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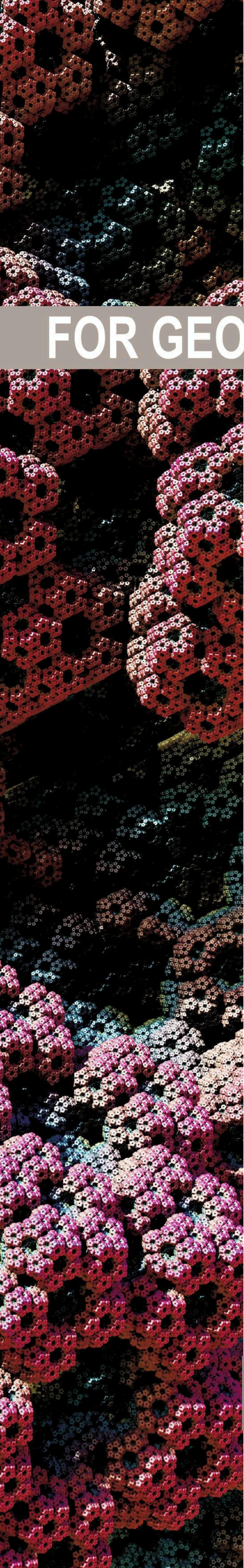

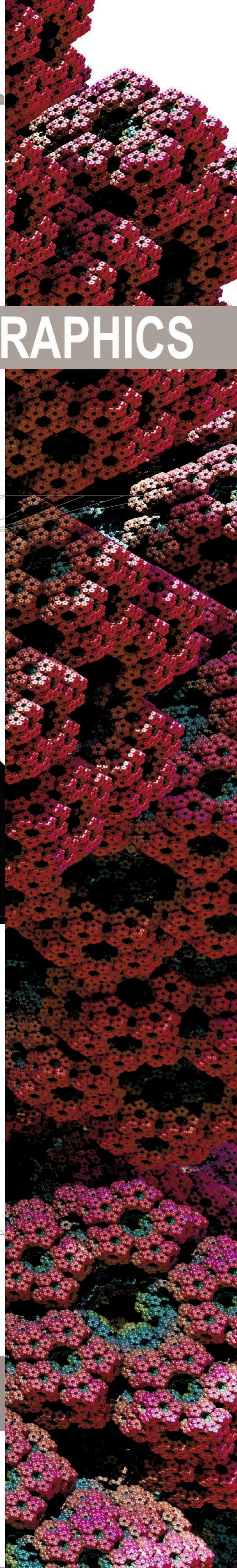

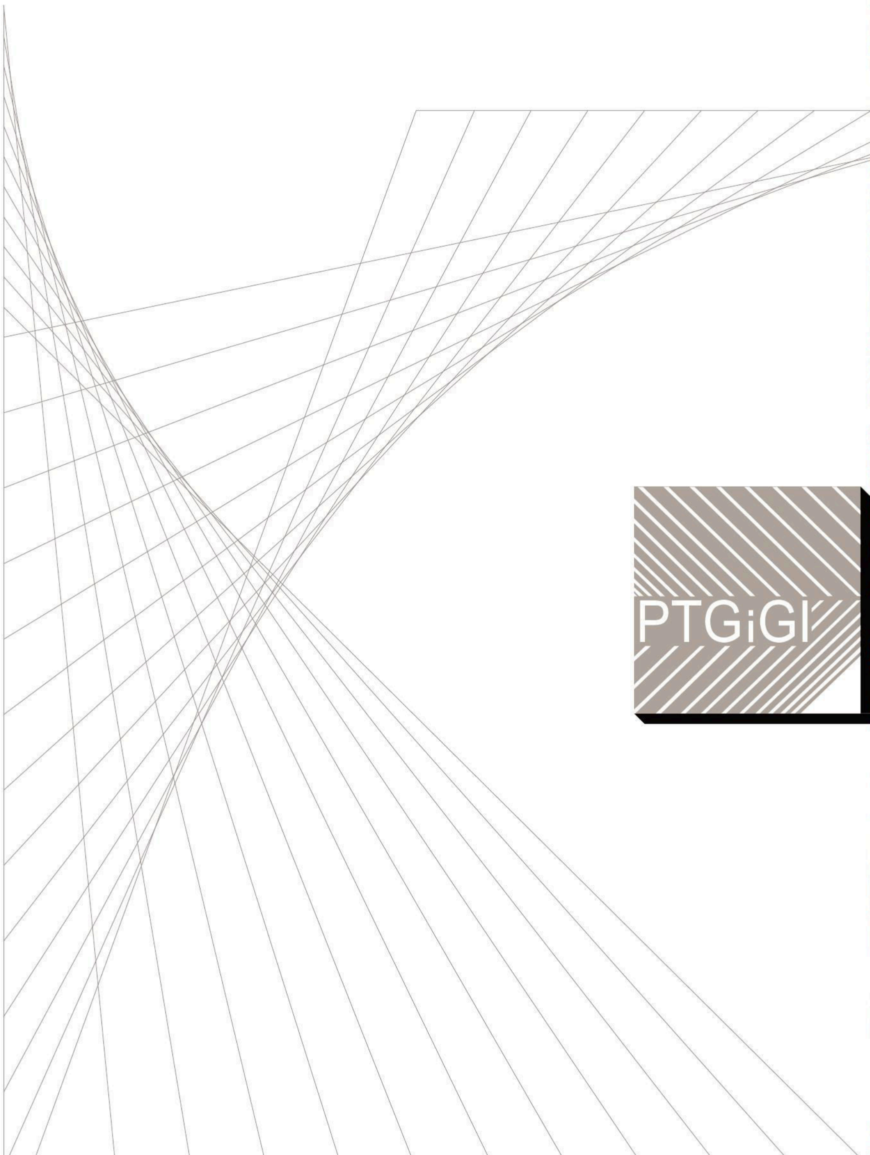

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DISCOVERING GEOMETRIC STRUCTURES OF BUILT ARCHITECTURE

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Abstract: The analyses of geometric structures in built architecture can show various aspects of the role of geometry for design processes in architecture. The structures can be found in floor plans, facades, ornaments or city structures. We will show some examples which had been selected by students of architecture in an optional course, called “Design Geometry” (“Gestaltungsgeometrie”) in 2017.

