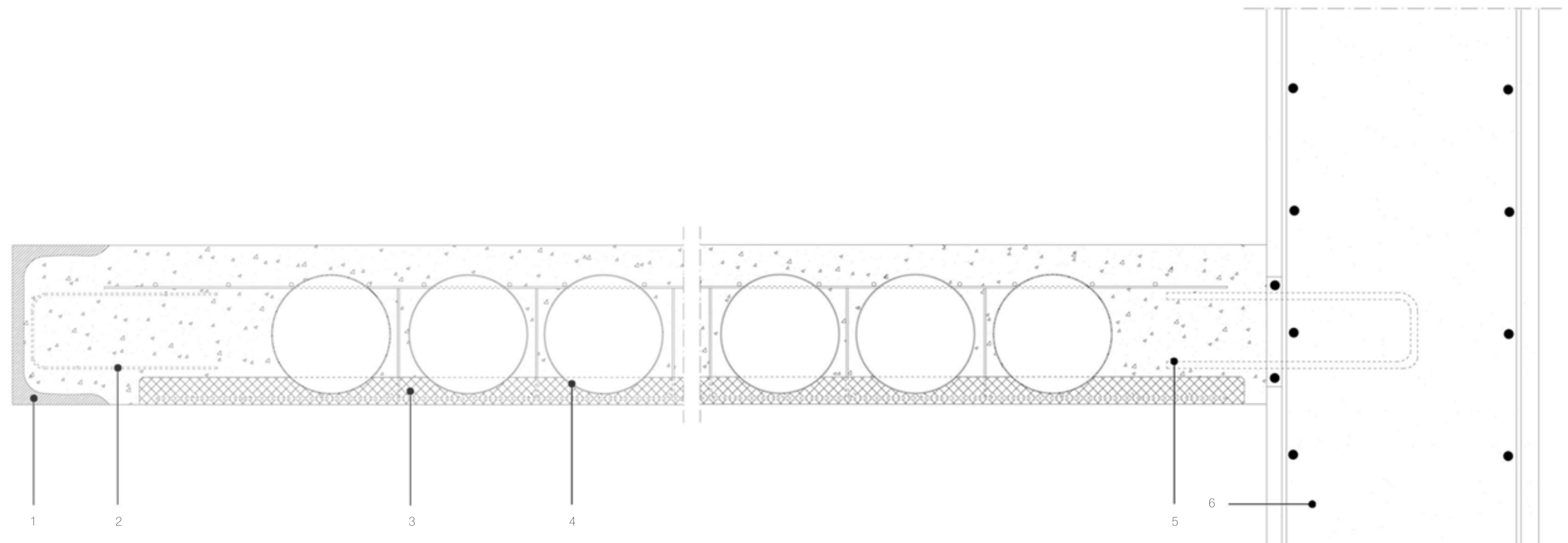
Structural Design LIGHTWEIGHT BIAXIAL FLOOR SLABS



