



Proportional Systems in Late-Modern Architecture: the Case of Alejandro de la Sota

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Abstract The aim of this paper is the analysis, in terms of proportional systems, of a number of buildings designed by the Spanish architect Alejandro de la Sota, whose work is characterized in general by a particularly clever and unconventional use of different dimensional and proportional systems, and can therefore be regarded as a significant perspective in the understanding of the design strategies in Modern architecture. Beyond the well-documented use of modules and grids in his work, these analyses try to show the presence of proportional systems based on the Golden Mean in some of this architect's designs. These analyses lead also to a discussion on the nature of proportioning techniques in architecture, their relationship to analogous structures in musical composition, and the necessary compromises between the ideal proportions and the reality of construction, something inherent to the very nature of the architectural object.

Keywords Alejandro de la Sota · Modern Architecture · Design theory · Geometric systems · Golden section · Modules · Proportion · Proportional systems · Proportional analysis

Introduction

The aim of this paper is the analysis, in terms of proportional systems, of a number of buildings designed by the Spanish architect Alejandro de la Sota (Pontevedra, 1913- Madrid, 1996), whose work is characterized by:

1. A neo-constructivist attitude (Frampton 1995, p. 367), with a very careful concern for the tectonic aspects of design. Some of Sota's most outstanding

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- works feature experimental construction systems developed by the architect himself, showing his interest in technology and his preference for contemporary construction systems and, in particular, for prefabrication, which Sota seems to regard almost as a way to think of architecture (Gallego 2004).
2. A preference for simple rectangular volumes conceived as functional containers [see, for instance, (Sota 1989, p. 176)], in which the tension between the complexity of the functional and site requirements and the simplicity of the building shell constitutes one of the most remarkable aspects of the design. This preference is consistent with Sota's tectonic approach, favouring at the same time compactness and economy, both in an idealistic and in a pragmatic sense.
 3. An explicit refusal of any forms of rhetoric or formalism, argued either from an ethical standpoint (Baldellou 1975) or for the sake of rationality, in the line of the most orthodox Modern Movement principles (Puente 2003, p. 151), an attitude tempered by a non-positivist pragmatism. Explicit rejection also of personal expression (Sota 1989, p. 221) or mimesis (Puente 2003, p. 70) in architecture.
 4. A particularly clever and unconventional use of different dimensional and proportional systems in his designs. This aspect of Alejandro de la Sota's work is the subject of this paper.¹

Dimensional and Proportional Systems in the Work of Alejandro de la Sota

In Modernism, architects have often employed proportional systems in the design of the architectural object, taking these resources directly from history, in spite of their purported break with the past. The best known example of this approach, although by no means unique, is the work of Le Corbusier, who divulged the way in which he employed proportional systems, in particular those based in ϕ , in his own designs.² Other examples of the use of proportional systems can be found in architects of late Modernism such as Kahn (Fleming and Reynolds 2006), Aldo van Eyck (Fernández-Llebrez and Fran 2013) or Rudolph Schindler (March 2003; Park 2003). In this sense, the work of Alejandro de la Sota, as we will try to show here, constitutes a particularly rich and complex example of proportional systems in architecture, and can be regarded, therefore, as a significant contribution to our understanding of the design strategies in Modernism.

The notion of 'proportional system' transcends the use of modules and grids in a merely utilitarian manner; rather, it refers to the way in which the architectural elements constitute a unitary and structured whole. Le Corbusier himself warns us

¹ Note on the reference material: as we are dealing with an architect whose work is located almost entirely in Spain, there is hardly any literature in English on Alejandro de la Sota. However, most of the published drawings cited in the references come from the archives of the Fundación Alejandro de la Sota, and are freely available at: <http://www.alejandrodelaSota.org>. Therefore, all the drawings and data mentioned in this paper can be checked at the foundation's web site. For those who may be interested in Alejandro de la Sota's work, an excellent bibliography can be found in (Martínez and Pemjean 2007, pp. 179–197).

² See for instance (Le Corbusier 1995, pp. 61–64) and (Le Corbusier 2000, pp. 120–141).

in this regard: a *trace régulateur* is not merely a mesh, but a unitary geometric structure which defines in a congruent manner the proportions and positions of the elements that constitute the architectural object (see Le Corbusier 1983, pp. 36–37). Thus, the mere use of specific dimensions related to constructional or structural systems or to functional requirements does not yield by itself the kind of form under consideration here, as the proportions thus defined do not allow, in principle, a self-similar³ pattern. As opposed to this, some rectangles, like the Golden Section or the root-*n* rectangles, ‘replicate through endless divisions’ (Fletcher 2008) in a self-similar repeating pattern (Figs. 1, 2), and their use permits the construction of the unitary geometric structures discussed by Le Corbusier, among others.

This ‘fractal’ nature of form,⁴ which presents the same structure on all levels, is analogous to that property called *commodulatio* by Vitruvius and *concinnitas* by Alberti: the harmony of the whole that ‘derives from the repetition of the fundamental form of the work in all its subdivisions’ (Ghyka 1977, p. 222). It is, likewise, that aspect of architecture and music, where the elements’ defining parameters, be they spatial or sonorous, are strictly regulated by an a priori-defined structure, in which the different parts that constitute the whole are generated as variations of that fundamental structure. We will see how this aspect of architecture, to which Le Corbusier refers in the first pages of *The Modulor* (Le Corbusier 2000, p. 15–17), is essential in the understanding of the work of Alejandro de la Sota.

The possibility of this sort of structure resides in the geometric properties of the chosen proportional system, so the proportions and dimensions of the corresponding architectural elements are inherently contained in those properties,⁵ in the same way as the possibilities of variation of a musical theme are contained beforehand in its musical structure. The work of architecture thus conceived will show what we might call a ‘symphonic composition’ (Ghyka 1977), featuring that formal richness-in-unity derived from the exploitation of the possibilities of variation contained in the fundamental structure.

The works of Alejandro de la Sota analyzed here will be interpreted in terms of this conception of the dimensional-proportional structure, identifying in this sense different strategies for the configuration of the architectural object in his work.

For one thing, in some designs Sota shows a preference for some specific dimensions. Thus we sometimes find a recurrent use of the 600 cm square grid, as for example in the Gobierno Civil de Tarragona (Sota 1989, p. 44), in his design for the Anthropological Museum in León (Ábalos et al. 2009, p. 496) or in the Maravillas Gymnasium (Ábalos et al. 2009, p. 187).⁶

³ Self-similarity can be defined as ‘symmetry across scale’, and ‘implies recursion, pattern inside of a pattern’ (Gleick 1998, p. 103).

⁴ The ‘fractal’ nature of form is analogous to the mathematical concept of self-similarity as it is defined in the field of fractal geometry; see (Mandelbrot 1983).

⁵ The readability of the object’s geometric construction can be regarded as an essential moment of its aesthetic experience, closely related to the idea of scale as a reading of the relationship between human stature and the size of the architectural object. In certain designs, it is precisely the reading of the geometric construction what allows the understanding of that relationship.

⁶ The Anthropological Museum’s design is based on a 600 cm square grid in plan and a floor-to-floor height of 300 cm. In the Maravillas gymnasium, the trusses accommodating the classrooms over the basketball court are set at intervals of 600 cm; the design is in general based on a 200 cm square grid in plan.

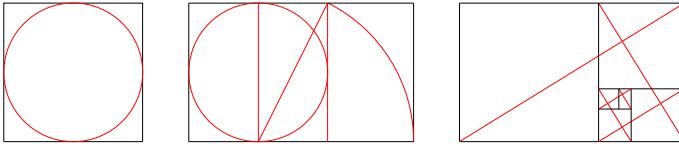


Fig. 1 Construction of a Golden rectangle and similarity of its divisions, after (Fletcher 2006, p. 77)

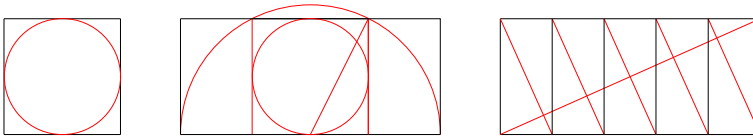


Fig. 2 Construction of a root-five rectangle and similarity of its divisions, after (Fletcher 2008, pp. 150–154)

On the other hand, in many of his designs Sota uses geometric structures consisting of cubic or square grids, with dimensional scales based on the 60, 80 or 120 cm modules, in a rather orthodox manner. Such is the case of the design for the children's summer residence in Miraflores de la Sierra, Madrid, based in plan on a 600×300 cm grid (Ábalos et al. 2009, p. 112), or that for the Universidad de Granada Faculty of Law, laid out on a 360×360 cm grid, both in plan and section (Ábalos et al. 2009, p. 342). This kind of grid is widely used in a broad range of applications by many architects, and the combinatory properties of these dimensions are well known to any practising architect.

An example of the use of this kind of dimensional systems is the building for classrooms and lecture halls at the Universidad de Sevilla, built in 1971. This design is based on a 120 cm square grid in plan, while the elevations seem to be regulated by a 120×75 cm rectangular grid; notice that: $120/75 = 1.6 \approx \phi$. Both dimensions are, besides, multiples of the common module of 15 cm (Fig. 3).