Keywords: design geometry, architectural design, ornaments, built architecture

1 Introduction

The analyses of geometric structures in built architecture can show various aspects of the role of geometry for design processes in architecture. The structures can be found in floor plans, facades, ornaments or city structures. We will show some examples which had been selected by students of architecture in an optional course, called “Design Geometry” (“Gestaltungsgeometrie”) in 2017. The range and diversity of design geometry as fundamental background for architectural design gets obvious. At the same time, cross references between first disparate topics could be discovered. An overall geometric foundation for architectural design had been a result in this way, starting empirically with fascinating examples.

2 Patterns and Ornaments

Inspired by an excursion to Andalusia, studies of ornaments and their symmetry groups had been one of the fundamental topics. The analysis of a mosaic in the Alcázar in Sevilla led the student to work on the wall paper groups based on the possible tessellations.

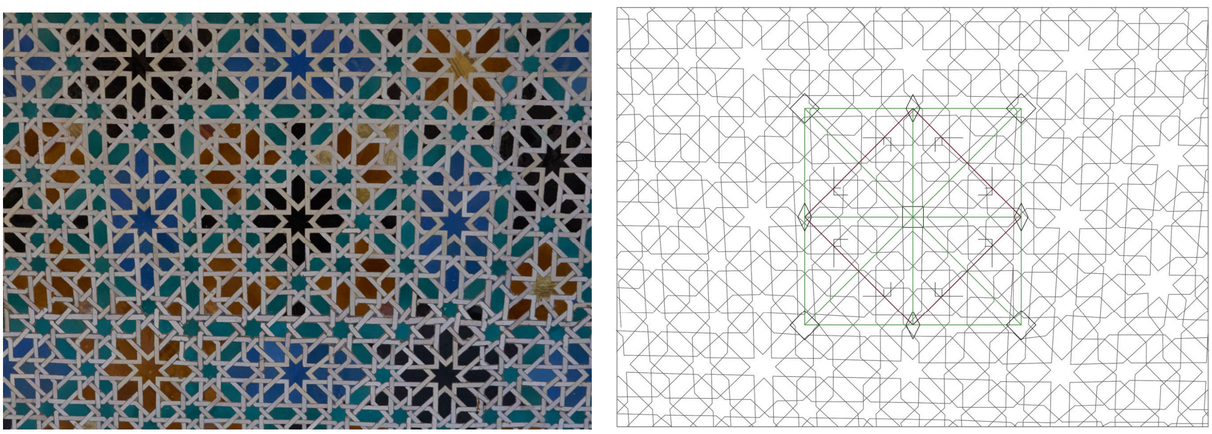

Figure 1: Mosaic in the Alcázar in Sevilla and the analysis of the symmetry group p4m by student Katharina Sondenheimer

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On the basis of a regular tessellations by squares, the group p4m has two rotation centres of order four, and reflections in four distinct directions. It has additional glide reflections whose axes are not reflection axes; rotations of order two are centred at the intersection of the glide reflection axes and all rotation centres lie on reflection axes. [1]

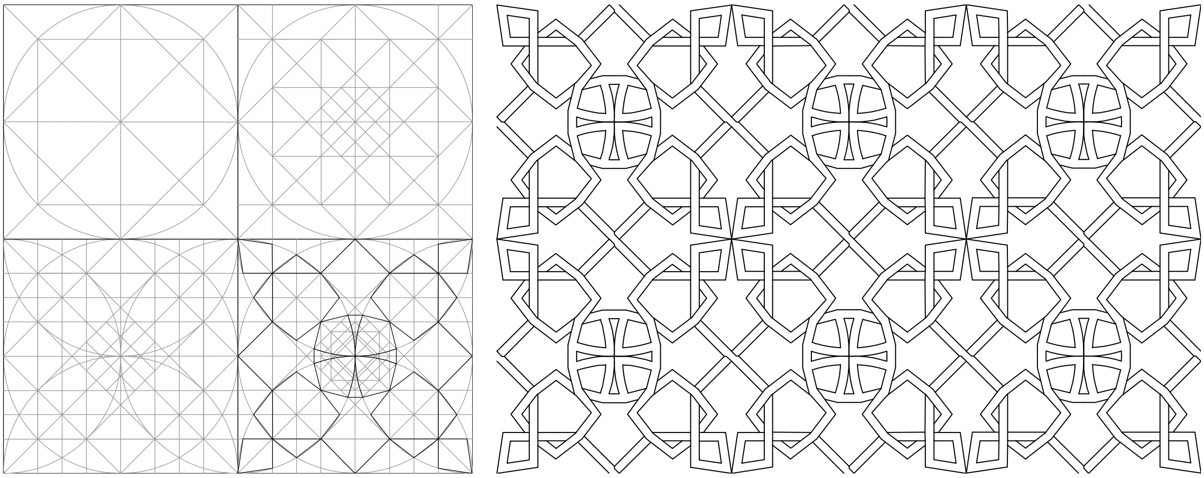

Figure 2: Creation process of a pattern by Katharina Sondenheimer with introducing of interweaving

The book of El-Said and Parman [2] was helpful for the own pattern creation process, starting with a square and developing root two proportions by further subdivisions. By selecting lines in the subdivisions and introducing interweaving, the student produced her own patterns in simulated interweaving with laser cutting and real interweaving with polymer clay.