FLOOR SLABS DETAIL
VERTICAL SECTION scale 1:10

1 boundary profile

2 reinforcement bars d 20 mm

3 pre-cast concrete biaxial slab 50 mm

4 HDPE polyethylene spheres

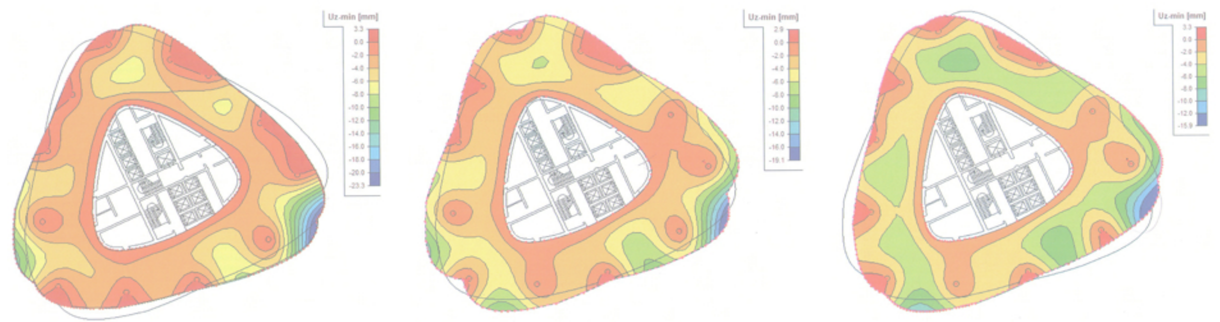
5 concrete column d 800 mm

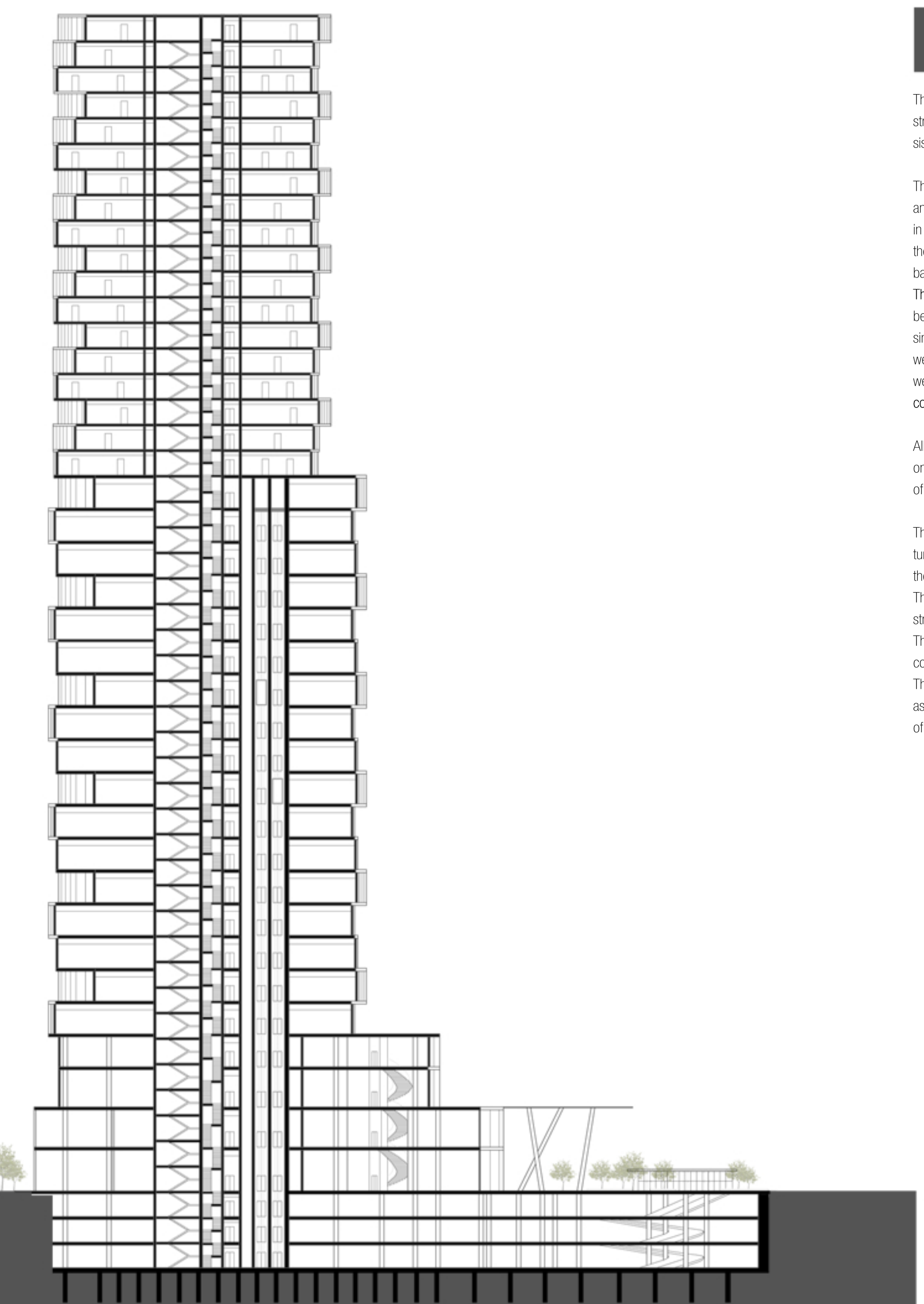
6 core-anchor steel element

The structure of the floors is realized through lightweight biaxial slabs known as bubbledecks and constituted by a precast concrete deck integrated with HDPE spheres and iron reinforcement cages. Lightened floors structures are mostly required when large spans have to be realized without the use of protruding beams or when the big load of the structure has to be reduced because of its large dimensions.