Due to the additive properties of these dimensions, this design shows an interesting analogy with the possible combinations of the different types of musical notes in a measure according to the time signature, in which the durations of the notes keep the same proportional relations as the dimensions used in this design. Sota's interest in music is well known; he was a notable piano performer. Miguel Ángel Baldellou (1975, pp. 41–42) shows how his knowledge in musical matters might have inspired some aspects of his approach to architecture.⁷

In the last group of works that are analyzed in this paper, the mere use of dimensional grids and modules is transcended, and we find geometric structures based on irrational proportions, mainly the Golden Mean. In these works, in spite of their often complex forms, which are closely related to the design requirements of program and context, Sota achieves that rich 'symphonic' character, thanks precisely to the complexity of these designs.

⁷ A similar relationship between the use of proportional systems in architecture and the ability for music performance can be observed in Kahn (Fleming and Reynolds 2006, p. 36).

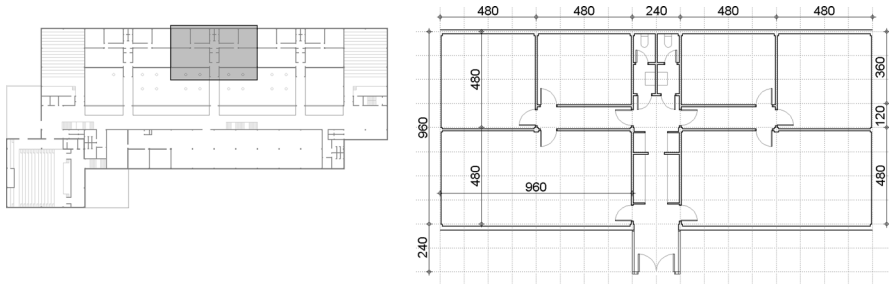


Fig. 3 Alejandro de la Sota, Building for classrooms and lecture halls, Universidad de Sevilla. Drawing by author, after (Sota 1989, p. 144), showing the use of the dimensions derived from the basic module of 120 cm in the lecture hall wing

Accuracy of regulating lines in Architecture

The analysis of the proportional systems underlying a given design is sometimes complex, as a work of architecture, unlike a work of sculpture or painting, is subject to independent and often contradictory requirements, during both the design and the construction stages, and the purity of its geometrical structures is easily distorted in order to conform to such requirements. According to André Lurçat:

Si la méthode employée pour le mise en proportion d'un ensemble et de ses éléments apporte à son application de multiples avantages au point de vue de l'harmonie, elle ne peut cependant être considérée comme un moyen d'atteindre toujours une solution valable. Rarement, en effet, l'artiste se verra doté d'une liberté telle qu'il puisse, sans aucune entrave, l'utiliser intégralement; il lui est indispensable, en raison du respect des nécessités pratiques qu'il implique chaque programme constructif, d'envisager cette méthode plutôt comme un moyen de contrôle, dont le choix n'est pas laissé à son arbitre, mais est déterminé par le sujet même auquel il doit s'adapter (Lurçat 1957, p. 112; our emphasis).

[If the method used for the proportioning of a whole and its elements gives a lot of advantages from the harmony point of view, however, it cannot be considered as a means to always achieve a valid solution. *Rarely, indeed, the artist will be allowed to work in such freedom that he or she can, without impediment, use these techniques integrally*; it will be necessary, in order to satisfy the requirements implied in every construction program, to conceive such methods more as a means of control, in which the choice is not left to his/her will, but it is determined by the very subject of the design, *according to which it must be adapted* (my trans.).]

Bearing this in mind, the analysis of architectural works must take into account the necessary adjustment of the ideal proportions according to requirements such as the dimensions of construction elements or the rounding of dimensions to whole

numbers.⁸ On the other hand, it can be argued that, in every design, it is always possible to find a proportional scheme if one uses a complicated enough geometry in the analysis. In our case, we sometimes find significant deviations from the ideal proportions, apparently contradicting the hypothesis of any underlying patterns; the confirmation of these hypotheses will come more from the whole of the analysis, as it is not just that the overall real proportions have to be close to the ideal, but also the fact that the divisions follow (although, again, not with absolute accuracy) the harmonic decomposition of the basic proportion, and that these geometric techniques can be found, time and again, in Sota's work. Furthermore, the analyses carried out here are very simple and straightforward: they cannot be accused of a sophistication that tries to make the facts fit into the hypothesis. When proportioning techniques have been used, it is unequivocal, in spite of the deviations. In this regard, Sota's work offers a lesson about the compromise between the ideal proportionality and the real building, an instance of how this compromise can be achieved.

In general, designs of a certain degree of formal complexity are rarely suitable for an exhaustive and univocal analysis as often, in these cases, only the overall proportions maintain some sort of structure. In general, it is in smaller works that such analysis can be carried out more easily and yield better results. That is the case, for instance, of Sota's Alcudia housing design (Fig. 4), the analysis of which will put us on the trail of the geometrical devices used by this author in designs of greater complexity.

It is possible to confirm that this form is based on a double-square rectangle in plan, in which the central square corresponds to the living room while the two remaining double-square rectangles on both ends of the initial rectangle correspond to, on the one hand, the master bedroom and the kitchen, and, on the other, to two smaller bedrooms. These divisions follow a 150 cm square grid, as well as a smaller 15 cm constructional grid, displayed by the floor joints (Fig. 5).

The elevation grid is defined, on the one hand, by the 150 cm plan grid, and on the other, by the 90 cm width of the facade panel [see (Martínez and Pemjean 2007, p. 113)]; these panels are the same width as the panels used in the León General Post Office, see *infra*. Note that the resulting proportion is: $P = 150/90 = 1.66 \approx \phi$, meaning that the main elevation, whose overall proportion is a 1:4 rectangle, is also regulated by a Golden Section grid (Fig. 5). This combination of the square and the Golden Section geometries is possible due to the fact that the total height of the house, that is, 450 cm (without skirting), is a multiple both of the 150 cm module in plan and the 90 cm module in elevation.

It is easy to check that the different elements are laid out on these grids, as it is shown in Figs. 4 and 5. But, surprisingly, the skirting between the bottom panel and the ground measures, not 30 cm, as it would be expected, but 35 cm (Martínez and Pemjean 2007, p. 113), which probably constitutes an exception due to construction issues.

Other works of greater complexity do not allow such a clear and neat analysis. We will see, however, how the works analysed here show a proportional structure

⁸ A similar argument, regarding the relationships between ideal proportions and building dimensions in the work of Louis I. Kahn, can be found in (Fleming and Reynolds 2006, p. 38).

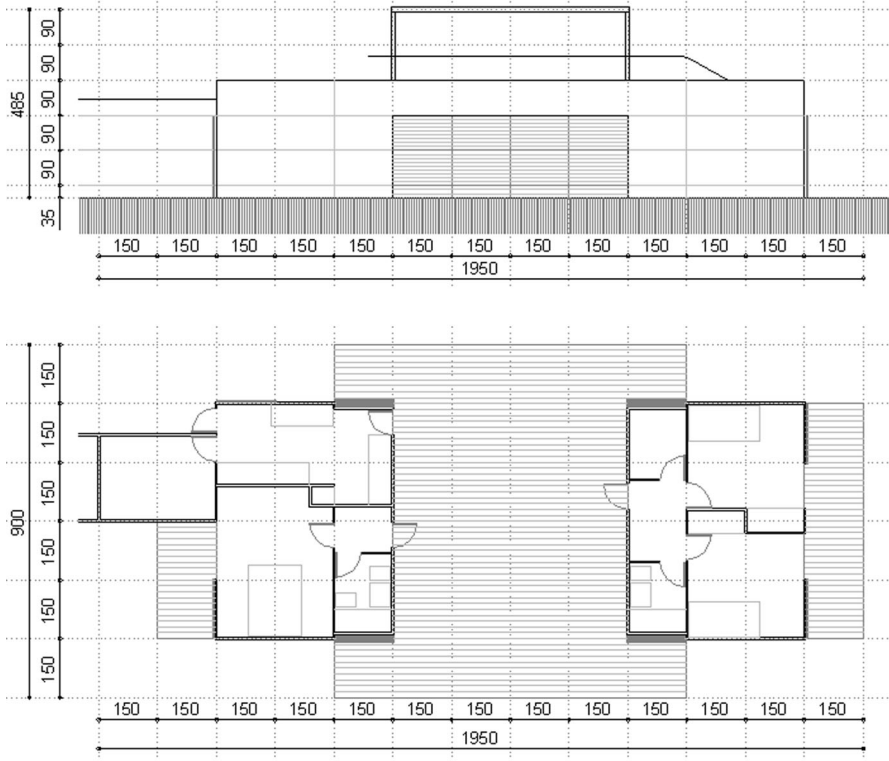


Fig. 4 Alejandro de la Sota and Mauricio Sánchez Bella-Carswell, design for Alcudia housing (unbuilt), garden elevation and ground floor plan. Drawing by author, after (Sota 1989, p. 201) and (Ábalos et al. 2009, p. 487). Dimensions in cm

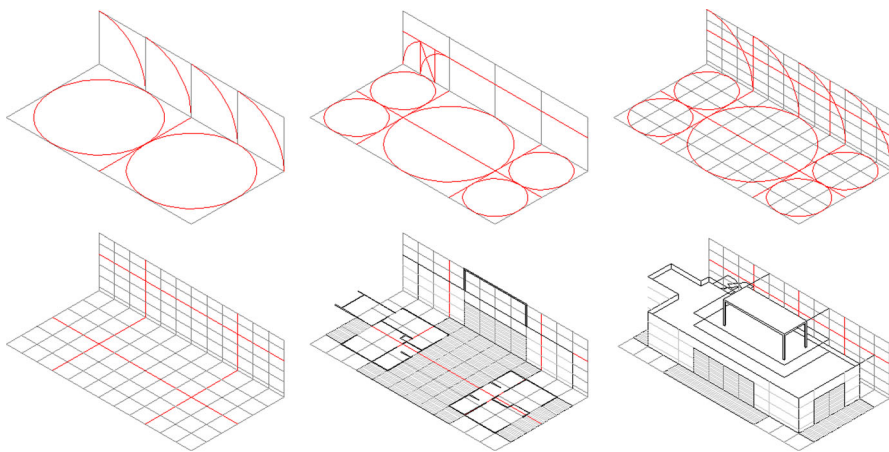


Fig. 5 Alcudia housing. Diagram by author showing the design's proportional system

which, in spite of the difficult compromise between form, brief and construction requirements, and the congruence of the dimensions used in plan and elevation, will be very close to that ‘symphonic’ character referred to by the concept of harmony in architecture.