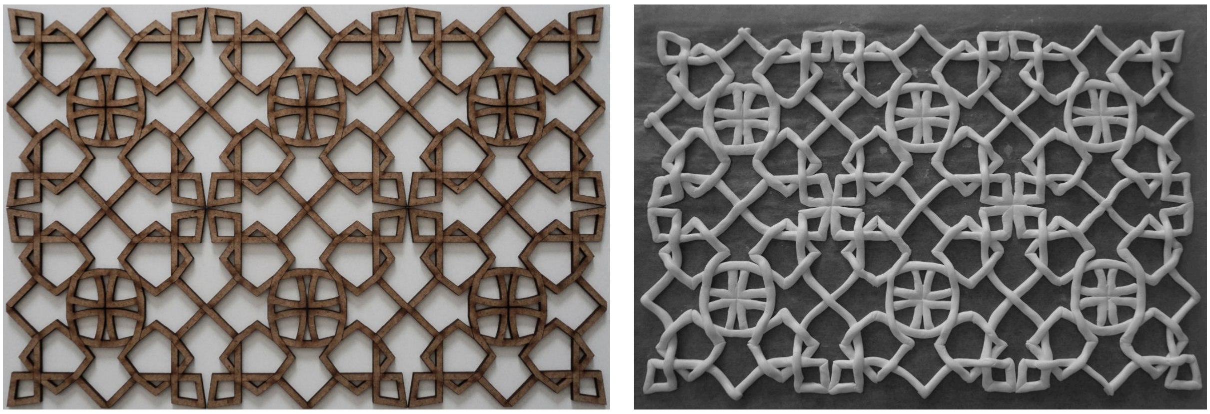

Figure 3: Models of the simulated and real interweaving patterns by Katharina Sondenheimer

Another study of ornaments had been stimulated by the Nordic animal ornamentation, found in the Portal of the wooden stave church Urnes, Norway, 11th – 12th century AD. Investigations on braided ornamentations complemented the background for own ornaments for a facade by Moritz Brucker.

Figure 4: Ornamentations at the church Urnes, Norway [3] and braided ornamentations [4]

The next step in his studies had been the combination of both ornamentations and possibilities of ornament compositions around the edges and connections between its particular parts. Fig. 5 shows the ornaments und their combinations, created by the student Moritz Brucker. The student developed modules of braided ornamentations which solve the problem of connections in various situations (Figures 5 and 6).

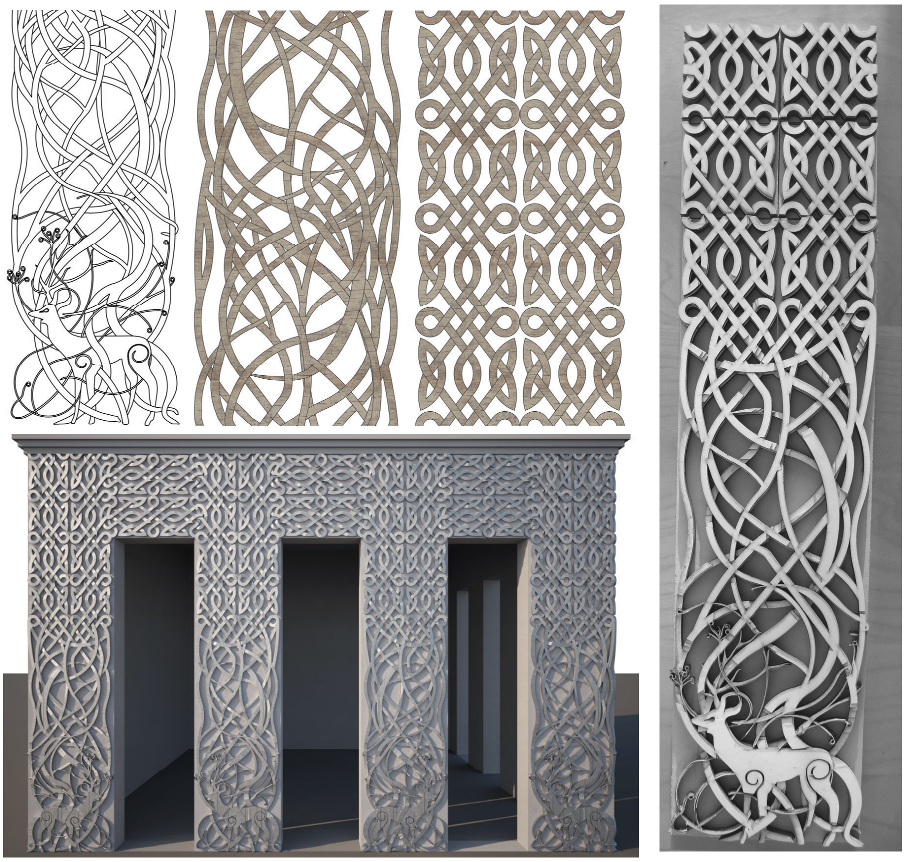

Figure 5: Animal style and braided ornaments with their combination, created by student Moritz Brucker