The necessity to have big spans with few columns is worth to the flexibility of the spaces, more and more required: in this sense the use of this kind of technology helps in reaching the goal. The main characteristic is the possibility to employ bi-directional decks that allow the bubbledeck floor to be used for large surfaces to be covered without, or at least minimizing, the use of beams of big dimensions and several columns.Materials commonly used in bubbledecks constructions are steel, typically FeB 550/460, concrete made by standard portland cement C45/55 and HDPE (High Density Polyethylene/ Propylene) spheres, also obtained from recycled materials.
Bubbledeck provides a graph in which for different value of the maximum moment acting on the plates, there is suggested the right thickness of the same to use to have a sufficient strength of the floor.

The images show the computer analysis of the vertical displacement caused in the floor slabs by gravity loads for the three different configurations. The critical points are evidenced by the blue traces, which are of course emerging in the overhangs and where the projecting spans are the largest. The less solicited parts are, instead, those around the columns and the core.
The slab dimension that satisfies the verification is the 450 mm thick for the office floors and the 340 mm thick for the residential floors.





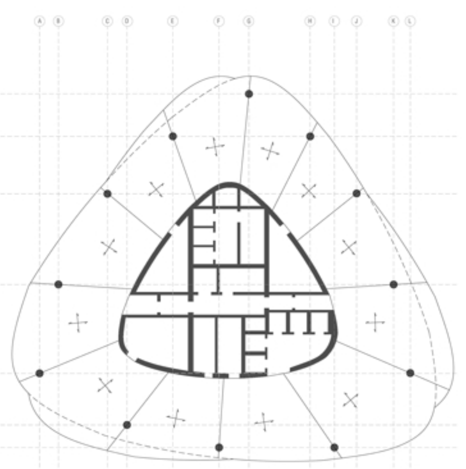
CENTRAL BEARING CORE

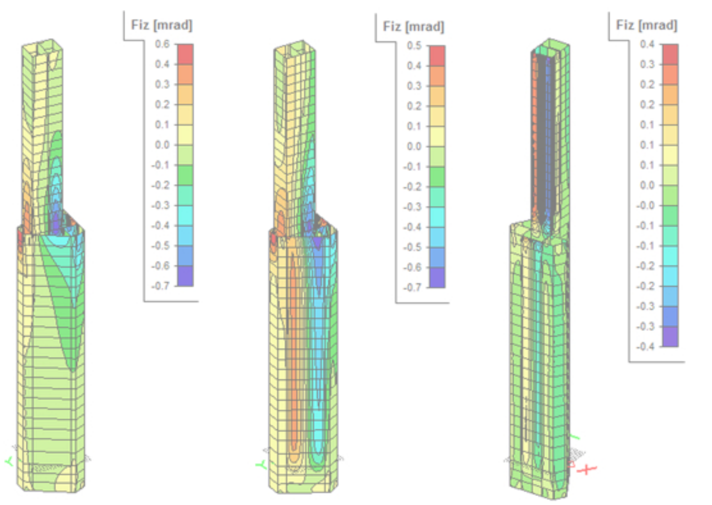
The structure of the designed building is constituted by a central bearing core, which carries almost the whole lateral load of the construction. The core is a reinforced concrete structure realized with bearing walls whose dimension is calculated according to the resistance to the stress caused by wind action.

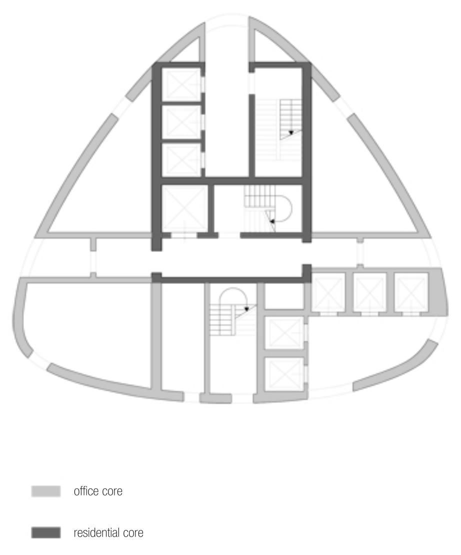
The central element hosts the services of the buildings, such as emergency stairs and elevators that allow the access to all office and residential floors. The bearing core for the two part of the building, which is subdivided, as described in the previous chapters, in height between the office part at the bottom, and the residential part at the top, is different: the residential core is smaller than the office's because the stairs and lift serving the first floors stop at the end of the lower block and the deposit spaces and common bathrooms that occupied the rest of the space in the core in the office floors are not necessary anymore here.
This is functional to reduce the self weight of the structure as the building rises in height, even if a lower resistance of the core have been necessary to be taken into account for the reduced mass of the same. However, the smaller core is included in the larger one since the first floors and is just reduced in size as the office part stops. The central core is integrated by perimeter columns that however have no role in the resistance to lateral sway. These have just the aim of bearing the vertical loads determined by the self weight of the structure, i.e. the floors or facade weight, and live loads due to the presence of people using the building. Part of this complex load is anyway carried by the central core as well to which the floors are anchored.

