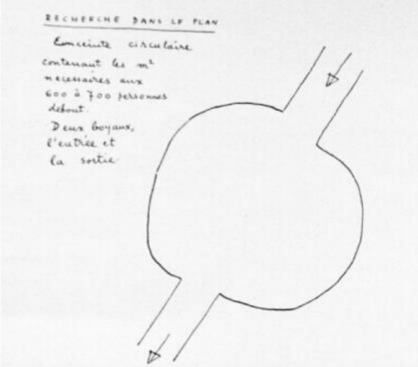


Figure 4 Circular space with two "spouts" as entrance and exit channels.

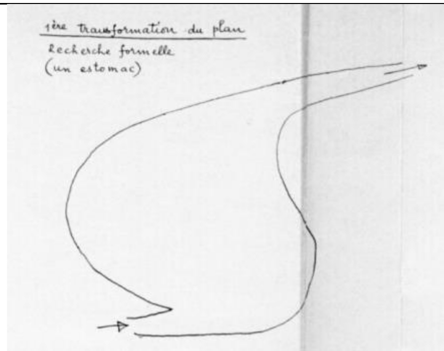


Figure 5 Further development of the plan form: partly from its shape and partly because of its function, the architect refers to it succinctly as "L'estomac"'.

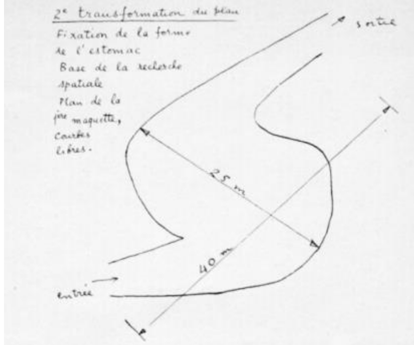


Figure 6 The ground-plan forming the basis of the first design.

Figs. 7-12: Stages in the development of the first design.

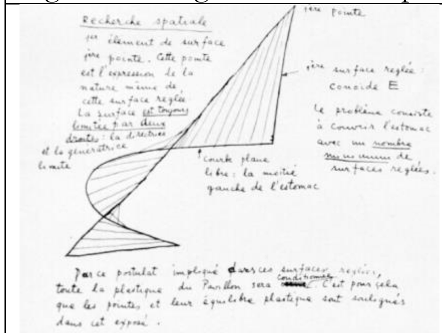


Figure 7 Ground profile of the left half of the "stomach. The intention was to build over the ground-plan a shell composed of as few ruled surfaces as possible. A conoid (E) is constructed through the ground profile curve: this wall is bounded by two straight lines. The straight directrix (rising from the left extremity of the ground profile) and the outermost ruling line (passing through the right extremity of the ground profile). This produces the first "peak"' of the pavilion.

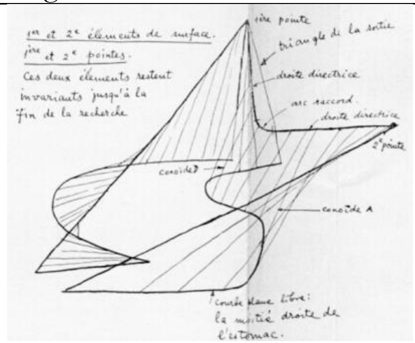


Figure 8 A ruled surface. but consisting of two conoids, A and D, is also laid through the curve bounding the right half of the "stomach". The straight directrix of D passes through the first peak. and the outermost ruling line at this side forms with that of F a triangular exit. The straight directrix of A passes through a second peak and is joined by an area to that of D.
This basic form is that used in the first design and was retained, with some modifications, in the final structure. The main problem of the design was to establish an aesthetic balance between the two peaks.

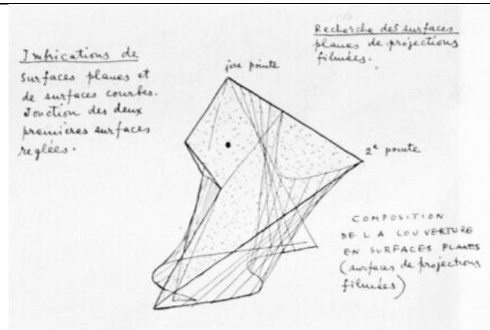


Figure 9 Attempt to close the space between the two ruled surfaces of the first design by flat surfaces (which might serve as projection walls).

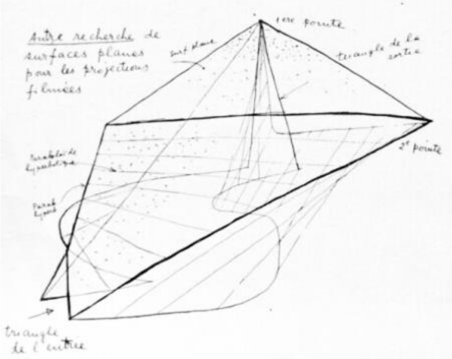
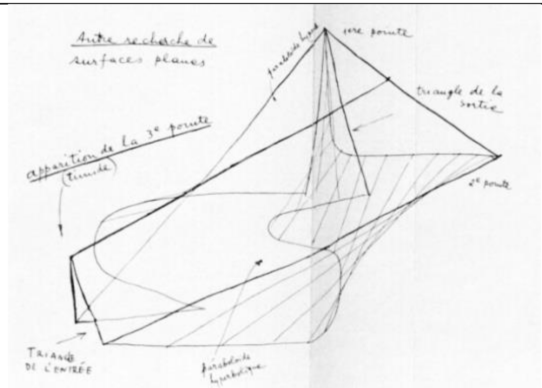
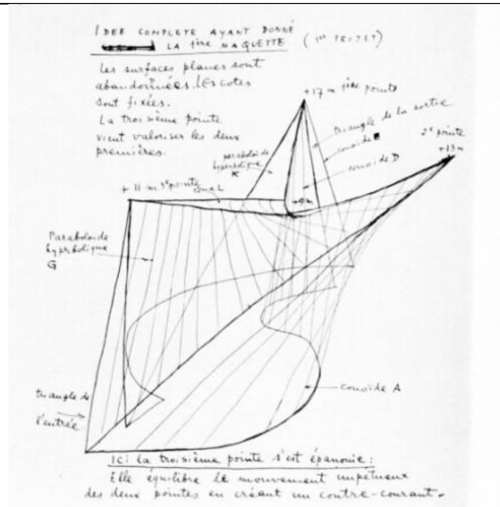
 *Figure 10 Another attempt. Above the entrance channel a small triangular opening is formed, flanked by two hyperbolic paraboloids (later denoted by G and A). and the whole is covered with a horizontal top surface.*	 *Figure 11 Elaboration of fig. 10. The third peak begins tentatively to take shape.*	 *Figure 12 The first design completed (see also the first: model. fig. 13). There are no longer any flat surfaces. The third peak is fully developed and creates, with its opposing sweep. a counterbalance for the first: two peaks. The heights of the three peaks have been established. The third peak and the small are connecting the straight directrixes of conoids A and D (see fig. 8) form, respectively. the apex and the base of a part of a cone L.*