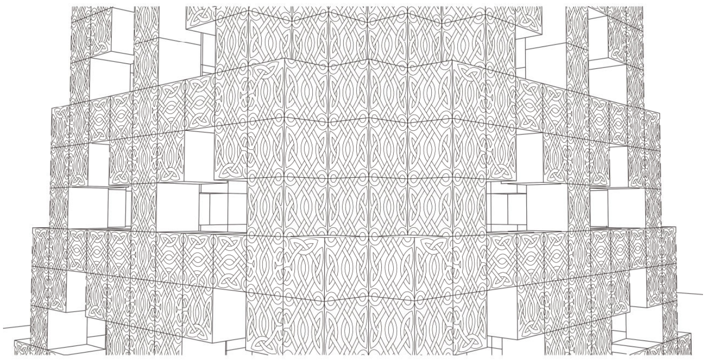
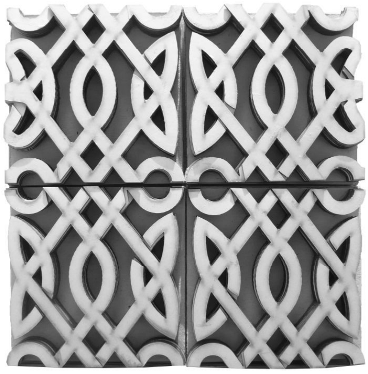

Figure 6: Structural modules for the braided ornaments with the connection possibilities by student Moritz Brucker

3 Modular Building Structures

An excursion to England and Scotland inspired another student to study the geometric principles of structuralism. The point of interest has been focused on the complex "The Lawn" which is the design of the student houses' quarter and developed by the architects Gilespie, Kidd and Coia (1961-79). The student had been fascinated by the possibility to develop an exciting building structure out of a simple geometric basic form, which can be expanded infinitely (Fig.7).


Figure 7: Photo and 3D model by Falk Ahlhelm of the student houses of Hull University, The Lawns, Cottingham

After studying the concepts of various structuralistic architecture for example the work of Herman Hertzberger [5] and experiments by Günter Günschel [6], the student Falk Ahlhelm chose the hexagon as his basic cell for a living module. An important characteristic of structuralism can be seen in working with predominantly simple geometric grids to reinforce the context and the communication relationships of the residents. The student tested structural formation processes by the transformations translation, rotation, reflection, stacking or juxtaposition. One concept had been created by stacking the hexagonal living modules along expanded hexagonal connecting routes, docking at a big communication core. The hexagon is appropriate for tiling and it gives also the chance to develop an interesting floor plan for one living cell by referring to a design by Günter Günschel with octagons. A second concept referred to Archimedean tiling with the combination of squares and hexagons in the shape of a ring. Extrusion, stacking and rotations of the tiling created the concept, shown in Fig. 8 right.

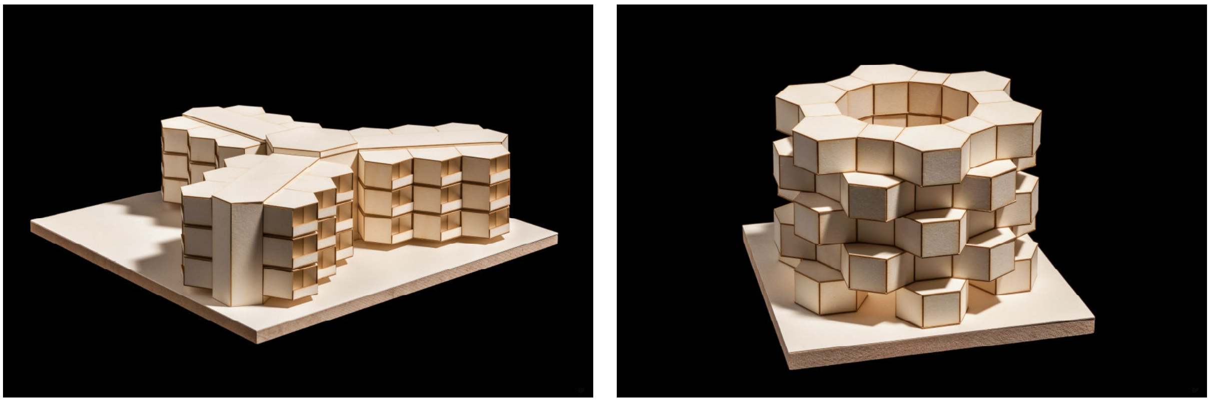

Figure 8: Modular building concepts for student housings by student Falk Ahlhelm, photos ©Bernhard Friese

4 Support Structures and Spatial Packings

The student Benedikt Blumenröder started his research with the analysis of the Hearst Tower in New York City, 2003-2006 by Foster and Partners. The façade had been analysed in reference to the composition by isosceles triangles. The triangular structure emphasizes the vertical proportions of the skyscraper and gives its expressive shape through the recut corners. In total, the building has 46 floors, of which 36 are each 4 m in height within the diagonal structure. Due to the outer diagonal support structure made of steel different sized floor areas are produced. Every eighth floor is rectangular, all others are octagonal. The proportions of the triangles result out of the concept, that the triangular frames extend over four storeys (Fig. 9).