All the calculations concerning the structural elements belong to a pre-dimensioning procedure based on the local regulations and on the Eurocode 1.The dimensioning of the bearing core is dependent from the influence of the lateral wind loads and on the shape of the structure.

The building is divided in two parts: one hosting mostly offices function and another dedicated to the residential function. The structure for horizontal loads, i.e. the core, is divided in the same two parts. The two parts of the core differ from each other because of the moment of inertia and of the wind load.
The core has been modelled in a three-dimensional analysis computer software in order to have a graphical output of the most stressed portions of the core.
The shape of the building is conceived as a triangular-like form, and then the calculations have been done investigating both the configuration with the "strong" angle toward the windward side, and the one with the plain facade surface toward it.
The images on the side show the deflection of the central core due to wind load for different configurations, with symmetric and asymmetric loading. The deflection at the top of the building has been verified to be under the limit value imposed by regulations of 320 mm.







Parametric Design OPTIMIZATION THROUGH GRASSHOPPER

METHODOLOGY

The parametrization of the project described has been pursued through the Rhinoceros plugin Grasshopper, a visual editor for scripting based on the algorithmic logic through which a sequence of instructions regulating different aspects of the model are traduced in three-dimensional visualization of the solution. A furthermore improvement of the same has been done by making use of Galapagos, a platform for Grasshopper useful for the optimization of the parameters defined in the latter and for researching for the best solution given a defined aim. The crucial point of this procedure is, therefore, the correct identification of the parameters that have to be analyzed and that have to deal to the final searched result. The approach here described is, then, methodological rather that resolutory in order to establish the most convenient, or at least so considered, procedure and set of parameters to reach the intended goal. The sequences of correlations established in Grasshopper can be improved, modified or integrated to be adapted to a different kind of aim rather than the one here described, or to make more precise the procedure to reach the latter.
In order to conveniently realize modifications to the project maintained as a base, some fundamental characteristics have been maintained fixed: in particular, the central bearing core and the vertical structure, i.e. the perimeter columns, have to be considered as a steady point.