Table 1 Design Process of attempt 1

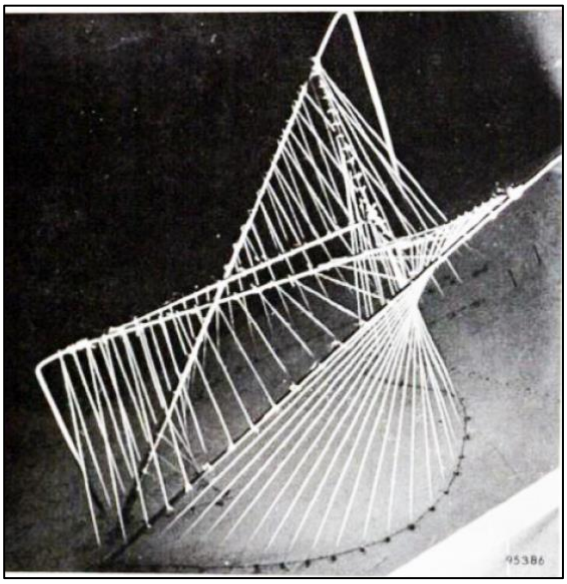


Figure 13 The first model. The "stomach" is set out on the base of the model; the strings indicate the ruled surfaces. The intersections of the ruled surfaces are represented by spokes of piano wire. Their bent-over ends have no structural significance. (photo: Lucien Herve)

b. The second design

At this point, the architects were advised on the building scheme by technicians of a Parisian contractors ' company.

Philips had specified a wall weight of 120 kg / m2 for sound insulation (concrete or cement, about 3 cm thick). The consulting engineers therefore considered that the pavilion must be constructed on a fairly heavy metal skeleton according to the wire spokes In the model with supporting tubular trenches corresponding to the vertical curved wires of the model. A The pavilion could not be built in the form of a tent, either with metal reinforced "canvas".

This advice was accepted by Le Corbusier and Xenakis, especially since they themselves felt that the first design had certain aesthetic weaknesses which in any case called for modification.

Xenakis started to experimentally convert the surfaces. His technique was easy. The strings created the ruling line of a hypar, the Geometry of which was determined by the range between the spokes, followed by a structure of elastic strings placed at equidistant places on each spokes. The location of the hypar relative to floor level is determined by other factors. In selecting each of the pavilion panels, the architect had to continue by test and mistake, concurrently changing all the above parameters; he instantly placed it down on paper as a orthogonal projection when he discovered a suitable shape for a particular surface.
For this purpose, it is sufficient to show horizontal and vertical projected positions of the two spokes and of two pairs of corresponding points on them (for example, end points of both outer edge strings on the spokes: see figs 14 and 15). All corresponding pairs of points are fixed, each pair defining the ruling line. This intersection can be part of a hyperbola or a parabola, or it can be straight lines, or in a special case, it can be a single point, if one of the spokes is below the horizontal plane. There are also some hypar shells in the model, which do not touch the floor on the portion of the surface employed.

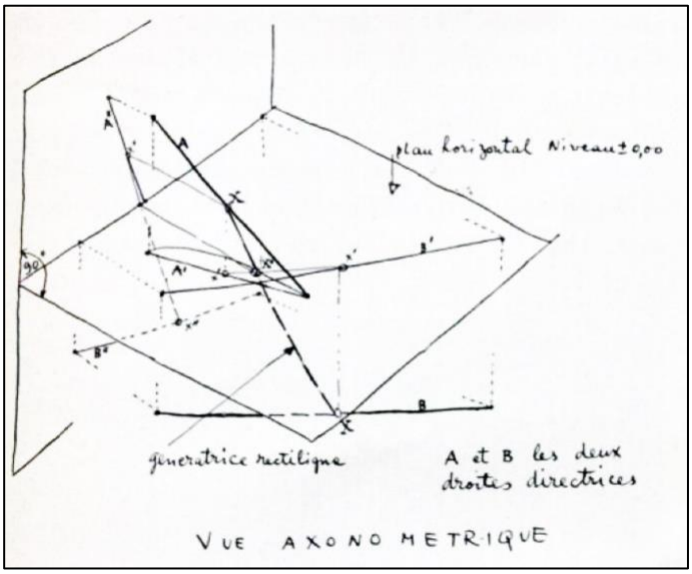


Figure 14 Isometric drawing to indicate how the orthogonal projection (fig. 15) of a hyperbolic paraboloid may be constructed. The two directrixes A, B are projected on to a horizontal plane (A', B') and on to a vertical plane (A", B"); two pairs of points, the end points of 4 and B, and their corresponding projections are shown.

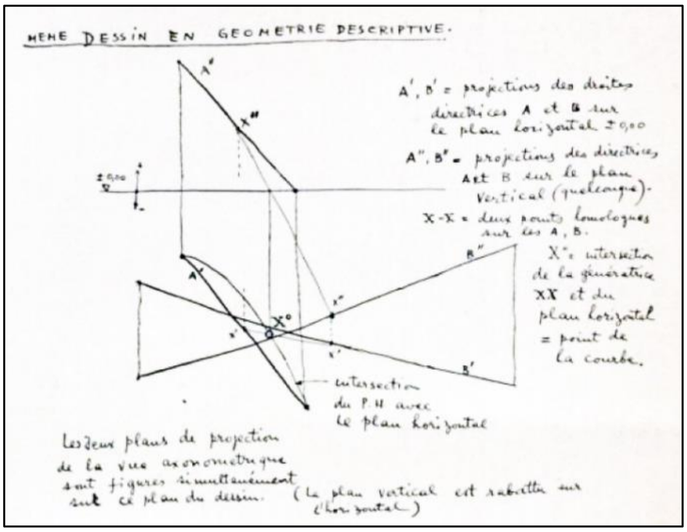


Figure 15 Horizontal and vertical projections of the directrixes of a hyperbolic paraboloid from fig. 12. Also shown are the projections X'X' and X"X" of an arbitrary generator line connecting two corresponding points X, X on the directrixes. This generator passes through the horizontal plane at point X°.

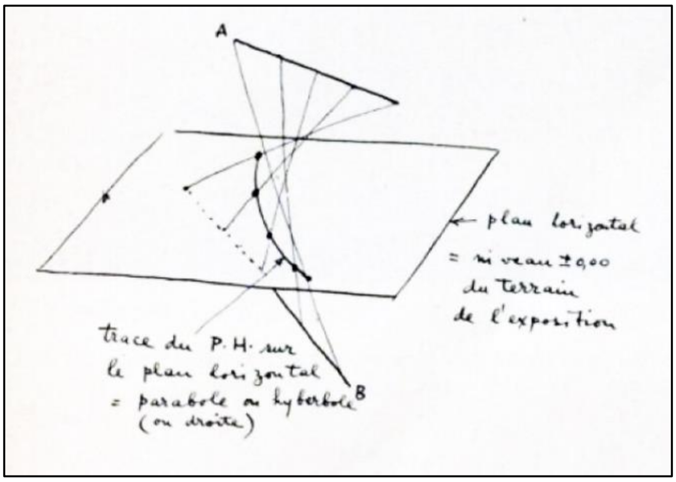


Figure 16 The intersection of a hyperbolic paraboloid with the horizontal plane is constructed from the points at which a

The first stage in revising the initial layout was to alter the stance on the three summits so that harmonious ratios could be obtained. It was necessary to emphasize the difference between the first peak and the third peak, and the central cone L widened.

The architect now fixes the high peaks at 21 m, 13 m and 18 m, and then proceeds to experiment alternatively with the model of spokes and strings and draw on found surfaces to establish the hyperbolic parabolic surfaces, both giving an esthetically satisfactory shape and providing crossings with the ground level that were as close to the original as possible.