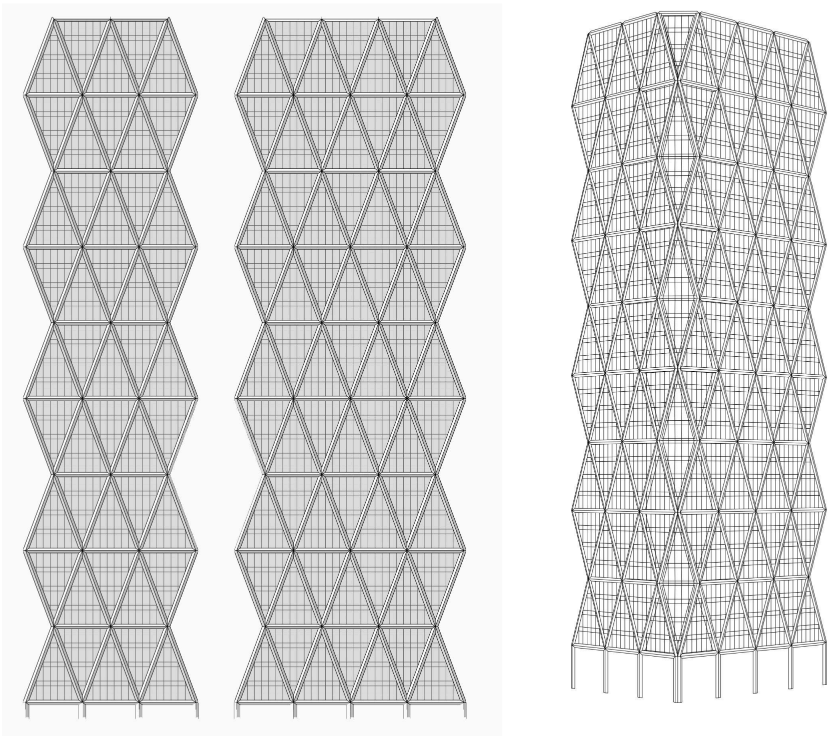

Figure 9: Hearst Tower, facade view drawing and 3D-model by student Benedikt Blumenröder

During the research, the student studied further examples of triangular structures in facades of different types of buildings, for example the church Iglesia de Soca, Uruguay, 1959, by Anonio Bonet. Each equilateral triangle of the surface is divided according fractal principles in several steps in triangles. The structure can be formed by a tetrahedra-half-octahedra package (Fig.10).

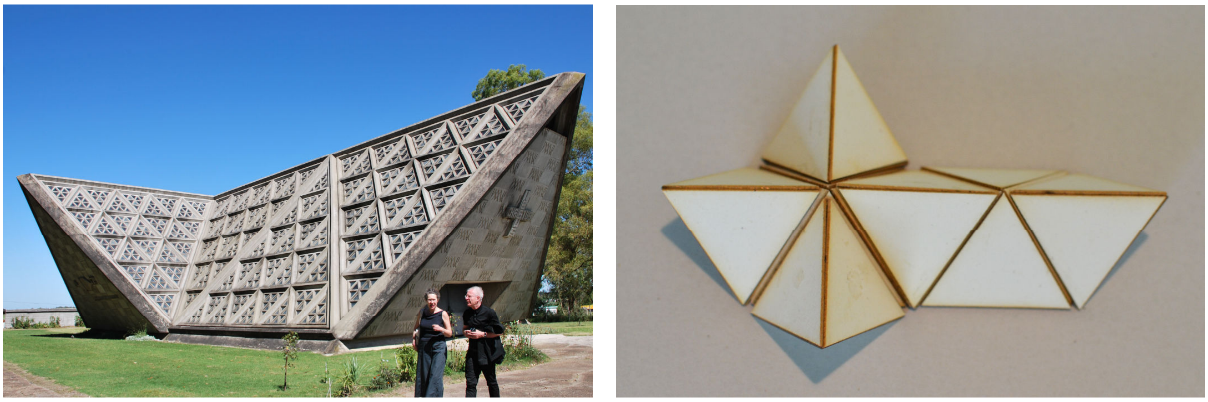

Figure 10: Iglesia de Soca, Uruguay and the structure as tetrahedra-half-octahedra package

The structure of the Philadelphia City Tower, a high-rise design for Philadelphia, USA, 1957, design by Louis I. Kahn and Anne Tyng, not realized, is also based on packages of tetrahedra and half octahedra. One level consists of three hexagons joined together. The construction of the support structure results from tetrahedra, lying half-octahedra. Each level is created by 18 tetrahedra, seven octahedral and four half-octahedra. The support structure of the tower is developed by translations from level to level in the different possible directions (Fig. 12).

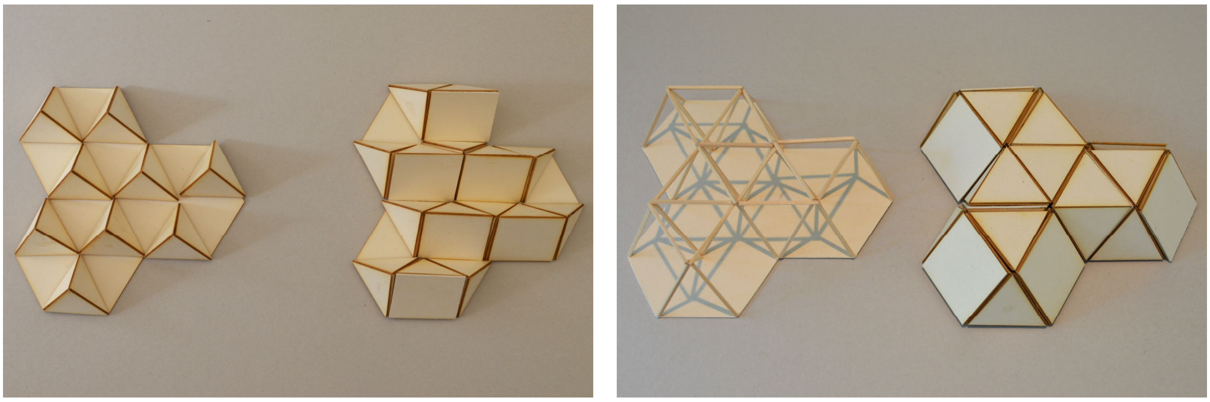

Figure 11: Construction of one level of the Philadelphia City Tower as tetrahedra-half-octahedra package