GOING FLEXIBLE THROUGH PARAMETRIZATION

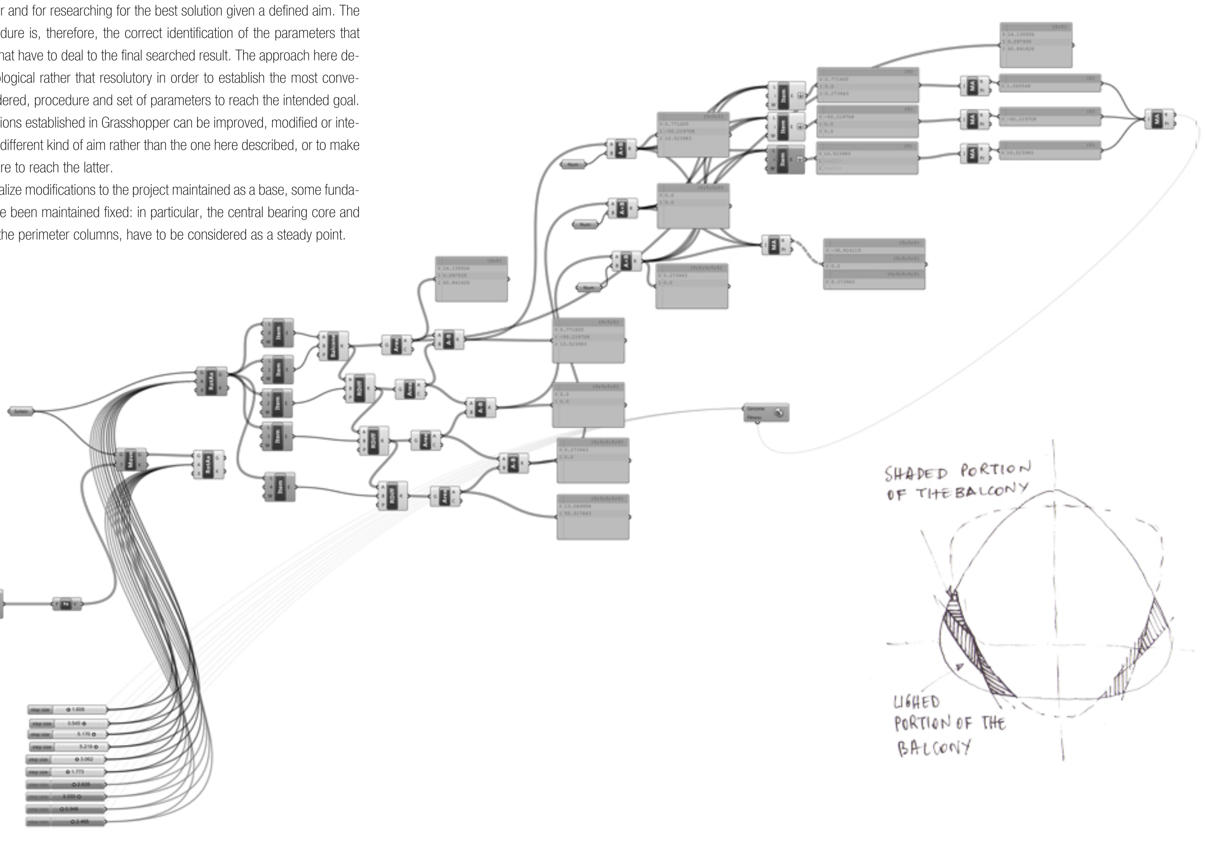
By applying a parametric approach to architecture is possible to realize a network of relations between several elements of the building and its contingencies, i.e. relations between the inside and the outside. While traditional architectural design process imposes some limits to the applicability of a project in different contexts, or at least requires a complete adaptation of the same, by applying a parametric approach with the systematic design of the single elements of the building and of the relations occurring between them, the adaptation of a same project to different context results feasible and quite easy. The project acquires, then, a certain degree of flexibility responding to changing situations in use, operation and location, interacting with the users and its framework. In this way the design process could be innovative and up to date with the contemporary design issues associated with technological, economic and social change.

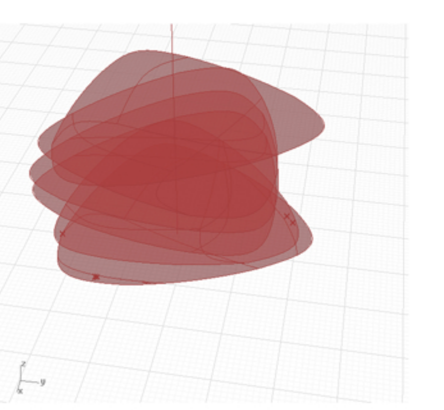
To "parametrize" the building components means to enslave the construction to certain parameters that can be modified in order to be adapted to the specific context in which the building is located. The parameters, which can be properties of the elements or relations between them, are associated to objects of different nature (colours, position, opacity, geometry, etc.) and these parameters can be associated in turn between themselves: parametricism is in fact based on the correlations which could be internal to the design or expressed between the design element and its context. Correlations internal to the design create an interdependency between the various subsystems and between the various components that constitute them. Correlation external to the design are substantially contextual adaptations. In this way the project assumes some characteristics of specificity and universality at the same time. Parametric architecture is of course more complex than traditional one, since it is not constituted just by the assembling of different and autonomous parts together with the others, but consists of the creation of a overall complex set of rules that regulates the final result.

In this way it is possible to regulate the transformation of the building by maintaining the coherence of the whole. Establishing some parameters that have to be site specific, these can be inserted in the project design as algorithms regulating corresponding characteristics of the building and therefore changing them according to the necessities changing in different situations. Using such an approach, it is therefore possible to realize a building which is coherent with the requirements of the specific project, but together easily adaptable to new situations and requests. The main part of the design becomes, then, the determination of the parameters that have to be managed through algorithms.