Comparing the second with the first design, we see that the hypars G and K (which form the most important surfaces for the projection of pictures) have been retained, but the cone L has been widened and the conoids A, E and D changed into five hypars A, E and B, N, D. In addition, two new hypars C and F appear. Surface F, which abuts on FE, provides the necessary space for certain installations (air-conditioning plant, toilets, control room) and for the extensive equipment needed for automatically performing, several times an hour, the spectacle of light and sound.

c. Final modifications

At this point, most contracting companies approached by Philips had only more or less standard building systems to suggest, clearly out of accordance with the innovative style of the building. Double walled shells with a complete thickness of 80 cm were proposed with relatively complicated skeleton constructions in timber, metal, or plaster. The only proposal which was really consistent with the intentions of the architect and at the same time reasonable in price was made by the Belgian contracting company "N.V. Strabed, led by "Dr. H.C. H.C. Duvster." Mr. Duyster planned to construct the pavilion as a shell framework with 5 cm thick pre-stressed concrete, which would be completely self-supporting.

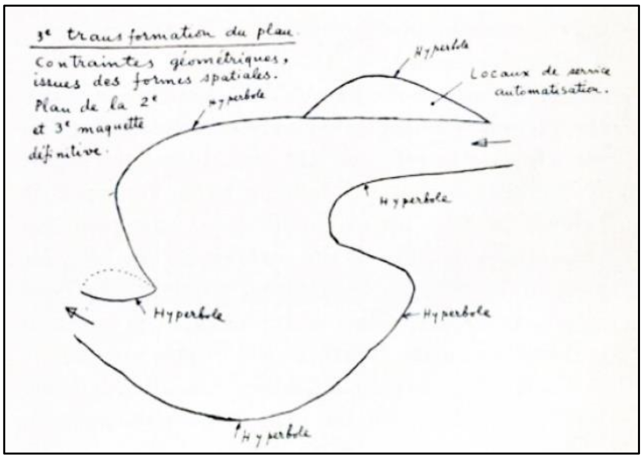


Figure 17 Revised ground-plan for the second (and definitive) design. The bounding curves are now composed of parts of hyperbolae (for practical reasons the entrance and exit were interchanged with respect to the first design)

Finally another change was chosen, which was of the greatest significance for the general architectural impact, although a minor one had an impact on the intensity of the building. The structure still provided for supporting stanchions, one of which was indeed in the enclosed space and was thus a nuisance. The architect Xenakis now proposed a slight modification in the new Hypar M and B to allow the stanchions to be completely dispensed. The reasoning was that the edge members (ribs) at the corresponding shell crossing should be able to take over the support function of the stanchions at least to a large extent.

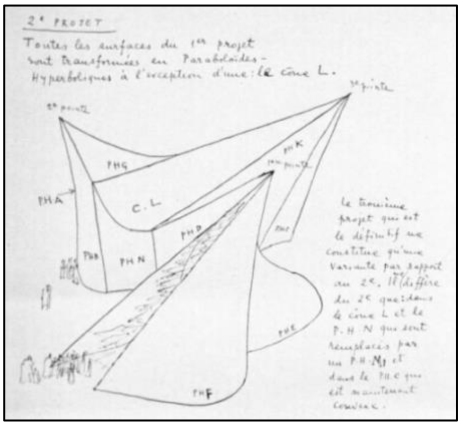


Figure 18 The second design. All surfaces of the first design. except cone LE, have now been converted into hyperbolic paraboloids, and two new hyperbolic paraboloids (F and G) have been introduced. Compared with fig. 12 in Table 1, the design is seen here from the opposite side as can be seen from cone L the apex of which appears top right in this sketch. The first peak is here in the foreground.

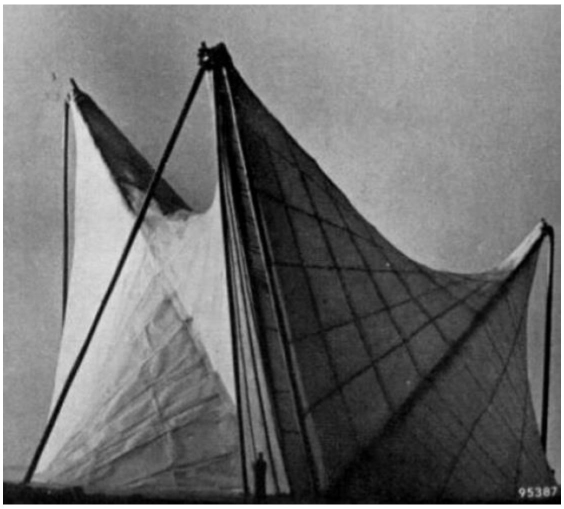


Figure 19 Second model, seen from the side which now forms the entrance; the third peak is in the foreground.

The model experiments verified that the stanchions were superfluous in the layout. The building was thus created totally self-supporting, i.e. there were no longer sustaining components embedded in the wall surfaces. The hypar C has been produced upright instead of concave, to enhance the third peak, which curves at a very close angle, and the two rectangular holes have been partially closing with additional links to the current one. Thus, as demonstrated in the plans of Fig.20, was the final structure of the pavilion.