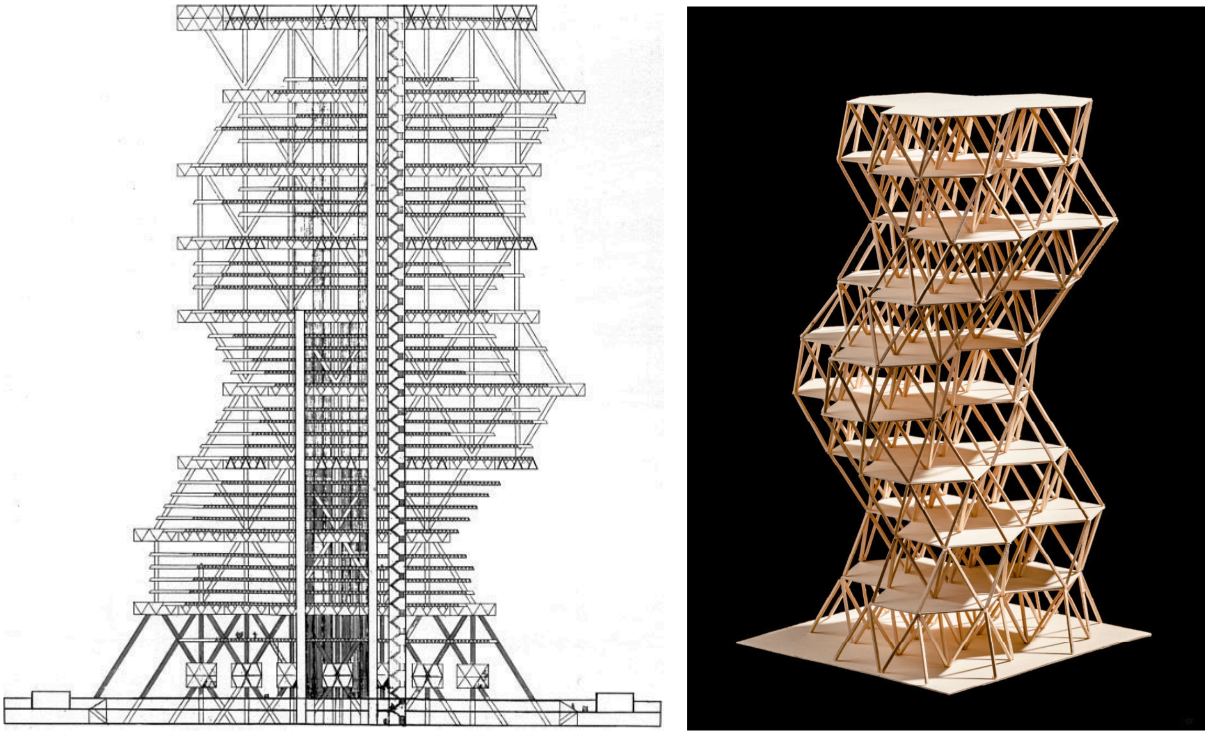

Figure 12: Philadelphia City Towers, section drawing [7] and model by student Benedikt Blumenröder, photo ©Bernhard Friese

The result of this studies had been a modular construction kit for an empirical development of building structures according the described system (Fig. 11).

5 Rational Architectures and Fractal Structures

On an excursion to Paris the student Viyaleta Zhurava discovered the design of Opéra Garnier, 1860-1875 by Charles Garnier, characterized by symmetries and repetitions of proportions and forms (Fig.13).

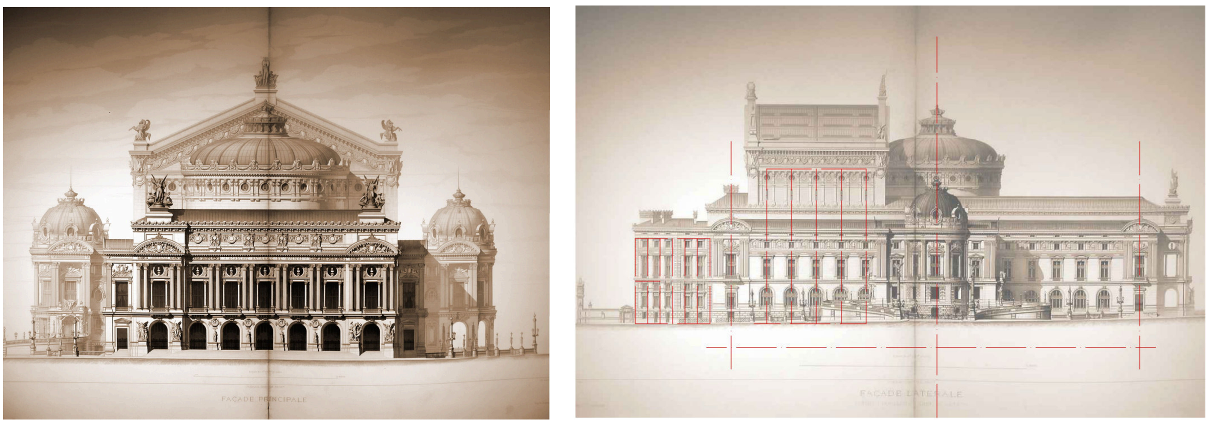

Figure 13: Opéra Garnier, front view [8] and side view with analytic lines [9]

After these analyzes the student got special attention to the design methodology of Jean-Nicolas-Louis Durand. His method is systematic and strongly linear. Starting with a simple form, it gets developed more and more composite and complex. Example of his design method, starting with a square, a rectangle, a circle or half circle are shown in Fig. 14.