In what follows, three works by Alejandro de la Sota will be analyzed according to these criteria: the extension to the Centro Nacional de Investigaciones Metalúrgicas (CENIM), the César Carlos student housing and the León General Post Office.

CENIM (Centro Nacional de Investigaciones Metalúrgicas)

The CENIM,⁹ situated in the Ciudad Universitaria de Madrid (the University of Madrid central campus), consists of four free-standing, roughly equal buildings, built as an extension to the pre-existing National Centre of Metals Research premises. Each building consists of a clear-span workshop with a four-storey office wing attached to its south side. The buildings have steel structural frames, externally exposed, and the enclosing skin consists of a brick facade executed in Flemish bond: according to Sota, the composition follows ‘Miesian principles’ (Sota 1989, p. 88).

According to my field survey, the structure’s main dimensions are:

- Laboratory area structural bay: 820×1964 cm axis (workshops area: 410×491 cm).
- Office wing structural bay: 507×491 cm.

The plan therefore consists of seven bays 410 cm wide, save for the office bay, which is 507 cm wide, running crosswise, and four bays 491 cm wide, running lengthwise. The resulting proportions are (Fig. 6):

- Office wing bay: $P_1 = 507/491 = 1.0325 \approx 1$ (deviation: $100 * [1 - (1.0325/1)] = 3.25$ %); the office wing is in plan a 1:4 rectangle, formed by a series of four roughly square bays.
- Workshops: $P_2 = 820/491 = 1.67 \approx \phi$ (deviation: $100 * [1 - (1.67/\phi)] = 3.21$ %); these bays are approximately Golden rectangles in plan.
- Laboratory area: $P_3 = (3 * 820)/(3 * 491) = 1.67$; the laboratory areas is also a Golden rectangle in plan.

The floor levels are shown in the building’s published sections (Sota 1989: 91), from which it is possible to reconstruct the structural grid in elevation. The typical floor-to-floor height in the office wing is 320 cm (with the exception of the top floor, in which it is 340 cm), so the proportion of the structural bay in elevation is: $P_4 = 507/320 = 1.584 \approx \phi$ (deviation: $100 * [1 - (\phi/1.584)] = 2.14$ %).

The side elevation also appears to be regulated also by the Golden Mean, from the whole and the main framing down to details like the openings layout (Fig. 7).

⁹ Drawings, sketches and photographs of this building are available at <http://archivo.alejandrodelaota.org/en/original/project/68> (Access date: 29 October 2015).

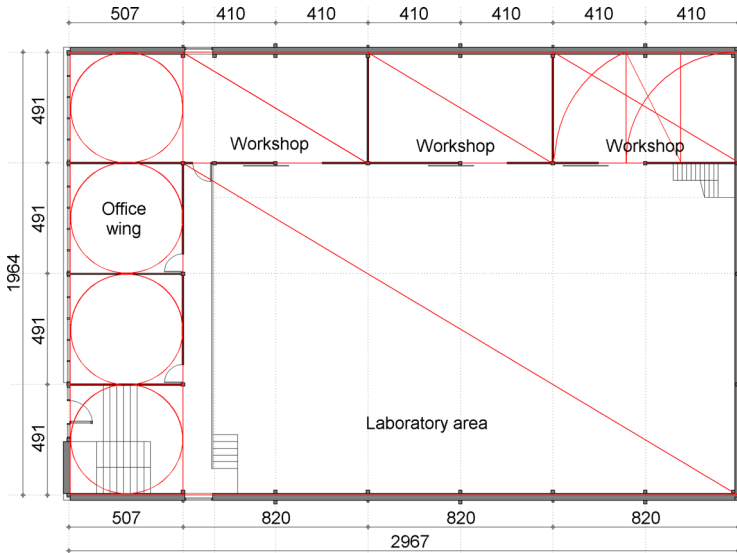


Fig. 6 Alejandro de la Sota, CENIM. Ground floor plan showing its proportional scheme based on ϕ . Drawing by author, after (Sota 1989, p. 90) and field work. Dimensions in cm

In the front elevation, on the other hand, the proportion of the structural bay is yet a little further from the Golden Mean (Fig. 8). Considering the structural bays of the office wing as square in plan, and supposing that the deviation from the square proportion is due to constructional issues or other, we can then suppose that, ideally at least, the proportions in the front elevation are the same as in the side elevation of the office wing, and that this front elevation is equally regulated by the Golden Mean.

In reality, the actual proportion of the structural bay in this elevation is $491/320 = 1.53$ (deviation: $100 * [1 - (\phi/1.53)] = 5.75\%$). This layout does not take any advantage of the harmonic decomposition of the Golden Mean. Only the fact that this proportion has been used in plan and in the side elevation suggests that this elevation could be structured according to the Golden Mean and that the deviations from ϕ are due to construction or other issues. In spite of this, the regulating lines show how this elevation is configured according to some specific proportion: it is possible to check how the proportions of the typical structural bay are repeated in the openings layout: the front elevation consists of an alternation of solid and void horizontal bands, in which both bands are roughly the same width, approximately 160 cm, so they are rectangles with a $2 * \phi$ proportion. Furthermore, the mid panels of the void band repeat the proportion of the structural bay (approximately ϕ), and the smaller panels on the upper and lower ends of the void band follow approximately the proportion of the void band itself, that is to say, $2 * \phi$.

In this analysis we have taken into account only to the elevations published in the literature, as it is not possible to measure the window framing in the actual building, due to the fact that the original framing has been substituted, and its layout has been altered.

As a result of these analyses, it is possible to reconstruct the spatial grid that regulates the whole of the building form, confirming that it does not consist of the