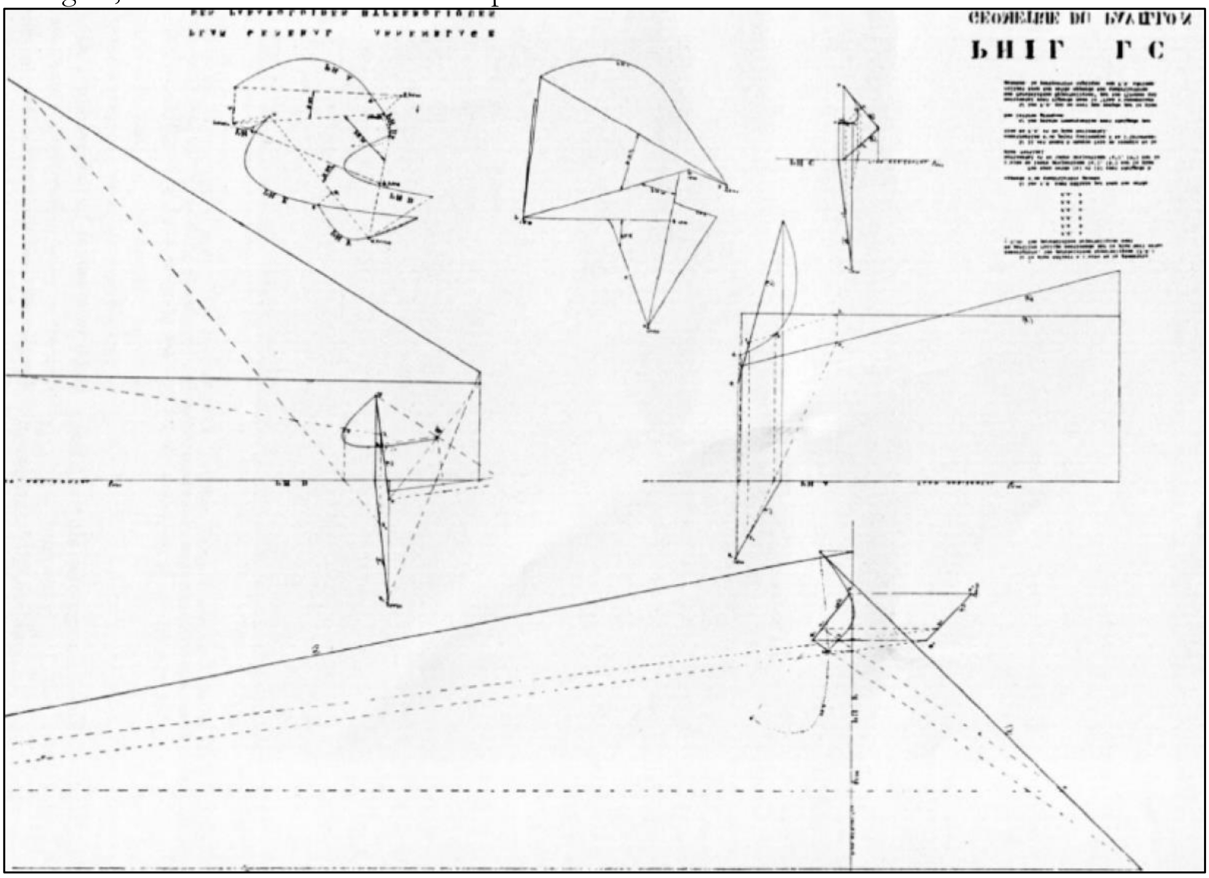


Figure 20 Part of the scale drawing 1: 200 of the wall surfaces of the definitive design, signed by the architects Le Corbusier and Xenakis.

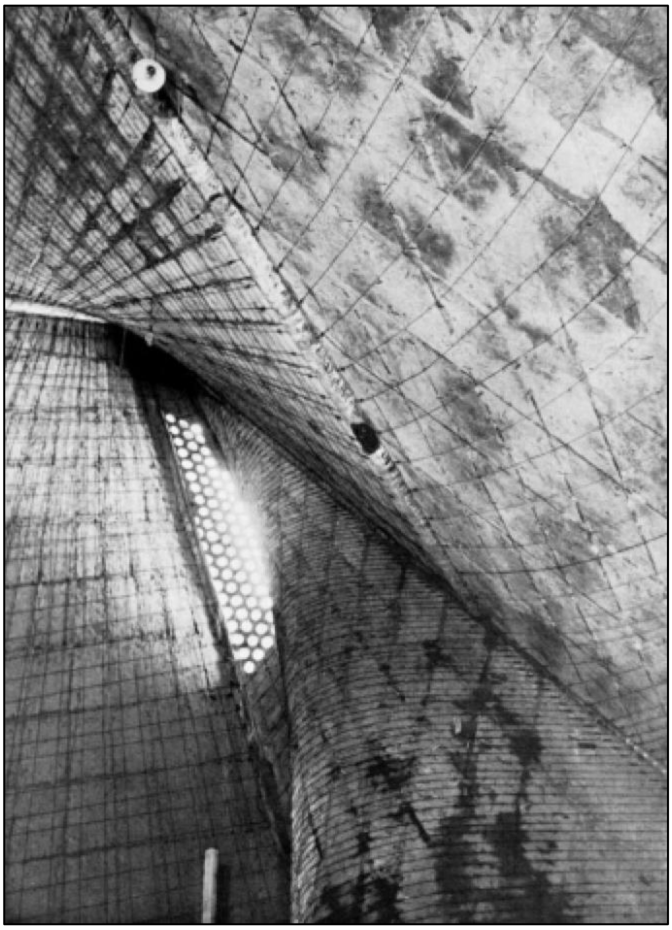


Figure 21 Photograph of part of the interior of the pavilion. The pre-stressing wires on the concrete, which enhance the plastic form of the structure, are unfortunately concealed in the finished pavilion by a surfacing required for the projection of colors and pictures.

The Concept Of "Non-Directed Linearity" Explained

Subverting a formal reading of the Pavilion as a generator reflects the continued interest of Xenakis in complicated, abstract types that can reorganize first principles such as reasoning and likelihood, requirement, continuity and fragmentation into potent experience catalysts. (Xenakis I. , La musique stochastique: Elements sur les procedes probabilistes de composition musicale', Revue d'Esthetique, 1992) Never to withdraw from grandiloquence did he write about the project retrospectively: "Architecture hasn't been a spatial volumetric phenomenon since old times. It is focused mainly on two aspects…. Only a simultaneous conversion in the direction of the plumb line reaches the third aspect." (Xenakis I. , The Philips Pavilion at the Dawn of a New Architecture, 1971) In his mind, he imputed the extrusion into three dimensions of an architectural design— a procedure which he imputed to all pre-Philips Pavilion structures.

It reflects an excessively causal creative model. The architectural perspectives of Xenakis matched with his musical experiment. In 1955, he published a controversial paper in Gravesaner Blatter's experimental music journal, accusing modern twelve-tone or serial artists of excessively' linear' thinking. Even if all the music is observed along a temporary axis, he wrote, it should be feasible to conceive it diachronically as a continuation of natural occurrences and, simultaneously, synchronously as surfaces or masses, by linear or statistical activities, to shape complicated musical processes. (Xenakis I. , La crise de la musique serielle, 1955) Much of this job was graphically developed in a two-dimensional Cartesian settings. The famous illustration of the recent measurements (that makes the y-axis pitch and the x-axis time pitch) shows concurrent sliding glissandi or soft drawings, as row sections that jointly form curved webs (Fig.

22). In his latter papers, Xenakis defined the Pavilion's planning method as a kind of conversion of music into architecture, boasting that the two arts are "intimately linked." (Xenakis I. , Formalized Music) Although this claim was often referred to as the obvious similarity between the graph of the metastasis and the shape of the pavilion, the similarity is not to be overemphasized. Although the curved diagram was an important step in Xenakis ' work, elsewhere, he maintained that the quinines of music was not just the material that was used to conceive or produce music but the sound of the performance. A normal characteristic of the Expo 58-style architecture were ruled surfaces, which had been in place for centuries in European houses. Xenakis explicitly acknowledges the use of engineer Bernard Lafaille in Philips pavilion. (I., 1957)If there is an "intimate relationship" between Metastases and it, it resides more in their manner of defining idea and development, by using geometry to shape progression and simultaneity relationships, than in a specific visual vocabulary.

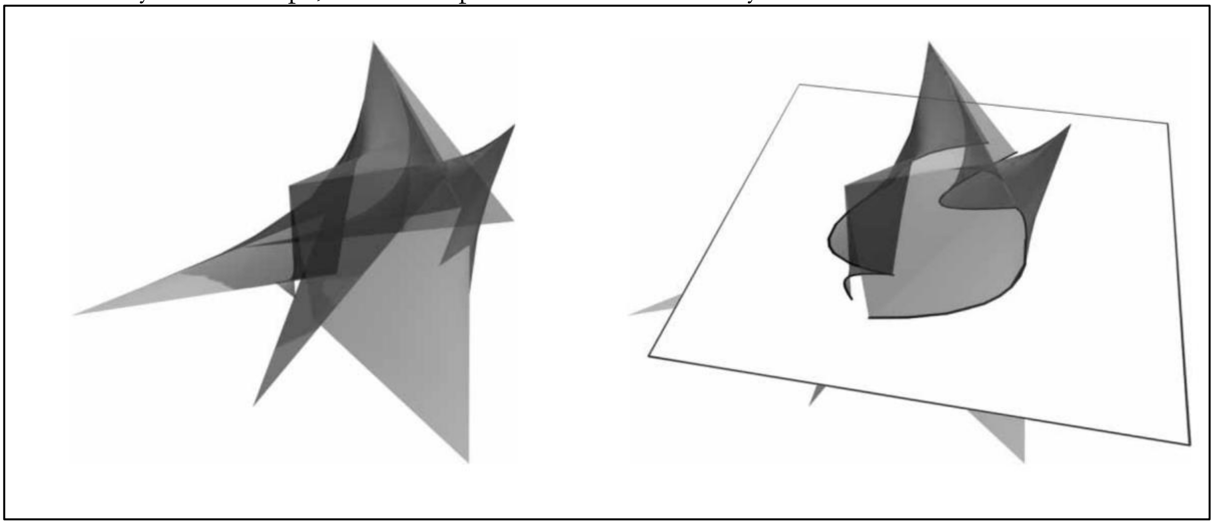


Figure 22 'Stomach' plan produced by intersection with ground plane (© 2012 Joseph Clarke).