The sequence from the simple to the complex reminded of the principle of fractal structures. From these ideas arose a basic element, which is applicable for the creation of living houses.

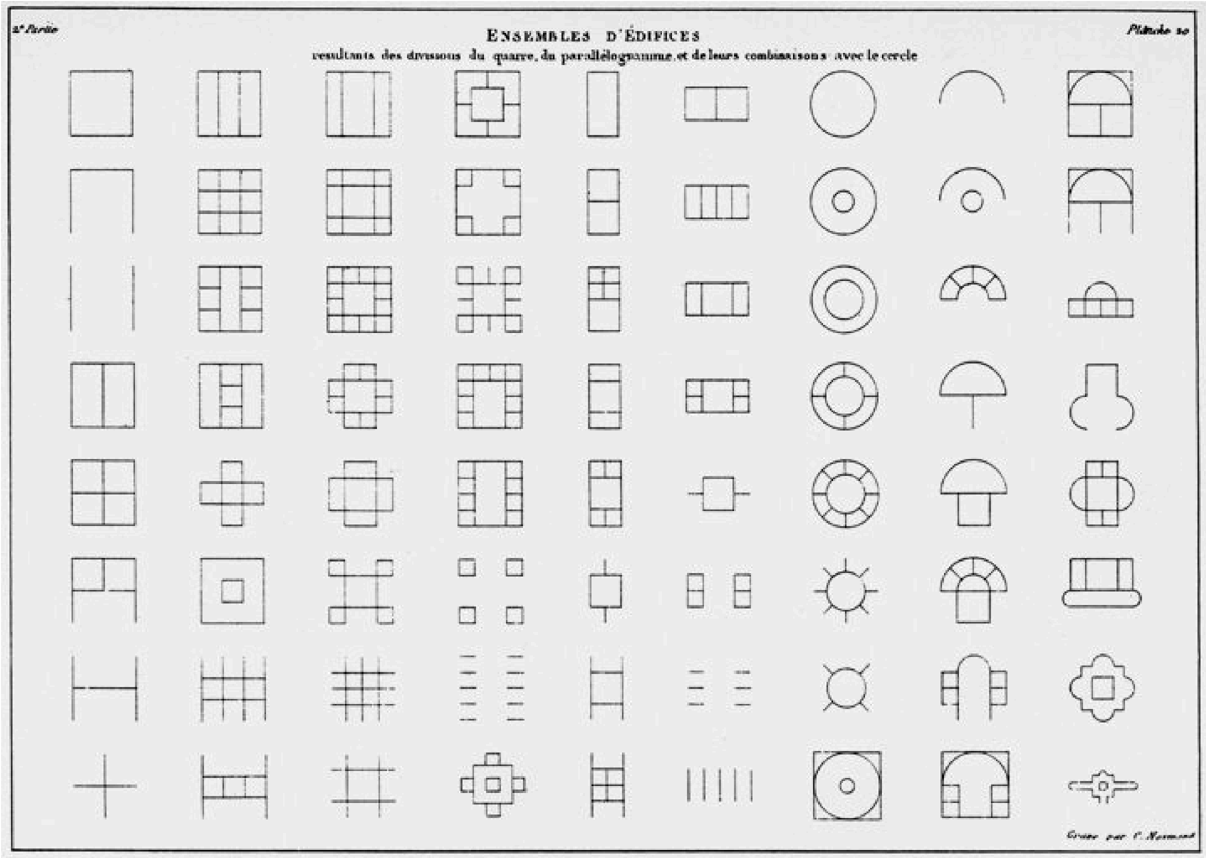

Figure 14: Jean-Nicolas-Louis Durand: Précis des leçons d'architecture. Table 20 [10]

Four apartments, which are accessed by a circular staircase, form a spiral-like structure that can be inserted into a cuboid (Fig. 15, left). From this idea, a group of buildings is formed out of four buildings. They are different, but build together an overall view, which looks from all sides like the basic figure (Fig. 15, right). Fig. 17, left, shows the model of this first fractal concepts for a residential area.