These parameters can be related to the architecture of the building, to the urban context, to the climate and energy systems. Here follows a description of the parameters that can be parametrized, that can be modified as required to make the final product suitable also for a different set of needs. The kind of parameters selected establish different kinds of correlations, both internal to the design, meaning, as explained, the interdependencies between elements of the building itself and of its subsystems (e.g. the height of the floors and the dimension of the structure) and external to the design, putting in relation the project with its context (e.g. dimension of the footprint in relation to the site, or height of the building according to the surrounding).

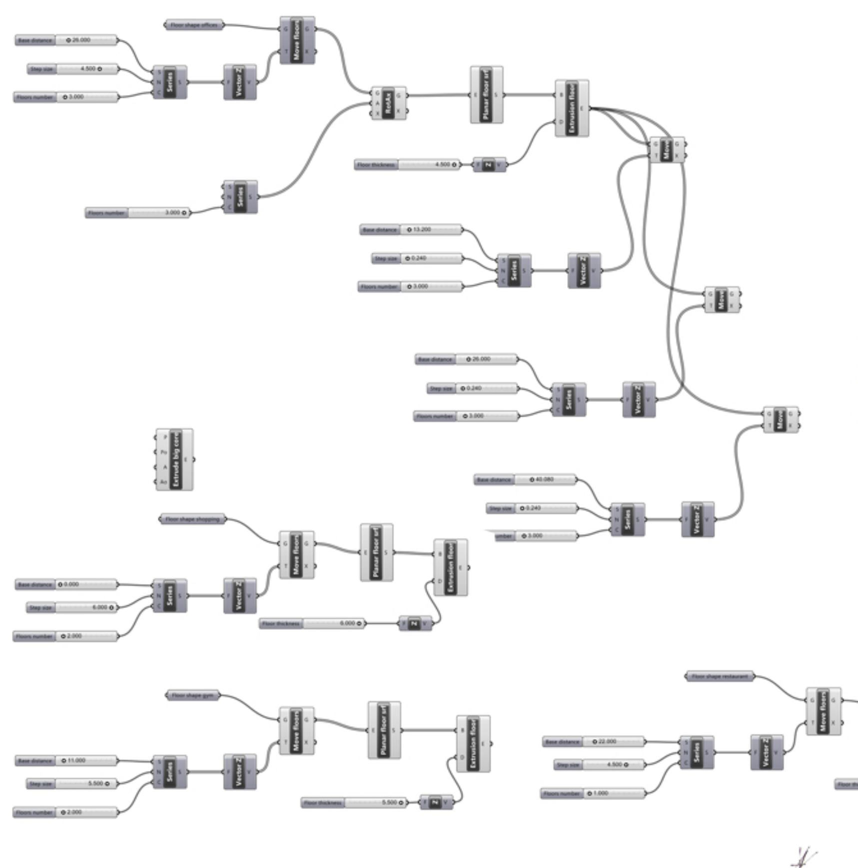
MINIMIZATION/MAXIMIZATION OF BALCONIES MUTUAL SHADING

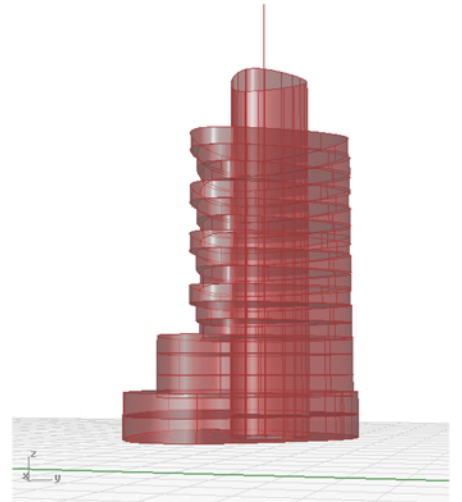




A possibility for implementing an algorithm for the parametrization of the building features, is to act to the rotation of the floors in order to have a reciprocal position that allows to have on each overhangs, that could be used as a balcony, the less or the highest protection derived from the floors above.
This scenario evidences the possibility to create protected terraces, from the sun or from rain, whereas they have to be used by people, or to leave as much free as possible whereas these projecting elements have to be used for plantation that need the maximum possible quantity of rain and sun. The described result could be obtained by parameterizing the rotation of the floors, and once evidenced the shape of the shadow produced by each of this floor due to a simplified vertical source (in this case rain is quite well represented, while sun should be adapted according to the inclination in the location and in the desired moment of the year) minimizing or maximizing the area of the shadows of all the above floors, according to the pre-determined goal. Since going higher the protection of the floors' overhangs is relatively less useful, almost proportionally to the distance between the two floors considered, a reduction factor for the shadows of the successive floors has to be adopted in order to take into consideration this element. The summation of the areas of the shadows projected on the decided floor is the "fitness" parameter for Galapagos, while the rotation angle of the different floors remains the "genome" information.