Le Corbusier's citation of musical structure as a model for the time-dependence of architecture was naïf by the standards of twentieth-century composition, however. Just as he was looking to music as a figure of 'successive' aesthetic experience, experimental composers were starting to critique directed linearity by proposing various 'specializations' of musical form. Eighteenth- and nineteenth-century Western music had generally followed what might be termed a narrative temporal schema in which a work began with the introduction of sonic ideas which were gradually developed and, in the end, resolved; it thus not only occupied time, but also used internal melodic and harmonic progressions to portray directed temporal experience. (Langer, 1953) During the first half of the twentieth century, new compositional structures began to emerge in which musical events did not 'follow from' earlier ones in a causal succession. (Kramer, The Time of Music: New Meanings, New Temporalities, New Listening Strategies, 1988) In the 1960s, Gyorgy Ligeti looked back on Anton Webern's compositions as having 'brought about the projection of the time flow into an imaginary space by means of the interchangeability of temporal directions provoked by the constant reciprocity of the motivic shapes and their retrogrades'. In Ligeti's account, Webern's musical structures do not proceed in linear fashion from beginning to end, but rather 'circle continuously in their illusory space'. (Ligeti, 1965) Xenakis's compositions owe much to this tradition of experimentation. In the first and last sections of Metastases, the contiguity that links one instant to the next lacks the causality of a classical progression, in which movement is implied by the setting-up of expectations which are then either fulfilled or subverted (the middle part is composed in an older serial idiom which he would soon abandon). Metastases is not nonlinear, and its temporal unfolding may even be an harmonic process on some level, (Squibbs, 2011) but it exhibits what the music theorist Jonathan Kramer calls 'non-directed linearity'. This kind of music 'carries us along its continuum, but we do not really know where we are going in each phrase or section until we get there'. (Kramer, J. Kramer explicitly assigns Xenakis's Syrmos, 1959) In the light of Xenakis's musical research into time and perception, the Pavilion's disruption of the promenade architectural as Le Corbusier had theorized it is especially significant. Its smooth surfaces refused to cohere for the moving observer into discrete snapshots which might suggest a clear architectural progression. Xenakis intended for the building to overwhelm the body's conventional methods of apprehending architecture: Plastic materials of the future will shape the fertile river of forms and volumes that are concealed not only in biological beings, but above all, within the most abstract mathematics. The referential system for the human body will no longer be the right angle and flat surfaces that are horizontal and vertical. Its sensibility will be shaped by curved surfaces. From the psycho-physiological point of view, this is a new and enormous enrichment, with yet unforeseeable consequences. When someone is in the Philips Pavilion, he doesn't consider its geometry, but succumbs to the influence of its curves. (Xenakis I. , The Philips Pavilion at the Dawn of a New Architecture, 1971) Architects and landscape designers had begun to pay special attention to the optical effects of movement sequences in the middle of the eighteenth century. In French aesthetic theory, such effects were often conceived in relation to the aesthetic category of le picturesque. Jan Kenneth Birksted writes that while the picturesque of eighteenth-century English gardens was backward-looking, typically featuring classical allusions and nostalgic ruins, the distinct French concept of picturesque was more often invoked to celebrate urban modernity, emphasizing 'radical change, innovation, and progress'. (Birksted, 2009) Le Corbusier embraced this tradition while insisting that the coherence provided by a stable plan was essential to preventing 'that sensation, unbearable to man, of formlessness, of something mean, disordered, arbitrary'. (Courbsier) In the Philips Pavilion, plan and three-dimensional geometry were locked in an un-decidable relationship; its critical operation was to discipline the phenomenal 'formlessness' of shifting optical impressions not with a generating plan but through the formal economy of repeating a single surface in nine variations.

Model Tests For Proving The Construction Of The Pavilion

The purpose was to determine the stresses in the ribs and in the shells, in order to determine the required dimensions and the magnitude of pre-stressing to be applied, and to verify the stability of the construction. At first the tests were carried out on a complete model (Model 1) in sheets coated with plaster, which simulated a monolithic structure, then, in front of the intention of the Strabed to use shells composed of prefabricated slabs assembled in work and kept together by pre-stressing on the inner side, the other tests were carried out on a model of a part made of wood plates (Model 2). (BOUMA & Ligtenberg, 1959)

<u>Model 1</u>
1:25 scale model in iron pipes, cloth and plaster.
T.N.O Institute in Rijswijk - Netherlands
Technical Manager: ing. A.L. Bouma
January 1957
Thickness of the plaster walls: 2.1 mm
Ribbed steel pipes of diameter 8.4 mm and 0.7 mm thick.

The behavior of the walls of plaster on fabric, is similar to concrete and behaves elastically according to Hooke's law. The measurement of the deformations may be interpreted as a good approximation proportional to the effort.

The tests for the application of loads have required the construction of a mechanism very complicated and have considered, in the most unfavorable combinations, the actions of:
1) Effect of own dead weight
2) Snow load on a single surface, including those closest to the horizontal
3) Wind on different surfaces separately

The measurements of the vertical and horizontal movements were made with 4 deflectometers with an accuracy of 0.01mm; while those of the extensions with the strain gauges, in a first phase in the number of 40 then brought to 130, four for each measuring point, two on the inner side and two on the outside. On the ribs were bonded two strain gages (if possible 3) for the measuring point.

The results were given low values of the tensions in the walls, at the rate of 20 kg/cm. with peaks of 40 kg/cm. on big walls closer to the vertical. The extreme forces on the ribs were determined in 30 tones (both in tension and compression). The condition set by the Office of Audit of Belgium was that for a stress equal to its own weight and wind values double the normal (150 kg/cm) there were no hazardous conditions. The model under conditions increased compared to the requests, showed no deficiency.

The results of tests on the model thus authorize the execution, despite the approximations and uncertainties due to its difference with reality when construction was not monolithic. Were still found notes, in first approximation, the tensions to which the structure would be submitted.