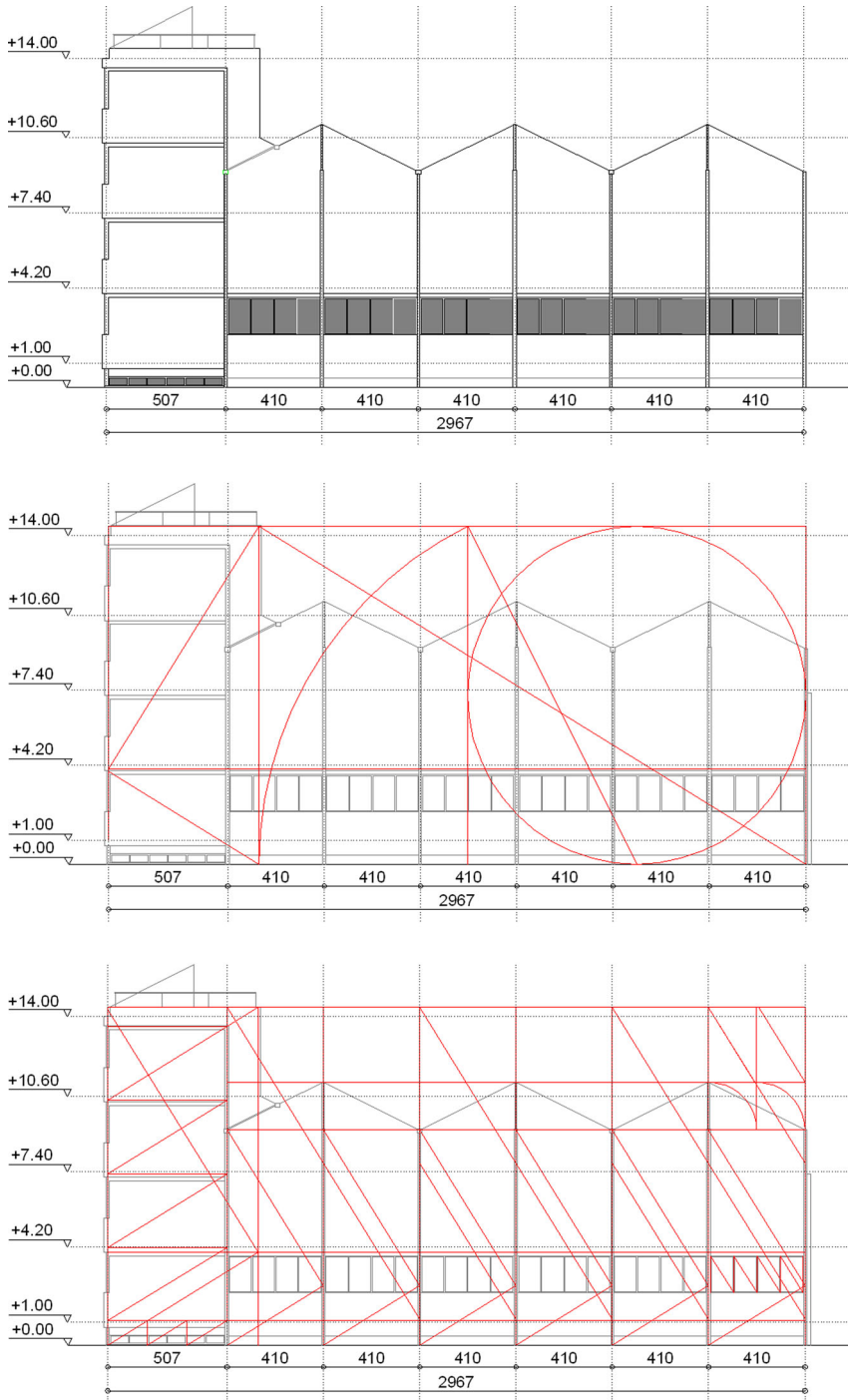


Fig. 7 CENIM. Side elevation showing proportional scheme. Drawing by author, after (Sota 1989, p. 91) and field work

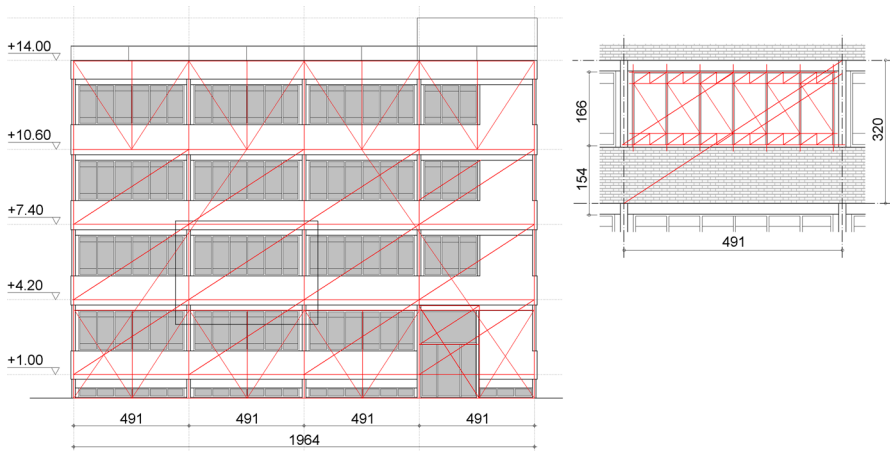


Fig. 8 CENIM, front elevation showing proportional structure. Drawing by author, after (Sota 1989, p. 88) and field work. Dimensions in cm

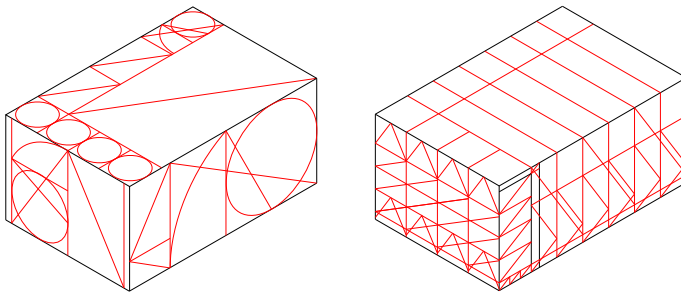


Fig. 9 CENIM, diagram showing proportional system in space according to the precedent analysis. Drawing by author

application of *traces régulateurs* on each projection in an independent way, but consists rather of a three-dimensional conception (Fig. 9).

César Carlos student housing

The César Carlos student housing of 1967,¹⁰ also located in the Ciudad Universitaria de Madrid, consists of two separate buildings, linked by an underground passageway: one is a five-storey residential building containing the dormitory rooms, with accommodation for about one hundred students, plus a small library in the basement and a gymnasium in the attic, and the other is a two-storey 'social building' housing the dining, meeting and lounge facilities, supplemented by such functions as kitchen, reception desk and vestibule, administration, staff

¹⁰ Drawings, sketches and photographs of this building are available at: <http://archivo.alejandrodelaota.org/en/original/project/81> (Access date: 29 October 2015).

accommodation and other service areas. Our analysis will focus on the social building, as the dormitory building is based on a more conventional geometry.

We find here, again, an original use of the geometry of the Golden Section, although only in plan. No accurate elevations of this project have been found other than those repeatedly published in the literature (which provide no levels or dimensions whatsoever), and the analysis has not revealed any regulating lines or underlying proportioning systems.

The proportions of the structural bays are deduced from the foundation plan as published on the website of the Fundación Alejandro de la Sota (see note 1). The field work has confirmed the overall consistency of this plan with the actual building, as well as with the other published drawings.¹¹ The overall proportion is, according to the foundation plan: $2975/2500 = 1.19$, which deviates approximately 4 % from the $2:\phi$ ($=1.236\dots$) proportion. This corresponds to a rectangle formed by two Golden rectangles joined at their long side (Fig. 10).

This rectangle is subdivided in 3×3 bays with a proportion of: $700/600 = 1.167$ m which deviates 6 % from $2:\phi$, plus three bays with a proportion of: $600/525 = 1.143$, which deviates 8 % from $2:\phi$. The other bays seem to follow proportions close to other ratios usual in architecture, but they may be regarded as residual, as their geometric properties are not exploited in the internal layout (Fig. 11).

The proportions based on ϕ have been employed in those areas of the plan corresponding to the more fragmented spaces, in order to take advantage of the harmonic decomposition of the Golden Mean. This corresponds approximately to the spaces situated on the northeast half of the plan, while the ‘residual’ proportions, as well as the square bays, correspond to the porch and the more open spaces, located on the southwest half (Figs. 11, 12).

This is due to the fact that the plan is organized, roughly, according to the northeast-southwest diagonal of the base rectangle,¹² so the southwest half contains the more public spaces, oriented towards the garden area, the swimming pool and the tennis court, while the more fragmented and private areas would constitute a sort of barrier facing the street and the less favourable orientation (Fig. 12). Thus, the geometric structure of the design does not have an abstract or *a priori* character, but rather constitutes a response to the site conditions. Therefore, the design seems to be based on the $2:\phi$ proportion, although some deviations from that ideal proportion can be observed. This may be explained by the need to adjust these incommensurable, ideal proportions, to dimensions suitable for construction. Note that the dimensions used in the design, both in the overall form (the structure as a whole

¹¹ The October 1967 plan of the social building (Couceiro 2008, p. 25), an intermediate version that is very close to the final design, shows that the columns have a constant cross section of 30×20 cm, while in the actual building the column sections are variable, with a minimum of 30×30 cm. This could mean a change in the structural material at some stage: the columns were originally conceived in steel, but were later executed in concrete. This spoils the original similarity between the proportion of the column section, initially $30/20 = 1.5$, and the rest of the design proportions, based on $\phi \approx 1.618$. In any case, the fact that the architect tried to integrate the dimensions of the structural elements in the building’s proportional system is remarkable.

¹² This design is, in this regard, similar to Le Corbusier’s Villa Savoie at Poissy.

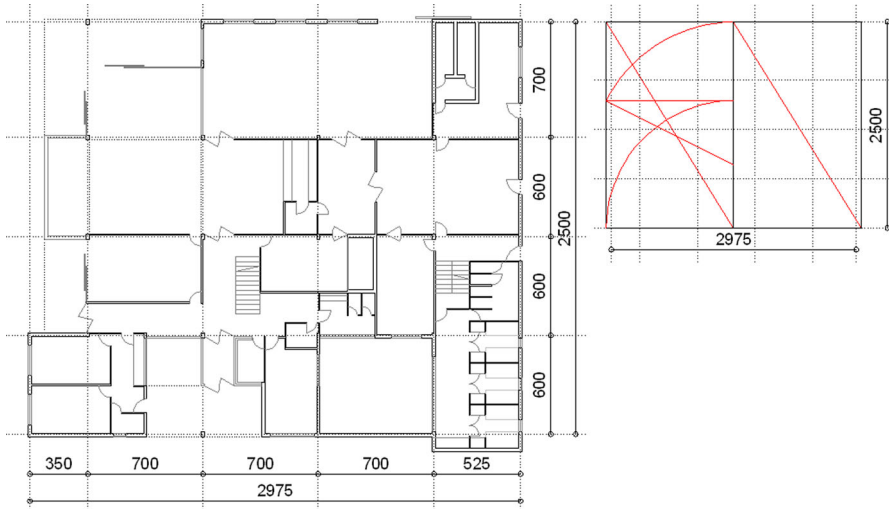


Fig. 10 Alejandro de la Sota, César Carlos student housing. *Left* social building, ground floor plan. *Right* overall proportions based on the $2:\phi$ rectangle. Drawings by author, after (Sota 1989, p. 119) and field work. Dimensions in cm

