Civil Engineering and Architecture 13(1): 653-663, 2025 http://www.hrpub.org
DOI: 10.13189/cea.2025.130141

Green Area Coefficient (GAC) Developed for Use in the Greening of Buildings

Sema Karagüler

Department of Architecture, Faculty of Architectural, Yeditepe University, Turkey

Received July 2, 2024; Revised November 21, 2024; Accepted December 11, 2024

Cite This Paper in the Following Citation Styles

(a): *[1] Sema Karagüler , "Green Area Coefficient (GAC) Developed for Use in the Greening of Buildings," Civil Engineering and Architecture, Vol. 13, No. 1, pp. 653 - 663, 2025. DOI: 10.13189/cea.2025.130141.*

(b): *Sema Karagüler (2025). Green Area Coefficient (GAC) Developed for Use in the Greening of Buildings. Civil Engineering and Architecture, 13(1), 653 - 663. DOI: 10.13189/cea.2025.130141.*

Abstract Today, as in every subject, architectural designs gain new qualities under new approaches and disciplinary trends and are shaped according to new perspectives. Therefore, there is a need to introduce new sanctions in line with the advancing trends and developments in the design and application of architectural projects. In architectural project design, parcel-based construction rules such as "Building Height", "GCR", "FAR" (See Appendix) and "Building Approach Distance" may not be sufficient to produce solutions suitable for today's urbanization conditions, architectural trends and approaches. In this regard, it has been thought that new solutions should be sought, emphasizing the need to support the construction rules with some additional sanctions. In this article, a new construction rule is explained. This rule supports the consciousness of the infiltration of the green element into urban building parcels and the buildings on the parcels as in parallel with today's ecological settlements that are at peace with nature, green architecture and increasingly developing new urbanism trends. For this purpose, first of all, the importance of reflecting the green element on the building level is explained in terms of the phenomenon of urbanization in accordance with new trends with a nature-friendly and sustainable approach. Then, the Green Area Coefficient (GAC) at the building level, which is proposed and formulated in this sense, is defined. In the rest of the article, GAC and the shares of this coefficient formulated on the building and its plot are stated. Then, the calculated values of the construction rules in question with certain assumptions are presented in tables, and a flow chart is proposed for calculating the amount of planted area at the building level depending on all these coefficients. As a result, schematic explanations are made for the newly proposed GAC construction rule and the application is clarified.

Keywords Green Area Ratios, Green Area Coefficients, Planting on Buildings

1. Introduction

Since the industrial revolution in the world, green areas in cities have become much more important. Because green areas have been used not only for functions, such as establishing a relationship with nature, relaxing in the open air, and visual appeal, but also for air purification, noise prevention, controlling solar radiation, protection from disasters such as wind, flood, erosion, landslide, etc. It has also undertaken a wide variety of tasks brought about by the sustainability movement, which also responds to many ecological functions, such as control of natural disasters. However, the ever-increasing dense population in cities, technological developments and land constraints resulting from construction have led to a decrease in green areas in the city, making the formation of concreted urban textures, mostly on hard ground, almost inevitable. In other words, green areas, which need to be increased in cities due to the increasing functions they undertake, are gradually decreasing due to today's dense urban construction, thus the main problem of accessing green areas, at least in cities, is becoming more difficult. This emerging paradox brings to the agenda the need for new searches and the development of new approaches for green in urban

planning. Based on these developments, this article explains a new construction rule proposal supporting the understanding of the infiltration of the green element into urban building plots and buildings on these plots, in parallel with today's ecological settlements in harmony with nature, green architecture and the developing new urbanism trends.

