Building design Optimization Problem

The purpose of this work is to establish the geometric characteristics of a building for a factory. The objective is to minimize the cost of the energy consumption per square meter, subject to certain constraints.

The following picture shows the main features of the problem

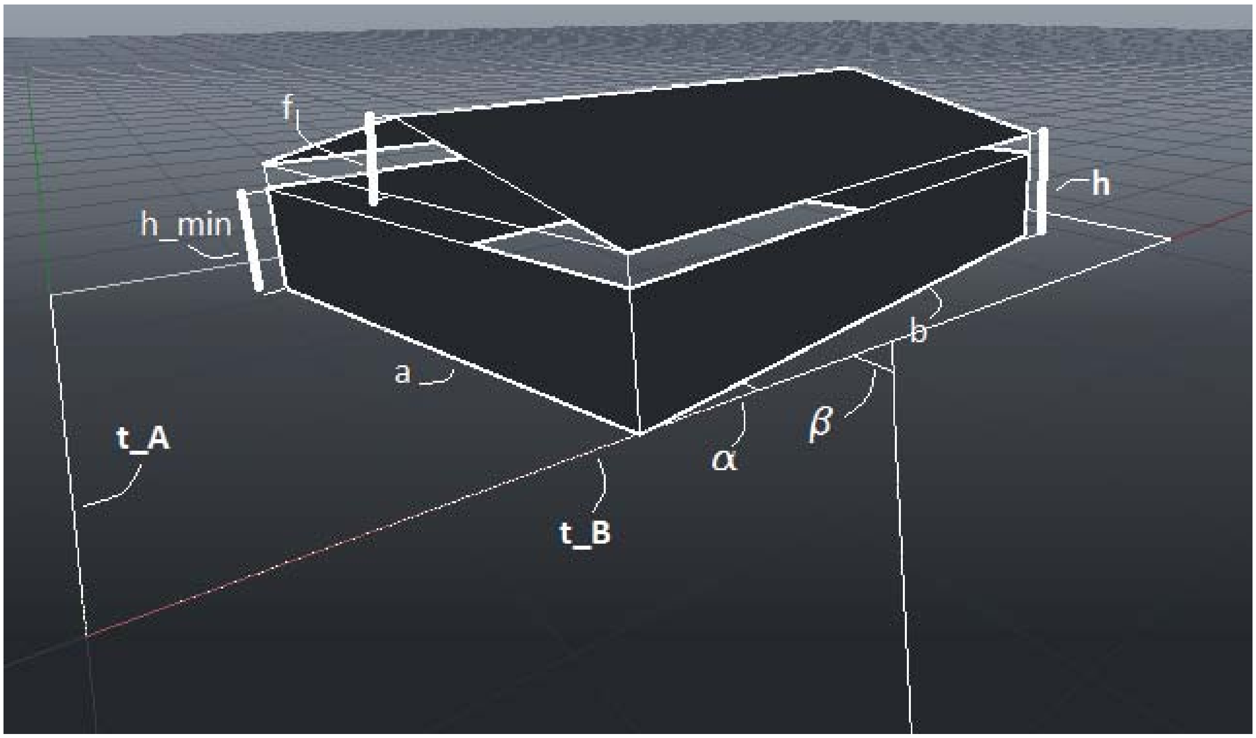

Fig. 1
Description of the problem

The building has a rectangular floor, with sides ***a*** and ***b***, which for constructive constraints must be integer values, and a gabled roof aligned to the ***b*** side. This building has to be erected on a parcel of size ***t_A*** = 50m and ***t_B*** = 80m, and its layout can be askew to the parcel a certain angle ***a***.

The future use of the building poses some constraints to the building:

The walls can't have any windows from the floor up to a height of ***h_min*** = 8m. Then they must have a continuous strip of windows whose height can't be less than ***hw_min*** = 0.5m. Also, given the internal layout of the factory, the windows on the ***b*** sides of the building can benefit of only ¼ of the light that enters through them. Nothwithstanding, the windows on the ***a*** sides, both the rectangular and the triangular ones, can take advantage of the 100% of the light that reaches them.

For structural reasons, the rise of the roof, ***f***, can't be less than the eight part of the length ***a***.

Finally, the total height of the building is limited by the urban code to a height ***h_tot*** = 15m.

The floor plan must have at least 2000 m2, and a shape factor (the greater of ***b***/***a*** and ***a***/***b***) less than 1.6.

The cost of the building should be less than 2000 $\$/m^2$, given that the cost of the walls is 500$\$/m^2$, the cost of the rectangular windows is 1000$\$/m^2$, the cost of the triangular windows is 4000 $\$/m^2$, the cost of the cover is 800$\$/m^2$, and the cost of the floor is 200$\$/m^2$.

Since the structure cost will depend on the size of the sides, we will use the following empiric table to approximate its value. In the columns we have the structural arches direction, that in our case corresponds to ***a***.

	20	30	40	50	60	70	80
20	$ 40,000	$ 60,000	$ 80,000	$ 100,000	$ 120,000	$ 140,000	$ 160,000
30	$ 80,000	$ 120,000	$ 160,000	$ 200,000	$ 240,000	$ 270,000	$ 310,000
40	$ 130,000	$ 200,000	$ 260,000	$ 320,000	$ 390,000	$ 450,000	$ 510,000
50	$ 190,000	$ 290,000	$ 380,000	$ 480,000	$ 570,000	$ 660,000	$ 760,000
60	$ 260,000	$ 390,000	$ 520,000	$ 650,000	$ 780,000	$ 910,000	$ 1,040,000

Table. 1
Structure cost
in function of size of the floor plan

The table can be written in the form:

$$struct = \mathbf{b} * cc * \mathbf{a}^k$$

The cost of the energy consumption of the building can be divided in two costs: 1) The cost of heating, which is calculated using the heat losses through the different surfaces of the building, and 2) the cost of lighting, which depends on the size of the windows and their orientation respecting to the South.

In order to calculate the heat losses we can use the following values for the thermal transmissivity:

*Windows: 3.3 W/m²*K*
*Roof: 0.15 W/m²*K*
*Walls: 0.25 W/m²*K*
*Floor: 0.1 W/m²*K*

As an average, the building will stand a ***Dtemp*** = 20°K between the inside and the outside. The cost of the energy will be ***kWh*** = $0.16

For the lighting, the monthly cost is related to the size and orientation of the windows, and is a negative value: -100$\$/m^2$. The windows' area to be considered should be calculated using the cosine of the angle that the normal to the windows forms with the South. To determine this angle is it needed to know that the side ***t_B*** of the parcel forms an angle ***b*** = 45° with the South. The windows that points North should not be considered in the computation of the area. Also, as stated, the windows on the ***b*** side can only benefit from only the 25% of the incoming light.