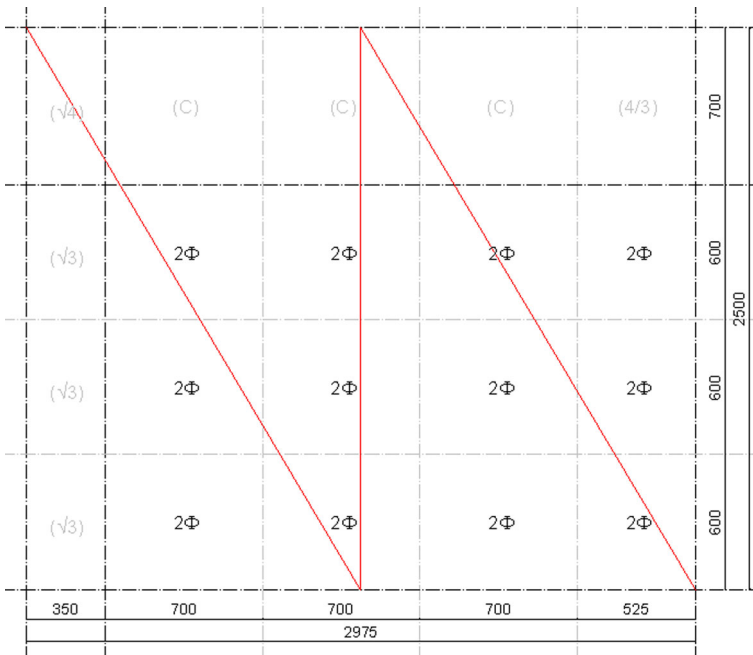


Fig. 11 César Carlos student housing. Diagram by author showing proportional system in the ground floor plan of the service block. The proportions in parentheses do not belong to the ϕ harmonic decomposition, and will be regarded here as residual. Dimensions in centimetres

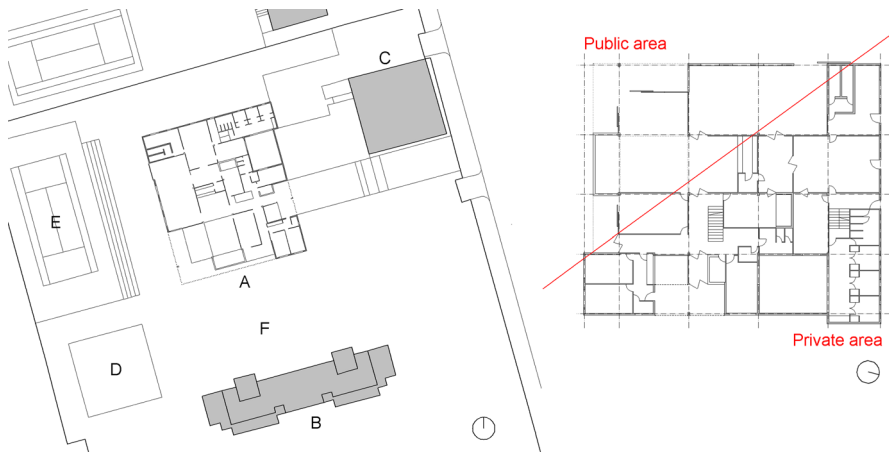


Fig. 12 César Carlos student housing. Site plan. The more open and public areas of the plan are oriented towards the more favourable side of the site. A = Social building. B = Dormitory building. C = Director's house (currently: library). D = Swimming pool. E = Tennis court. F = Garden area. Drawing by author, after the Madrid official cartography

measures 2500×2975 cm axis) and in the internal partitions (bays of 700, 600, 525 and 350 cm) are multiples of 25 cm, and therefore the ideal proportions would have been adjusted to these practical needs.

On the other hand, in spite of the small deviations, the plan layout should follow roughly the harmonic decomposition of the fundamental proportions. In other words: the correspondence between the actual divisions of the plan and those of the hypothetical geometry would constitute a confirmation both of the use of the Golden Mean and of the hypothesis of the compromise between ideal proportions and real dimensions.

We can indeed verify that the divisions carried out in plan correspond to the harmonic decomposition of the $2:\phi$ rectangle. If we take the area highlighted in Fig. 13, we can check how the divisions in both structural bays correspond to singular points defined by the square and the ϕ and $2:\phi$ rectangles. Likewise, it can be checked how the divisions carried out in the area highlighted in Fig. 14, in spite of the small deviation of the actual bay from the ideal $2:\phi$ rectangle, correspond roughly to the Golden Section geometry: the $2:\phi$ rectangle is subdivided into two smaller ϕ rectangles; one of them is subdivided again into a square and another smaller ϕ rectangle. That square area is again divided into a ϕ rectangle (corresponding to the bar area) plus a $(1 + \phi)$ rectangle, while the previous Golden rectangle is in its turn divided into a square area (corresponding to the small room on the lower right corner) plus another small ϕ rectangle. All these divisions follow the harmonic decomposition of the Golden Section.

Figure 15 shows another instance of application of these rules, although, far from repeating the described modes of division, new variations inherently contained in the chosen geometry are generated. This not only refers to that musical concept of 'theme and variations' that, as we saw before, constitutes the essence of harmony in

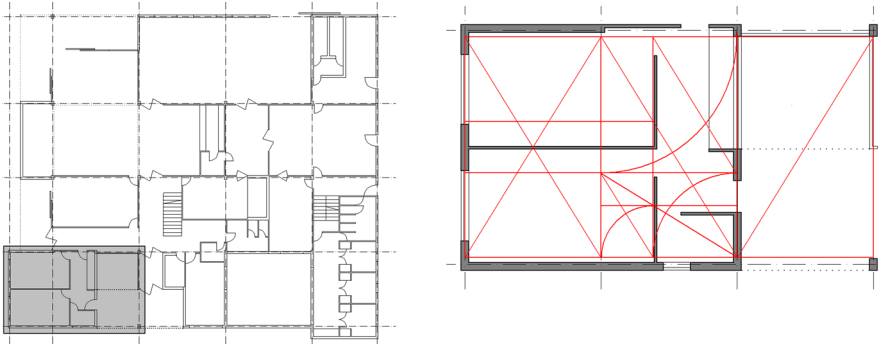


Fig. 13 César Carlos student housing. Diagram showing the proportional system corresponding to the structural bays highlighted in the reference plan (drawing by author)

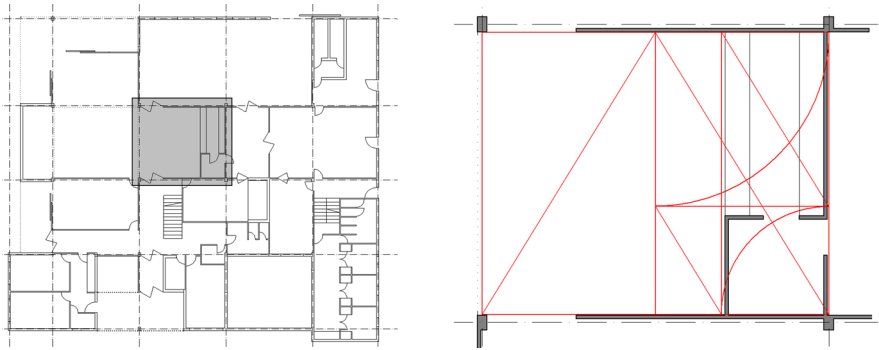


Fig. 14 César Carlos student housing. Diagram showing the proportional system corresponding to the structural bays highlighted in the reference plan (drawing by author)

architecture; it also proves the flexibility of the proportional system chosen, which allows to generate the required layout without any simplifying reductionism of the program. On the contrary, the plan follows function, avoiding any oversimplification.

The lack of elevation drawings with dimensions or levels prevents an accurate analysis of their proportions; therefore, we will not attempt here a reconstruction of the proportional system in space. However, the measuring on site of one of the windows of the dining room yields a surprising result: its dimensions, 1900×1500 mm, mean a proportion of $1900/1500 = 1.266\dots \approx 2:\phi$ (deviation: $100 * [1 - (1.266/2:\phi)] = 2.4\%$), that is to say, this opening has exactly the same proportion as the whole of the building plan, equal to two Golden rectangles joined at their long side, thus further reinforcing the self-similarity hypothesis.

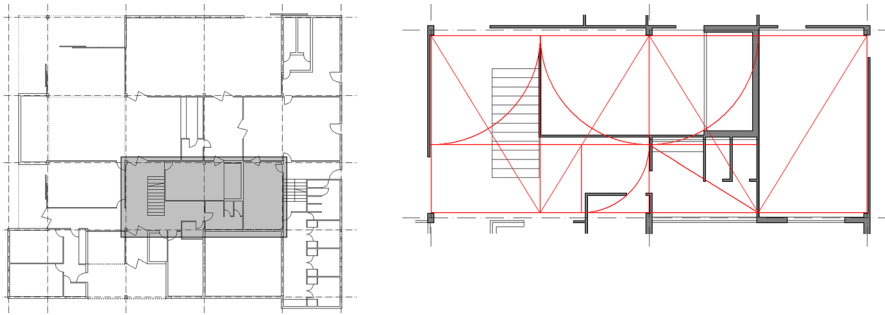


Fig. 15 César Carlos student housing. Diagram showing the proportional system corresponding to the structural bays highlighted in the reference plan (drawing by author)

General Post Office and Telecommunications Building in León

The General Post Office and Telecommunications building in León,¹³ designed in 1981, consists of a single rectangular volume into which the openings have been punched, and it is described by its author (quoting Le Corbusier) as ‘a cube that works’ (Sota 1989, p. 177), accommodating a complex program which comprises the city’s general post office, including all the associated functions, plus some staff accommodation in the attic, and featuring a steel skeleton as load-bearing structure (partially exposed inside) with a metal composite panel facade as envelope (Fig. 16). In this design, with even more clarity than in the previous ones, we can detect a spatial geometrical structure organized on three hierarchical levels: the volume as a whole as the main level, the structural grid as the second level and the constructional grid as the third one.