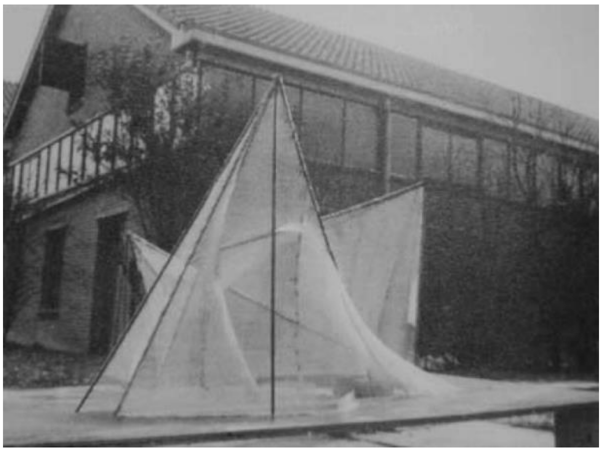


Figure 23 Framework of tubes and wire-gauze for making the plaster model of Philips pavilion

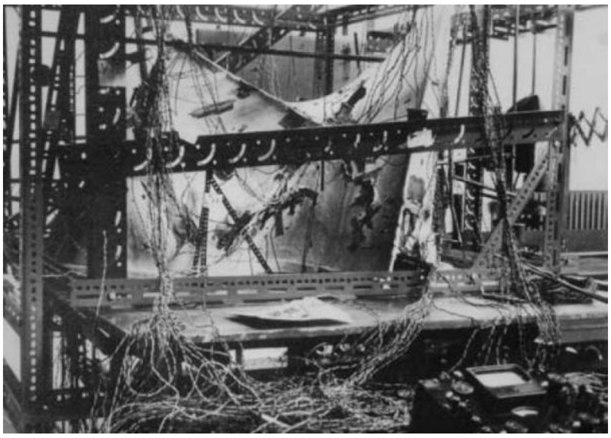


Figure 24 Equipment used for measurements on the plaster model. A series of displacement dial-gauges are mounted on angle struts and connected via long rods of the model. A large number of strain gauges are fixed to the shell surfaces are fixed to the shell surfaces and the ribs for determining the stresses.

Model 2
1:10 scale model of a portion of the pavilion
Stevin Laboratory - University of Delf - Netherlands
Technical Management. F.K.Ligtenberg
June 1957 (approximately)

This model takes into account the building system that Strabed intends to implement with walls made up of plates held together by pre-stressing tendons. Were used wood tiles triplex, the size of about 1dmq, positioned on the grid of cables, through a diagonal support in each tile (for the application of the load) and fixed temporarily with adhesive tape. As cables have been used nylon wires, that have produced relatively easily a pre-stressing system realistic. The modulus of elasticity of the wood used triplex was approximately half that of the concrete. Both the loads that the pre-stressing were taken equal to half the actual load. The phenomenon of instability and rupture was represented by the model in analogy to reality, while the deformations were reduced in scale 1:10. (BOUMA & Ligtenberg, 1959)

Then it was applied pre-stressing evenly. Immediately the ribs which included the model, free on one side, are twisted eccentrically for pre-stressing. A part of the surface that is almost vertical, is deformed. it was necessary to generate on these ribs a torque similar to that generated by the pre-stressing on the shell, through a complicated system of weights and pulleys. Once this pre-stressing has been assigned to the ribs, the tensioning of the shells was able to take place without difficulty.

Though the model was not representative of the reality regarding the effect of the forces resulting from a load, it seemed interesting to apply a load corresponding to its own weight and wind. The loads were applied with sandbags. Arrived at 90% of the load of its own weight, the lower surface, of a part of the model, close to the ground is curved abruptly. In the section under consideration, however, the model had been oversimplified, because, believing that the portions of the wall almost horizontal were the most dangerous, was not entered a stretch of vertical wall. Therefore the phenomenon of instability encountered, was deepened better. The model was downloaded and it was found that the instability was part, only after removing the load from the top of the wall which downloaded on the rib connection with the one that was buckling. It was modified the model to simulate the presence of nearly vertical and reapplied the load of its own weight and wind, without finding any abnormality. For further evidence, 5 employees of the laboratory mounted on the model, which proved more durable and stable.

During the execution of the tests under load, the stress state measurements were performed with the aid of plastic sheets and the photo-elasticity. Overall, the results confirmed the ability to perform the construction project of Strabed, with the warning to pay particular attention to the phenomenon of instability found in the test, even if the proposed Strabed put pre-stressing tendons also outside the walls, accepted by Le Corbusier and Xenakis, meant that the phenomenon became negligible.

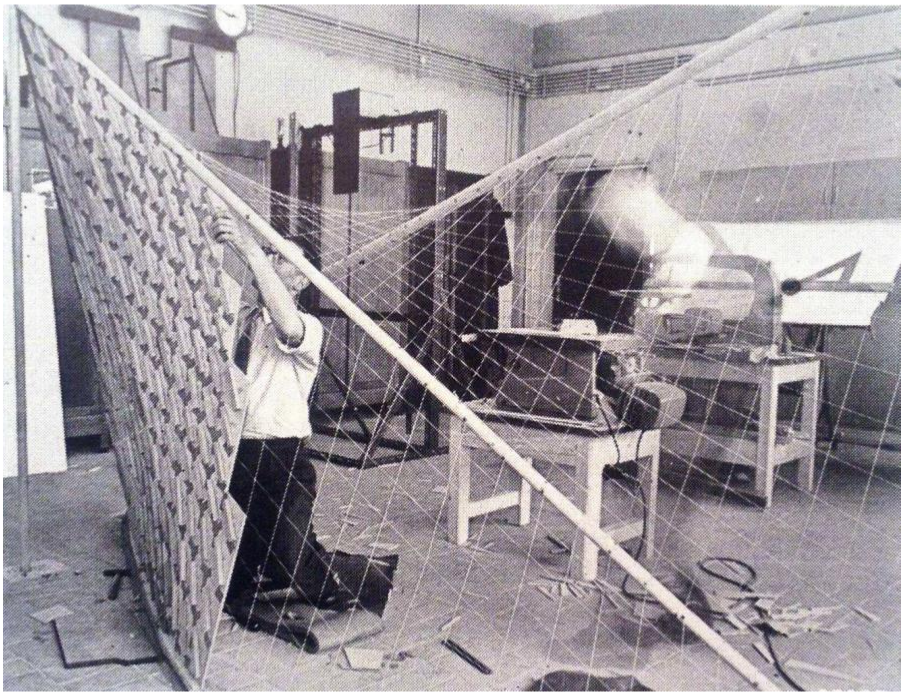


Figure 25 the plywood model in course of construction. In a manner similar to that to be used in the actual erection, the slabs are fitted together on wire "scaffolding", the wires being spanned between the previously erected ribs in accordance with rulings of the hyperbolic paraboloidal shells.

Figure 26 the plywood model severely overloaded.

Construction Of The Pavilion In Pre-Stressed Concrete

As H.C. Duyster said, When the Philips concern asked us to submit a proposal on how the pavilion designed by Le Corbusier and Xenakis might be built, our thoughts turned at once in the direction of self-supporting concrete shells, which would be no thicker than the minimum of 5 cm specified for reasons of sound- proofing by the acoustic engineers.

In its design we submitted that the walls consisted of hyperbolic paraboloids or surfaces, which could easily be transformed into hyperbolic paraboloid surfaces, and we were aware of the exceptional qualities of strength and stability of shells formed by hyperbolic paraboloids ("hypar" shells) from various projects as well as theoretical factors. Even if we did not do a thorough assessment, we could get an understanding of what stresses and deformations the building might have as conceived, that we were prepared to assess the power needed at different stages with the assistance of basic calculations. (Duyster, 1958)

Why Pre-stressing ?