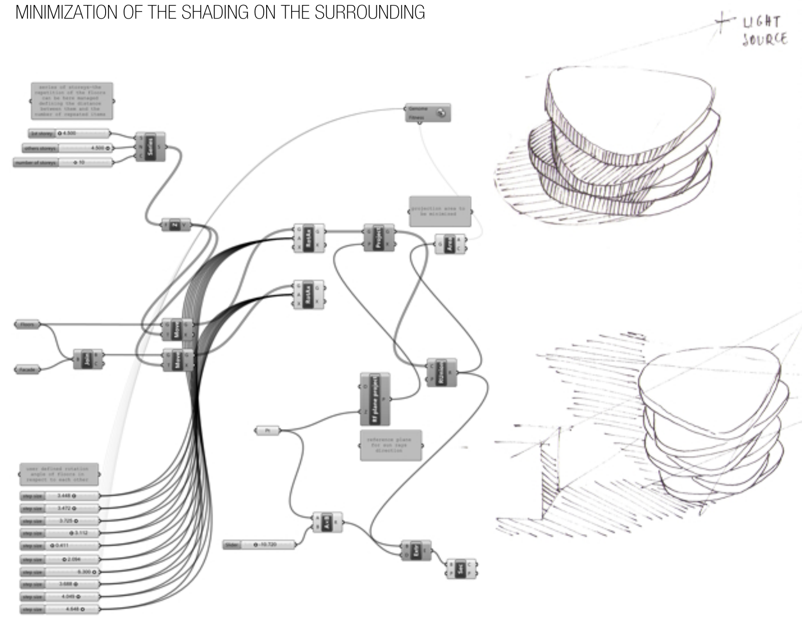
VARIATION OF THE NUMBER OF FLOORS

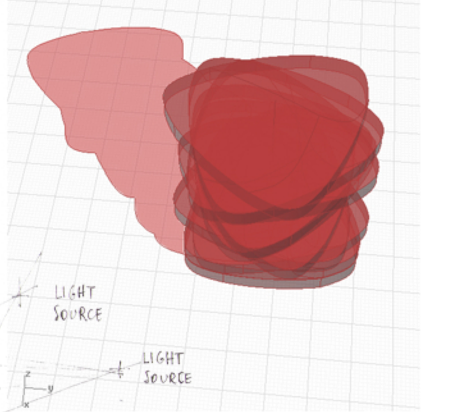




The required height could increase significantly, when dealing with a urban context where high rise constructions are set and no height limits are imposed, or when more space is required to be developed in height. On the other hand, the building could be placed in a context where such tall construction is not required or allowed. Therefore the height of the building could be modified by decreasing the number of floors. The factor times which the floors number is repeated is the parameter to be varied when a lower or taller building has to be realized. The factor could multiply the single floor or the blocks including the three floors rotated in respect to each other as conceived in the project.