Level 1: Overall Building Volume

The drawings published in the different sources do not show dimensions in plan, showing only levels in sections and elevations. However, the plan dimensions can be deduced from those of the construction elements; thus, in (Ábalos et al. 2009, p. 470), we find that the width of the structural bay in the long direction is 700 cm (Fig. 17)¹⁴. This dimension is subdivided in six, 116.66 cm wide segments, a dimension corresponding to the width of both the typical opening and the solid panel between openings. Furthermore, it is possible to deduce the facade panel width from the diagram showing the building levels (ibid., p. 448); this panel is 90 cm wide.

¹³ Drawings, sketches and photographs of this building are available at: <http://archivo.alejandrodelaota.org/en/original/project/102> (Access date: 29 October 2015).

¹⁴ Some minor corrections have been introduced in this drawing: the building’s columns appear in the Pronaos monograph plans as round, while it is possible to check, not just in the visit to the actual building, but also in the published photos, that they are actually square. The bow windows of the meeting hall do not appear either in the Pronaos monograph, and are taken here from (Ábalos et al. 2009, p. 468).



Fig. 16 Alejandro de la Sota, General Post Office and Telecommunications building, León. View from southeast. Photo: author

From this, the plans and elevations can be reconstructed. The long elevations are defined at the constructional level by a 116.66×90 cm grid, to which the openings and the other elements conform. However, this grid does not extend to the side elevations, and no equivalent grid has been found in them. Therefore, there is no way to find out the exact dimensions of the steel structure in the cross section from the available drawings.

Remarkable is the fact that the proportion defined by the dimensions of the constructional grid is $116.66/90 = 1.296... \approx 2:\phi$ (deviation: $100 * [1 - (1.296/2:\phi)] = 4.8\%$). As we will see, this proportion is the basis of the design's geometry.

According to this criteria, we will consider a total building length of $700 \text{ cm} \times 8 \text{ bays} = 5600 \text{ cm}$ axis. The height of building, measured from ground level to the topmost parapet coping (excluding the penthouse apartments), is $90 \times 23 \text{ panels} = 2070 \text{ cm}$. On the other hand, the building width can be estimated from the published drawings; we will assume here an overall width of 2690 cm axis.

The overall proportions can be deduced from these dimensions (Fig. 18):

- *Plan* $P_p = 5600/2690 = 2.081 \approx \text{double square}$ (deviation: $100 * [1 - (2.081/2)] = 4.0\%$).
- *Long elevation* $P_{le} = 5600/2070 = 2.705 \approx 4/\phi$ ($4/\phi = 2.4721...;$ deviation: $100 * [1 - (2.705/4/\phi)] = 9.4\%$). This is equivalent to a series of four vertical Golden rectangles. The real proportion is closer to the ideal one if the basement drawn in the south elevation in (Sota 1989, p.181) is considered, in which case the total building height is 2170 cm and $P_{le} = 5600/2170 = 2.58$ (deviation: $100 * [1 - (2.58/4/\phi)] = 4.3\%$).
- *Side elevation* $P_{se} = 2690/2070 = 1.299 \approx 2/\phi$ (deviation: $100 * [-(1.299/2/\phi)] = 5.0\%$). Again, the real proportion is closer to the ideal one if we consider both the additional height of the penthouse apartments and the additional width

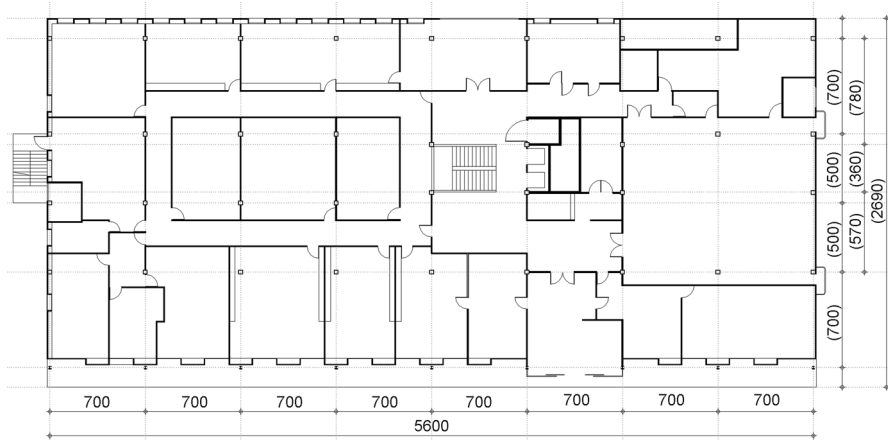


Fig. 17 GPO and Telecom building. First floor plan. Drawing by author, after (Sota 1989, p. 178). Estimated dimensions in parentheses

of the south elevation canopy (Fig. 19). In this case: $Pse = 2892/2340 = 1.235$ (deviation: $100 * [1 - (1.235/2/\phi)] < 0.1 \%$).

The inclusion of the canopy¹⁵ of the south facade as part of the overall volume, regardless of the real importance of this element in the actual building (despite its relative insignificance in the drawings), which at first sight may be regarded as a sophisticated procedure that tries to fit the section into some known proportion, can be, however, revealing of the nature of the interpretation of the work of architecture. We find a precedent of this in Peter Eisenman's analysis of Terragni's Casa del Fascio in Como (Eisenman 2003, p. 86). In Eisenman's analysis, the building plan only reads as a perfect square when the glass panel of the rear stairs (which relevance in the perception of the volume as a whole is negligible) is opened to its full extension (Fig. 20).

In our case, we find further confirmation of this when we analyse the cross section usually published (Fig. 21). We have not taken this section into account here, as it seems to correspond to an intermediate design stage, and it is not consistent with the rest of the drawings.¹⁶ However, as in the case of the side elevation, it is necessary to consider the canopy width to find a readable overall proportion, a square in this case. Likewise, it is remarkable that in these drawings this canopy measures approximately 250 cm, while the built canopy, as shown in the construction section published on the website of the Fundación Alejandro de la Sota, is only 150 cm wide.

Level 2: Structure

The building plan consists, in the long direction, of eight bays with a 700 cm centres width, while it is organized crosswise as a ABCCBA sequence in which

¹⁵ See this canopy in the actual building in Fig. 16, on the lower side of the photo.

¹⁶ However, no updated cross section has been published.

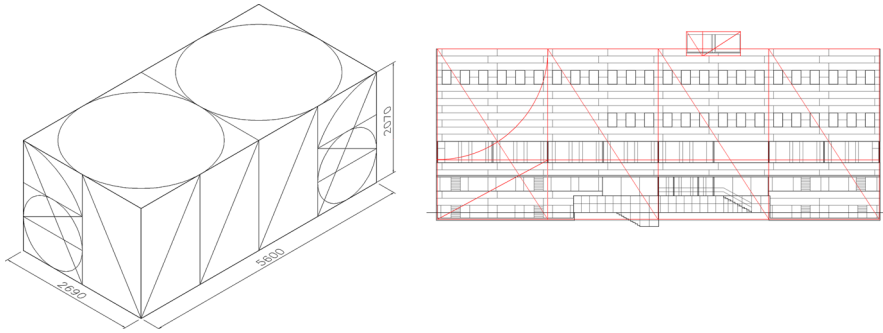


Fig. 18 GPO and Telecom building. Diagram showing proportional system in volume and in the south elevation. Drawing by author, after (Sota 1989, p. 181)

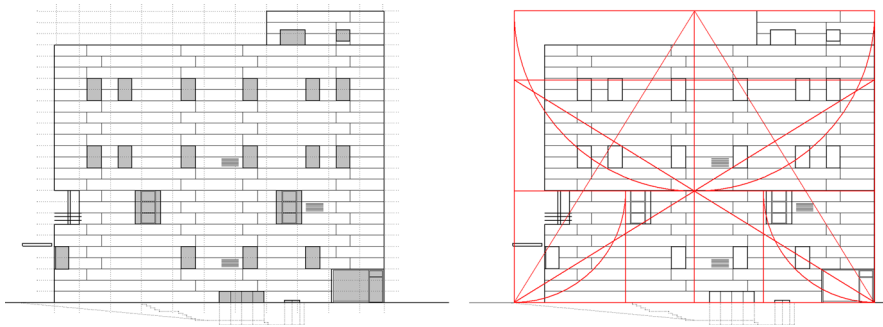


Fig. 19 GPO and Telecom building. East elevation and diagram showing proportional system. The overall proportion of this elevation is a $2:\phi$ rectangle as long as the entrance canopy (see it cantilevering on the left hand side of the elevation) and the penthouse dwellings are considered. Drawing by author, after (Sota 1989, p. 180)

$A = 150$ cm, $B = 700$ cm, $C = 500$ cm. It is necessary to estimate these dimensions from the published drawings since no explicit dimensions have been found in the bibliography. In the area surrounding the main staircase the structure changes slightly, adopting in the two consecutive bays the sequence: ABCDEA, where: $A = 150$ cm, $B = 700$ cm, $C = 570$ cm, $D = 360$ cm, $E = 780$ cm.