Green architecture and green building concepts were previously developed on a building basis for a sustainable life with energy conservation. Later, urbanization movements attach importance to green within the city, such as ecological settlements and new urbanism, developed and new city models such as "green city", "ecocity", "slow city", "compact city" and "smart city" emerged. Among these models, especially the "compact city" is based on the understanding of limiting urban expansion but using greenery within the city in order not to harm nature [1]. In this situation, on the one hand, there is a tendency towards sustainable living, and on the other hand, the negativities that reduce green areas in cities have led to the development of a common solution, such as the use of green at the building level. Among the benefits of plants and greenery in different aspects within the city, "Despite compelling evidence supporting the positive effects of trees and green spaces on health, the environment and the economy, there remains a notable gap in the translation of this evidence into urban planning and development decision-making processes" [2]. Incorporating green equipment at the level of buildings in cities will at least play a part in filling this gap. Ecological designs in architecture and urban planning, which require the use of plants at the building level, also contain important solutions to protect against disasters and dangers brought by climate change, such as heat waves. In this regard, "the need to make changes in zoning policies in order to reduce the concrete and asphalt load that creates urban heat islands and to increase green areas that will provide cooling in the city" is emphasized [3]. One of these zoning policies is, the introduction of construction rules that provide green sanctions on building surfaces, whose benefits are undeniable for the city as well as the buildings.

2. The Reflection of the Need for Green Space in Cities on the Building Level

When new cities are being established, urban green space standards can be reached to high values of up to 40m^2/person, as in new cities in England and small American cities. However, in dense and metropolitan world cities such as Osaka, Bombay, New Delhi and Istanbul, this standard cannot exceed 2-10m^2/person in practice [4]. Therefore, the use of green on the building may become even more essential in such cities. Especially with the rapidly developing "roof gardens" all over the world, the example of "Covent Garden" in London, which is a very old practice [5], and Malaysian architect Ken Yeang's urban design modeling with an ecological approach [6], green has become a component of the building. Many more various architectural examples are mentioned in the literature, where green texture is designed as very typical applications on building floors. However, in these initiatives, there are no sanctions regarding the use of greenery at the building level and the required green area size at the building level. In the doctoral thesis [4] made by the author about green areas at the building level, CGUB values of the required green area sizes at the building level, which can be valid in four different zone types, are stated.

In addition, a proposal for a ratio for green use at the building level, defined as the "Green Area Ratio (GAR)", has also been published in the literature [7]. However, this ratio is a relative ratio developed not concretely by the size of the green area in the building, but by landscape elements related to the unity of the building with nature. Within the framework of this ratio, it has been developed as a general ratio system used on a city basis, including all ecological structures of the building and its surroundings in European cities such as Malmö, Berlin and Washington. "Washington DC's Green Area Ratio Rule requires all new buildings with a Certificate of Occupancy to meet the appropriate Green Area Ratio (GAR) based on the zoning district. GAR is the ratio of the weighted value of landscape elements to the land area. The total score of landscape elements is calculated by multiplying the area of each element by a proportional value and summing the resulting scores. Landscape elements include: soil and amendments, biological protection, new and existing plants, trees, vegetated walls and roofs, and more. Vegetated roofs must contain at least 5-7 species, and no more than 20% of the total vegetation can be individual native species. Plants should reach a minimum of 80% coverage after 2 years. The minimum is 2 succulent plugs/sq ft or 10 lbs cutting/100 sq ft. Designs must include additional water. Green walls should contain 1 cubic foot of soil/10 square feet of green facade" [8].

In Melissa Keeley's study titled "2011 Study of Berlin's Green Ratio", "It outlines the metrics development and implementation procedures in Berlin and then analyzes how vehicle characteristics may affect the vehicle's potential environmental, social and economic impacts. Despite the policy gaps identified and the lack of adequate outcome monitoring in Berlin, the GAR tool meets the environmental planning needs of many urban communities, including compatibility with dense urbanism, the use of green infrastructure techniques, and the goal of comprehensive environmental planning" [9].

Washington DC's Green Area Ratio Rule, which is also applied in European countries, includes buildings and is a ratio for the sum of the weights of all landscape elements and all other elements active in the urban ecology. Building is only one of these values. In this article, it is aimed to concretely reflect the approaches and practices of planting buildings developing all over the world to the zoning rules under certain coefficients. Therefore, in this context, in the

relevant research project, a practical coefficient transformation that can be used in zoning plans was needed in order to be in application the minimum green surface amounts at the building and parcel level as a zoning sanction.