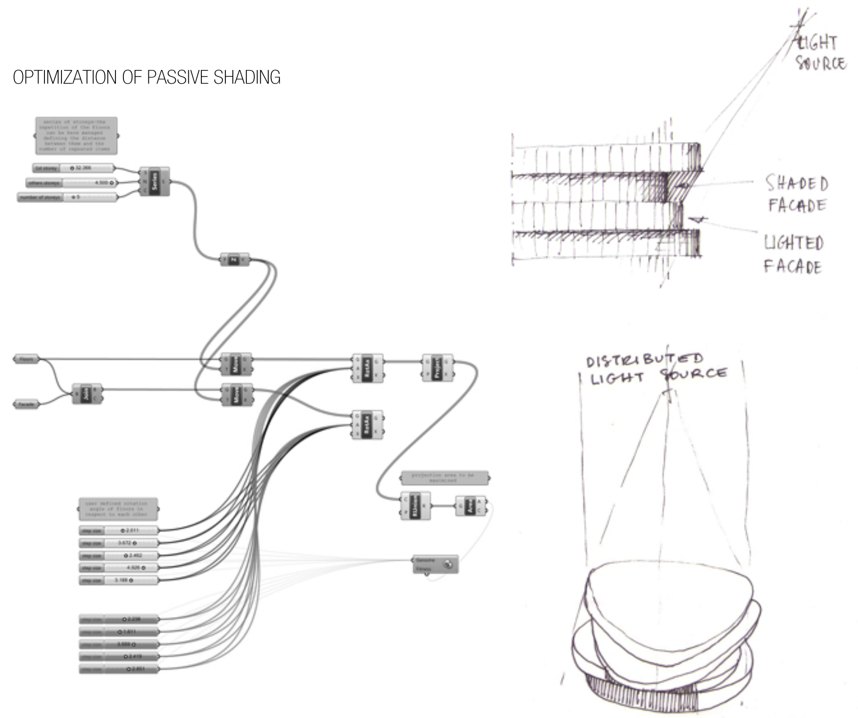
MINIMIZATION OF THE SHADING ON THE SURROUNDING

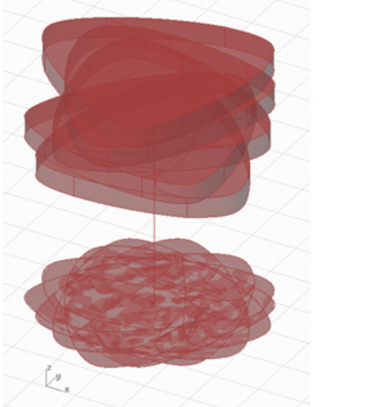




Considering the relation between such a high rise building and its context, a methodology to be explored could be the analysis of shading caused by the building presence on its context. The height of the building, in fact, could interfere with the surrounding fabric and then the analysis through the model could be useful to identify, for a given hour of a precise moment of the year, and then for a pre-set inclination of the sun rays, which is the portion in the shade.The situation is exemplified by projecting the shadow generated by the building subject to a light source with a pre-defined inclination. The area of the projected shadow is, then, the parameter to be analyzed in Galapagos. In order to have the minimum quantity of shadows, the area has to be minimized by the engine.

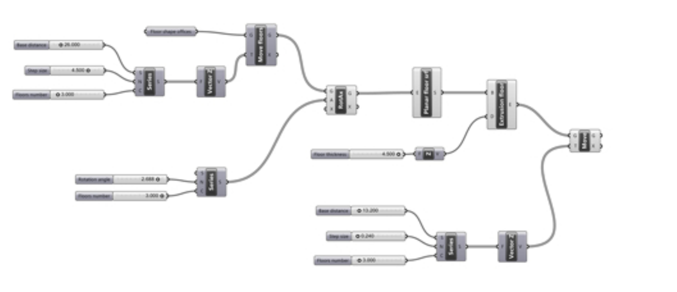
OPTIMIZATION OF PASSIVE SHADING

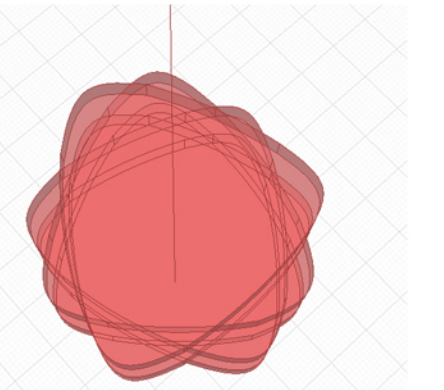




means that each floor acts, in part, as a horizontal shading system for the de of the floor below. This characteristic, even if partially, can be exploited to ide passive shading for the building. An extreme simplified situation has been zed: being each floor sticking out from the one below, considering a vertical e of heat/light, normal to the floor plane, it protects the floor below from this vertical projected shadow. When more than one floor is repeated in height, tal shadow projected by them can be assumed as a parameter to be modun order to reach the maximum possible degree of shading. The parameter shed to be evaluated is drawn out by projecting on the ground the shadow ted by the floors all together considered. This shadow evidences a shape whose area is then required to be maximized in order to obtain the maximum, as well, of shading.

ROTATION OF THE BUILDING ACCORDING TO THE WIND DISTRIBUTION





DIMENSION OF THE BUILDING ACCORDING TO THE PROJECT SITE