Therefore (Fig. 22; estimated dimensions in parentheses):

- $(780)/700 = 1.11$ (undefined proportion).
- $700/(700) = 1.00$ (square).
- $700/(570) = 1.22 \approx 2/\phi$ ($=1.236\dots$; deviation: $100 * [1 - (1.22/2/\phi)] = 1.3\%$).
- $700/(500) = 1.40 \approx \sqrt{2}$ ($=1.414\dots$; deviation: $100 * [1 - (1.40/\sqrt{2})] = 1.0\%$).
- $700/(360) = 1.944 \approx \sqrt{4}$ ($=2$; deviation: $100 * [1 - (1.944/\sqrt{2})] = 1.0\%$).

The proportions in the long elevation are therefore (Fig. 23; estimated dimensions in parentheses):

- $700/(414) = 1.69 \approx \phi$ (deviation: $100 * [1 - (1.69/\phi)] = 4.4\%$).

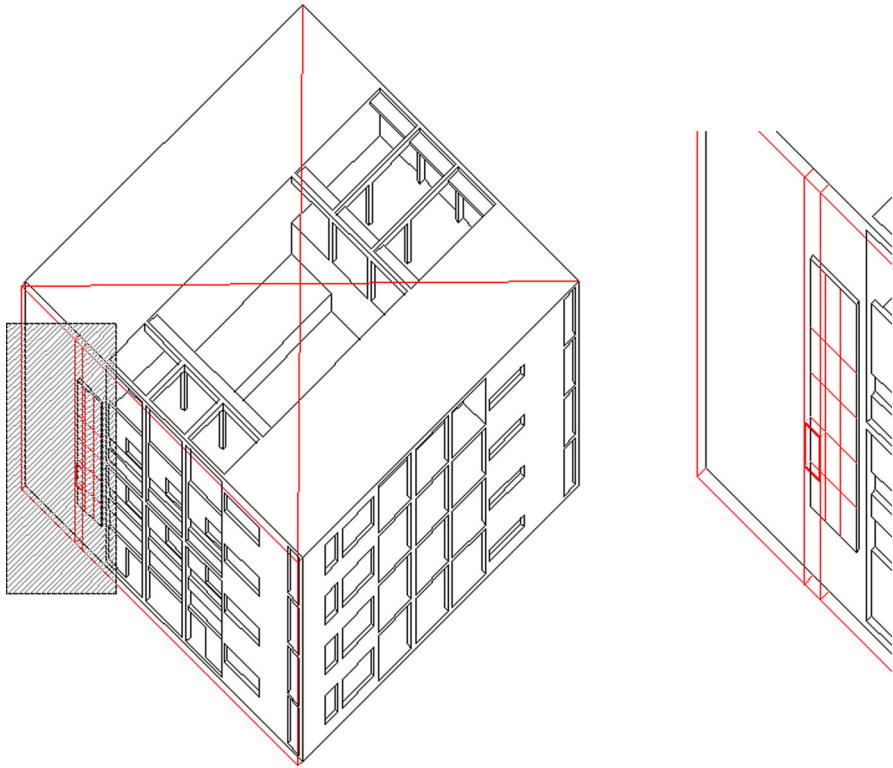


Fig. 20 Giuseppe Terragni, Casa del Fascio in Como. Diagram showing that the building is a perfect square in plan only when the rear glass panel is opened to its full extension. Drawing by author, after (Eisenman 2003, p. 87)

- $700/(312) = 2.24 \approx 1 + 2/\phi$ ($= 2.236\dots$; deviation: $100 * [1 - (2.24/1 + 2/\phi)] = 0.1 \%$).
- $700/357 = 1.97 \approx 2$ (deviation: $100 * [1 - (2/1.97)] = 1.5 \%$)
- $700/544 = 1.28 \approx 2/\phi$ (deviation: $100 * [1 - (1.28/2/\phi)] = 3.5 \%$).
- $700/408 = 1.71 \approx \sqrt{3}$ (deviation: $100 * [1 - (\sqrt{3}/1.71)] = 1.2 \%$).
- $700/280 = 2.5 = 5/2$.

This procedure yields similar results when applied to the side elevation (Fig. 24). From this, it is possible to reconstruct the proportional scheme of the three-dimensional object (Fig. 25).

Level 3: Construction

As mentioned above, the dimensions of the constructional grid can be deduced, on the one hand, from the detail drawing of the facade framework, as shown in (Ábalos et al. 2009, p. 470; see. Fig. 26), and, on the other, from the diagram showing the

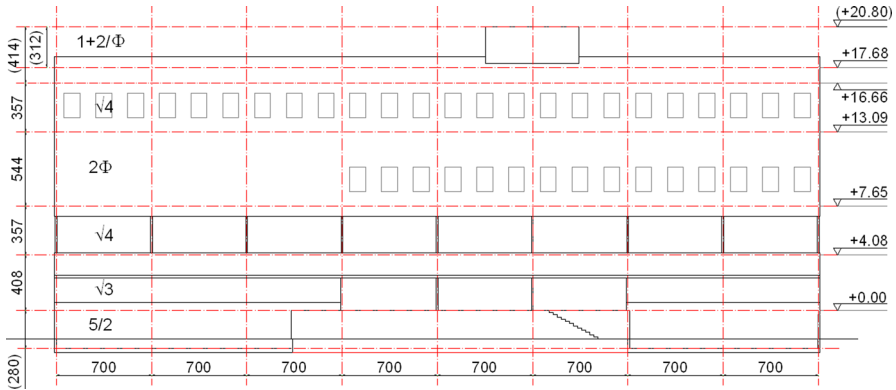


Fig. 23 GPO and Telecom building. Diagram by author showing proportional scheme in the south elevation. Estimated dimensions in parentheses

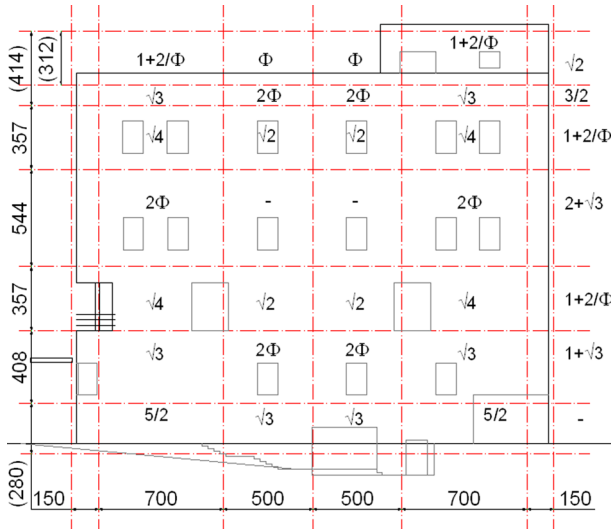


Fig. 24 GPO and Telecom building. Diagram by author showing proportional scheme in the east elevation. Estimated dimensions in parentheses

building’s levels in (ibid., p. 448). From this, it is possible to reconstruct the constructional grid (Figs. 27, 28).

The side elevations are laid out on the same 90 cm module of the facade panels, but their grid does not stick to the 116.66 module, even though the openings repeat the typical opening dimensions. However, the plan shows the position of the steel secondary beams supporting the floor slab, which are located at 252 cm centres. The grid underlying the side elevations is therefore a 252 × 90 cm grid, which may read as a 2 * √2 proportion (as 252/90 = 2.8, and 2 * √2 = 2.8284...; deviation: 100 *

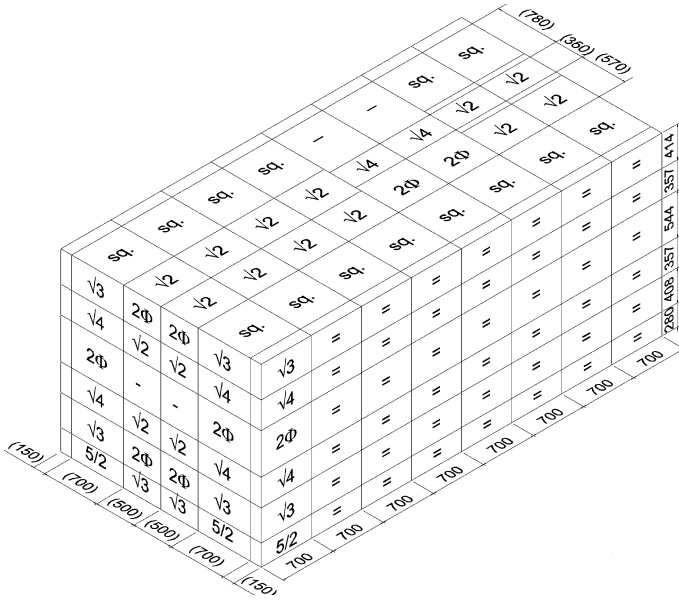


Fig. 25 GPO and Telecom building. Diagram by author showing proportional scheme of the overall volume. Estimated dimensions in parentheses

$[1 - (2.8284/2.8)] = 1.01\%$), although no advantage is given by the use of this proportion.