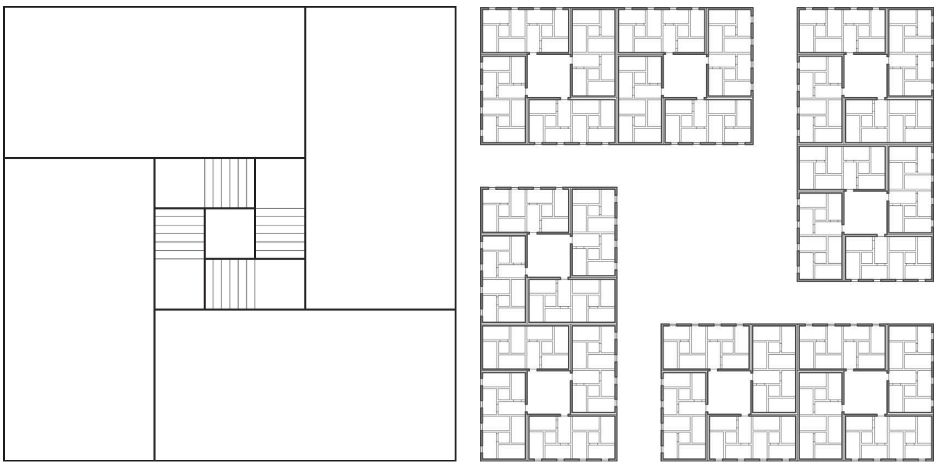

Figure 15: Fractal concept with basic element and more complex structure with four apartments

The second fractal concept is a cubic mega structure with a big number of apartments. The floor plan and all views are identical. The big number of openings in different sizes offer a generous amount of light as well as various usage scenarios like roof gardens, cafés, restaurants and further possibilities of a common usage. Fig. 16 shows the development of the fractal structure and Fig. 17, right, a model of this second fractal concept.

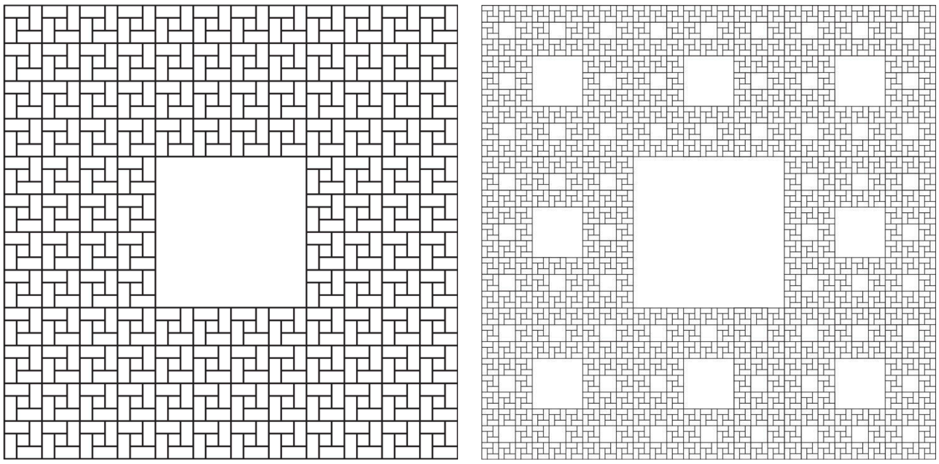

Figure 16: Fractal mega structure with openings of different sizes

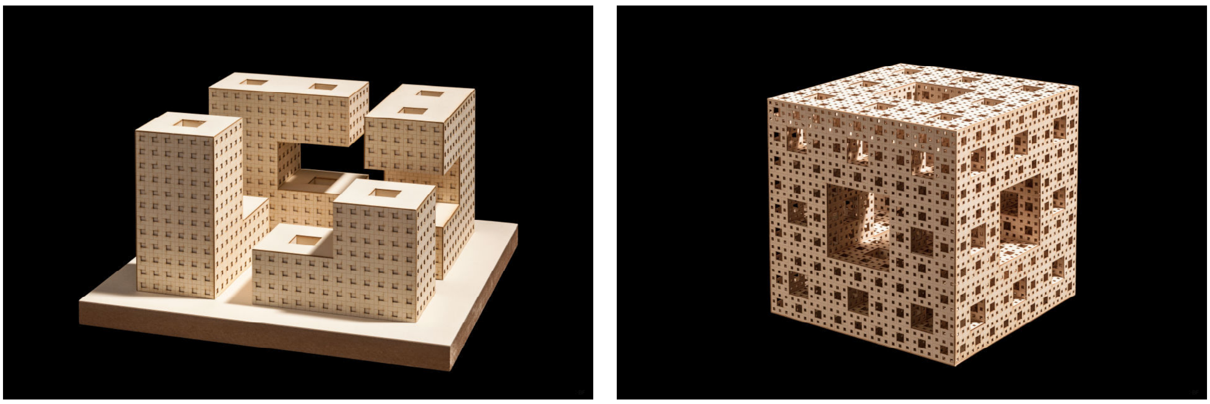

Figure 17: Models of two fractal structures for residential buildings by student Viyaleta Zhurava, photos ©Bernhard Friese

6 Conclusion

Presented here examples showed some ways to use geometric concepts for analysing and designing architecture. Design methods according to strong structural concepts give the chance to develop a geometric fundament for architectural design. The didactical approach with an empirical starting point and going only then more deeply in the underlying geometric principles turned out to be effective in the motivation of the students. Structural design geometry approaches had been a topic of research by the author also in other architectural relationships and examples [11], [12]. These examples together try to develop a design geometry for architecture.

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ODKRYWANIE STRUKTUR GEOMETRYCZNYCH PROJEKTU ARCHITEKTONICZNEGO

Analizy struktur geometrycznych w architekturze mogą ukazać różne aspekty roli geometrii w procesach projektowych. Struktury te można znaleźć w planach pięter, fasadach, ornamentach lub strukturach miejskich. W artykule pokazano przykłady obiektów architektonicznych, które zostały wybrane przez studentów architektury w ramach opcjonalnego kursu w 2017 roku, zwanego "Geometrią formy architektonicznej" ("Gestaltungsgeometrie"). Odkryto powiązania między różnymi elementami i w ten sposób powstała ogólna podstawa geometryczna dla architektury, której empirycznym źródłem były fascynujące przykłady.