Till perhaps be useful first of all to recapitulate briefly the idea underlying the pre-stressing of concrete. Concrete can safely withstand very considerable compressive stresses; up to 150 kg/cm2 in the case of good quality concrete.

Pre-stressing shell application has been determined using test outcomes for the decreased designs conducted at the TNO Institute for this event, weight, including acoustic filling, snow load and a wind pressure of 75 kg/sq have to be taken into consideration. Agent in various ways. The pre-stressing requirements are made in shells organized on the ground from the sequence of steel wires which have a strong elastic limit of 7 mm. Each cable can convey approximately 3,300 kg of tensile force. Assuming that the force brought into the frames is present everywhere (in the shell's core plane) and is transferred to the cable, the primary effort equations could then be established at each stage by the forces of pre-stress and voltages along and perpendicular to the joints. This allows us to determine the amount and place of the tendons to be pre-stressed. (Xenakis I. , 1959)

The aforementioned hypothesis is motivated by ph-for which the cables are arranged directly, provided that two conditions are met: the cabling must spread evenly over the shell surface and the shell must be able to deform free of charge when energised. This last condition was a special solution at various points, particularly for shells that rest on the foundation: the lower edge of such shells was first isolated with two sheaths of felt bitumen from the foundation (which were served in relation to the pond surrounding the building) and not attached to cement until pre-stressing had ended. Without this precaution, portion of the pre-stress power would be sent to the basis and the shell portion would not have had the required trajectory. (Giovannardi, 2015) The model of the scale produced in the Stevin workshop (triplex design) demonstrated that the building is doing what you want thanks to this equipment: the lack of local turbulence of the model (properly) under the in-service compression guaranteed that the pressures implemented did not turn considerably from cable management.

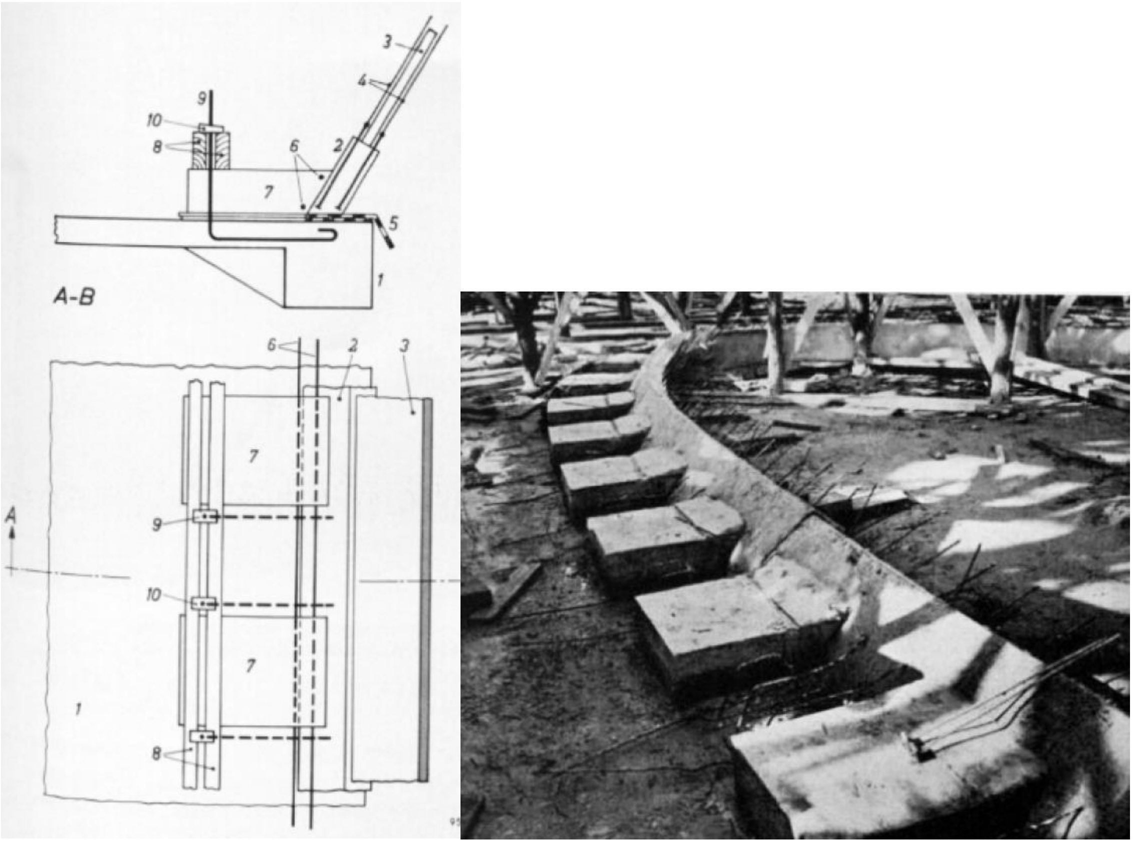


Figure 27 why pre-stressed concreted explained graphically

In order to pull all possible parts of pre-stressing, it is important to ensure that, pending the tensioning the bottom edge of the shells can move a few inches on the foundation, without tilting. To this end has been provided between the foundation (1) and the edge of the shell (2) two sheets of felt bitumen. The shell (3) is clamped on the edge (2) by tensioning cables (4). The same board is equally placed in compression, by the cables (6) along the perimeter. The tilting is prevented by the blocks (7) for rigidly the edges: these blocks are anchored, by their ends, to the foundation. The anchoring is achieved with the help of the wood joists provisional (8) which are fixed by means of clamps (10) of the flexible bars (9) anchored in the foundation.

In the photograph (fig.27) is resumed construction of the bottom edge with the blocks, before the construction of the shell. The intervals between the blocks are filled with concrete after installation and pre-stressing of the shells – after deformation has produced - to permanently attach the set to the foundation. The armature for the filling of the concrete also passes in the blocks. The flexible bars are bent temporarily down. Note that the blocks are always arranged in the inner part of the building. In the represented part of the building wall has the outward slope. It is also to be noted that, the lower edge built by this part, it can only slide, and not oscillate, a pre-stressing force possibly eccentric however introduced centrally in the shell: in this case, not the shell, but rather the foundation that absorbs bending moment. (Giovannardi, 2015)

The auxiliary devices used to apply the pre-stressing

All cables have been tense following a method designed and successfully implemented by SA Strabed method, which is characterized, in particular, for the possibility to tighten the cables within anchorages made before. Following traditional methods, they would have to pull the cables would have required making tensioners son through holes perpendicular to the axes of the ribs and anchor them at a later time, which - apart from the inconvenience aesthetic point of view – would have caused great difficulties everywhere because the ribs, many shells are connected by very small angles.

The method Strabed allows to place the cables very close to the wall to be put in tension (for the shells of the pavilion Philips at a distance of 2 to 3 cm). This is also advantageous to introduce the efforts voltage as centrally as possible in the shells, and from the point of constructive seen, this is important because each cable tension must be fixed to the wall of a series of points. The entire outer surface of the pavilion is coated with a special film waterproof, from which also the cables are coated equally tensioners. Finally the layer of waterproof base is still covered with a layer of paint to aluminum. (Giovannardi, 2015)

Figure 28 auxiliary devices used to apply the pre-stressing

The Acoustic Considerations and Edgar Varése music

Without the organization of visual perception, reverberation and resonance make us feel our environment, learned by practice. Reverberation and echo can also be artificially developed, so that the acoustic effect on the listener's environment differs significantly from their verbal experience. (Xenakis I. , 2003)This discrepancy between seeing and listening can evoke the feeling of something surprisingly new in an crowd. Electro-acoustic opportunities can well add to the growth of music.