Therefore, in this design it is possible to reconstruct a complete proportional structure which ranges from the constructional grid to the overall proportions of the whole, with the structural grid as an intermediate level. On the other hand, the fact that the panel measures approximately half of the Corbusian ideal man’s height (Le Corbusier 2000, p. 42), and that the typical opening has precisely that height (180 cm), suggests an interpretation of this proportional scheme in terms of scale: the continual reading of dimensions from the constructional level, which, as we have seen, refers directly to human size, up to the overall volume, admits a reading of the building’s dimensions in relation to human height, which constitutes the very definition of scale in architecture.

Conclusions

By the analysis of these three works, we have aimed at understanding of a very particular use of regulating lines and proportioning systems which constitutes, in our view, an original contribution to these techniques in Modern architecture. As opposed to a conventional use of standard grids, Alejandro de la Sota defines, for each design, the dimensional structure that is best suited to the problem in question, achieving at the same time a high degree of symmetry even in complex designs.

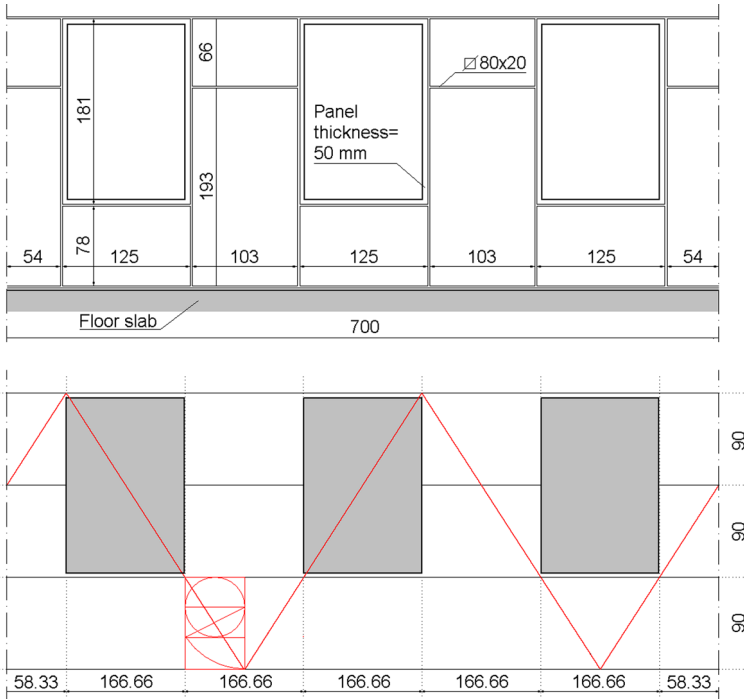


Fig. 26 GPO and Telecom building. Facade framework detail and elevation of facade openings, showing their proportional scheme based on $2:\phi$. Drawing by author, after (Ábalos et al. 2009, p. 470)

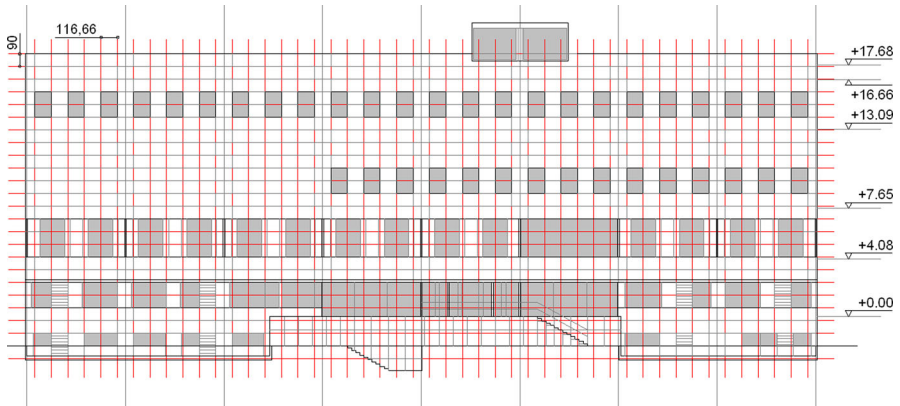


Fig. 27 GPO and Telecom building. South elevation showing the constructional grid. Drawing by author, after (Sota 1989, p.181)

The work of Alejandro de la Sota constitutes thus a rich sample of a non-conventional use of proportional systems in modern architecture. Therefore, aside from the outstanding architectural quality of his work, the analysis of his designs in

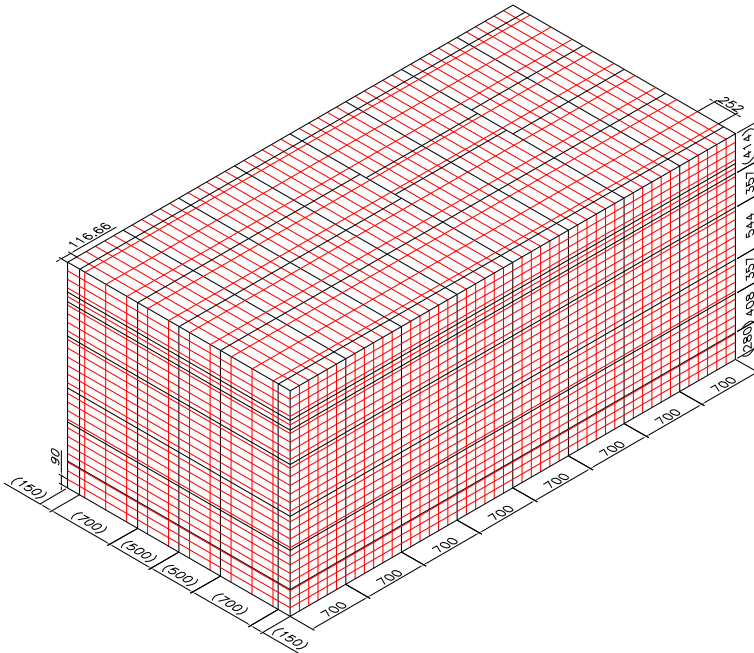


Fig. 28 GPO and Telecom building. Axonometric diagram showing the 3-D constructional grid

terms of proportioning structures gives a significant perspective in the understanding of the design methods in Modernism.

The meaning of these proportional structures does not correspond at all to an idealist stance towards architecture, but relates to the necessity of formal coherence in designs that have to satisfy complex requirements of site and brief. By means of these techniques, a ‘symphonic’ character is achieved, without resorting to an oversimplification of form that prevents an appropriate response to those requirements.

We find, among Sota’s autographic writings,¹⁷ an important clue in this sense. Regarding the César Carlos project, Sota writes:

...se ha luchado por una síntesis entre el racionalismo de la ordenación espacial y el organicismo de las circulaciones y de la textura, hablando en todo el diseño un mismo idioma (my emphasis).

[There has been a struggle for a synthesis between the rationalism of the spatial arrangement and the organic of circulation and *of texture*, speaking the same tongue in the whole of the design (my trans)].

¹⁷ This text, a small summary of the aims and achievements of the César Carlos design (apparently not intended for publication) can be found at <http://archivo.alejandrodelaota.org/en/original/project/81> (Access date: 29 October 2015) with the rest of the design’s drawings and documents.

We wonder whether this texture to which Sota refers here is the visual texture of the building materials and elements,¹⁸ in the usual sense of the word, or rather it refers to that texture which, according to the Encyclopaedia Britannica, consists of ‘...the structure, arrangement of the parts of a body, of a work’, that is to say, that ‘polyphonic’ proportional basis which contains inherently the design’s form, from the whole down to its details, ensuring the visual and spatial homogeneity-in-variety which constitute the classical idea of harmony.

It remains an open question whether the proportions found here are deliberate. To my knowledge, there are neither public statements of Sota’s in this regard, nor any published analyses of his work in this sense. Did the architect consciously use any proportioning techniques, or are they merely derived from his intuitive ‘sense of form’, in a more or less unconscious way? It can be argued that proportional systems may appear in a design as a result of the very attempt to generate a unitary form, even if no explicit proportioning techniques are applied. On the other hand, in those designs based on square grids, the divisions can often display, unintentionally, Fibonacci rectangles such as 5:3 or 8:5, and may therefore appear to be based on ϕ . However, despite the lack of any statements from the architect, and despite the deviations from the ideal proportions, wherever the ϕ rectangle is in the base of the design, it is quite patent, unequivocal, and clearly distinct from those designs in which it is not.

Acknowledgments I would like to thank the Director of CENIM for allowing me to visit the premises so as to carry out the field work necessary to confirm some of this paper’s hypotheses. I am also grateful to the reception staff at the César Carlos student housing for kindly showing me round the social building and letting me make some relevant measurements inside the building.

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¹⁸ Texture not just in the sense of the surface texture and relief of materials, but also as the visual features of their arrangement and combination. Giedion uses this term in this sense, for instance, when he speaks about the use of texture in Aalto’s Villa Mairea (Giedion 1967, p. 646).

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