These impacts were taken into account when Le Corbusier mentioned the sound effects of his "electronic poem" at the beginning of 1956. At that time of the intentions the music to be composed by Edgar Varése was still literally potential music. Electronic devices can be used to create completely new musical sounds. While philips did not yet know the composer's wishes, they were sure that stereophony and artificial reverberation would be important elements of the "electronic poem." (Xenakis I. , 2003)

This was enough to schedule the overall system of the required facilities in advance. We believed that the concurrent perception of three sound patterns from or in other directions would be an entirely fresh experience. Each of the three playback heads would supply countless loudspeakers via amplifiers. Varése went to Eindhoven to "generate" his structure with the collaboration of Philips when these plans were sufficiently developed.

A specially fitted studio was given for this purpose. Varése mainly focused on the personality of the tonal pattern in writing and most of it was left to decide on "intonation." The composition is defined by an exceptional richness of sounds, often with significant problems in their realization. The language defect was strongly sensed in this area, the absence of phrases to convey what is meant.

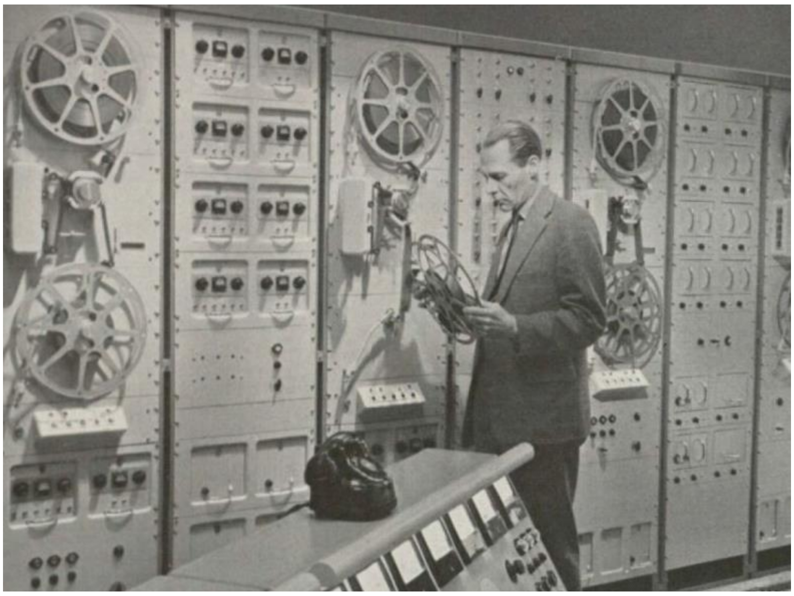


Figure 29 special playback machine carrying the electronic poem music by Varese

Varese frequently indicated his wishes by such expressions as "more nasal", "less biting', "more rasping", and it was Philips job to meet his wishes as well as possible by means of filters, mixers and frequency-shifting circuits. This system of «sound routes» was therefore adopted and has proved successful. (Xenakis I. , 2003)

Finally, a few words about the electro-acoustical equipment installed in the pavilion. Both the sound tape and the control tape have the same width and the same perforation as normal cinematographic film. The perforation is important with a view to the synchronous running of the two tapes.

Each tape is scanned separately in a special magnetic playback machine and driven by a rapid-starting synchronous motor. With the exception of the loudspeakers, the entire installation is duplicated, which means that there are four playback machines in the control room behind the balustrade . The other loudspeakers are mounted partly in compact groups and partly in dispersed groups , for example in «sound routes» along the shell ribs and horizontally.

By means of special signals the inputs of the various amplifier groups can be interchanged, allowing a free choice of the path along which a certain sound is to be reproduced. (Ouzounian, 2007)

Summary

Based on the L C Kalff concept, the Philips studio was intended and fitted to perform automatically a festival in light and sound, a so-called "Electronic Poem," a Le Corbusier story, and Edgar Varese's compositions. Y Xenakis undertook the architectural design under the guidance of Le Corbusier. Visual, acoustic and structural factors have resulted to the entire building of the pavilion from controlled surfaces. The development of the first model, including conoids, is demonstrated by a sequence of initial architectural drawings. The semi-experimental semi geometric technique, by means of which the first design sheets were totally transformed into hyperbolic paraboloids (second design), is then described. The transformation enabled us to embrace the building system suggested by the contracting company "Strabed," which was designed to construct the pavilion in pre-stressed concrete 5 cm thick as an independent shell.

A concisely explained hyperbolic membrane hypothesis after recapitulating the most significant geometrical characteristics of the hyperbolic paraboloid is provided. In the case of a uniaxial, consistent load applies parallel to the axis of the shell, the differential equations of stress have an extremely simple solution; then the shell is found to be a structure of equal strength. Also, offers formulae for somewhat more complex loads, important in practical conditions, and describes a simple graphic method for determining the primary pavilion forces and stress forces required to avoid any traction stresses within the shell (which concrete cannot resist). Finally, ribs disturbances happen when the boundary conditions are such that a solely membrane stress prevention exists. Some information are provided on the hypar shell strength against bending and buckling in the second order.

The theory provides an overview of the hypar shell behavior and enables alternatives to certain detailed issues, but it is impossible to fully determine the mechanical characteristics of such a complicated framework as Philips. In accordance with the design of the architect, the 1:25 model was made of the Paris plaster pavilion on a wire-gauze steel tube frame simulating the rod of the structure. A large number of pressure gauges and displacement gauges investigated the stress conditions produced in the model under different loads (dead weight, wind etc.). The result was that a 5 cm thick concrete framework with 40 cm thick ribs would be powerful enough. Two of the hyper shells were constructed in a second version 1: 10 from several hundred suitably-shaped plate wood. The shells were pre-stressed and the findings showed that the suggested building scheme was feasible using pre-stressed concrete slabs and pre-stressing cables held in the shanks. This building system was suggested and implemented by the company "Strabed". The consideration underlying this construction scheme was that the irregular, highly squeezed covers of the pavilion, which Strabed decided to keep as thin as possible (as required by acoustic insulation at least 5 cm) cannot be produced by casting concrete. The hypar covers therefore consisted of more than 2000 sheets of about 1 m2 each placed into open "Strabed" molds, constructed in the necessary shape. The plates were then installed on scaffolding site and tightly drawn by steel cables. The framework is also mechanically advantageous because the structure can be placed in a fluid condition of pressure roughly by the appropriate pressing of frames and border sections (ribs). The pre-casting and installation of the plate was significantly simplified by the reality that the walls were controlled. The pre-stressing wires (on both wall surfaces) follow the governing rows of the hyperbolic paraboloids in general. The cables were tensioned with a Strabed scheme. The unique characteristic of this scheme is that the cables are attached in advance to the framework, this obviously small detail had a significant influence on the effective construction of the pavilion. Besides the pressure-pressure and curved pre-tensioning, some

ribs were provided torsional pre-stressing, partially to offset the tensile times exerted on the shells by cutting ribs. This is considered the first torsional pre-stressing application for concrete.

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