3. Green Space Construction Rule at Building Level

The expression “green area at the building level” is used as the sum of the green surfaces on the building and the green area on the building parcel [4]. As stated in the formula (1) below; The "Green Use Coefficient at the Building Level" (CGUB), defined as the ratio of the "Total Planted Area at the Building Level" (TPAB) to the "Total Construction Area" (TFA), has been introduced to determine the standards regarding green use in buildings [4].

$$CGUB = TPAB/TFA \quad (1)$$

CGUB is divided into $CGUB_A$" on the land" and $CGUB_B$ "on the building" components, depending on the GCR (Ground Coverage Ratio) and FAR (Floor Area Ratio) values, as shown in the formulas (2), (3) and (4) below. In other words, CGUB is explained as the sum of these two components and is formulated as follows [4]:

$$CGUB = CGUBSA + CGUBB \quad (2)$$

$$CGUB_A = 0.80\ (1\text{-}GCR)\ /FAR \quad (3)$$

$$CGUB_B = CGUB\text{-}\ CGUB_{SA} \quad (4)$$

All these coefficients, as can be seen from the formula (1), are expressed as a percentage of the Total Construction Area (TFA); as indicated by the formulas (5), (6), (7) and (8), green area at the total building level (TPAB), and ($TPAB_{SA}$) and ($TPAB_B$), which are the shares of this area, to be created on the building and the land, are used to determine the amount of green areas:

$$TPAB = CGUB \times TFA \quad (5)$$

$$TPAB_{SA} = CGUB_{SA} \times TFA \quad (6)$$

$$TPAB_B = CGUB_B \times TFA \quad (7)$$

$$TPAB = TPAB_{SA} + TPAB_B \quad (8)$$

As can be seen from the formulas above; $CGUB_{SA}$ and $CGUB_B$ values vary depending on GCR and FAR. In the relevant thesis study, it was stated that the CGUB value may vary depending on the region types, and Table 1 shows the CGUB values determined for different region types whose qualifications are defined [4].

My project is in the Istanbul Research project; As CGUB, the coefficient mentioned above has been transformed into the "Green Area Coefficient" (GAC), which is a new construction condition that can be used on a building basis in the zoning plan and its implementation. In the following sections, the explanation of this new construction condition coefficient, its formulation, calculation, calculation flow schema and parcel-based calculation examples are included.

3.1. Green Area Coefficient (GAC)

The green area coefficient (GAC) is determined based on the contribution of greenery to be planned on buildings and parcels in urban areas to the improvement of the city. For this reason, the GAC coefficient determined in the said research project is used to provide a more practical use in urban design; CGUB construction condition, which is stated as a percentage of the total construction area, is defined based on the common denominator in the formulas of GCR and FAR coefficients, which are the basic construction conditions in zoning plans. Briefly; GAC is formulated as follows:

GAC= Total Green Area at Building Level/Site Area

In short, the formula:

$$GAC = TPAB/SA \quad (9)$$

is written.

According to formula (1), since TPAB= CGUB x TFA and TFA = FAR x SA, the formula (9) can be written as follows:

$$GAC = FAR \times CGUB \quad (10)$$

According to this formula, GAC values will vary according to both different CGUB values varying according to region types and different FAR values. Table 2 shows GAC values varying according to region types and GAC values.

Table 1. CGUB Values According to Region Types

CGUB	Region Type
0.50	Air and noise pollution is high, population is dense and vegetation is poor
0.40	Air and noise pollution is high, population is dense and vegetation is rich
0.30	Air and noise pollution is low, population is low density and vegetation is poor
0.20	Air and noise pollution is low, population is low density and vegetation is rich

Table 2. GAC Varying According to Region Types with different CGUB and FAR Values

CGUB \ FAR	1	2	3	4	5	6
0.20	0.20	0.40	0.60	0.80	1.00	1.20
0.30	0.30	0.60	0.90	1.20	1.50	1.80
0.40	0.40	0.80	1.20	1.60	2.00	2.40
0.50	0.50	1.00	1.50	2.00	2.50	3.00

3.2. Shares of GAC Construction Rule on Site Area and Building

Since the total vegetated area at the building level expresses the sum of the vegetated areas on the building and the building's site, the GAC value, which is the ratio of this vegetated area to the land, also needs to be calculated for its shares on the land and the building. For this reason, formulas that vary according to GCR and FAR values can be developed for the shares of the GCR value on land and buildings. Based on the formulas (2), (3), (4), (5), (6), (7), (8) and (10) specified in the above sections, the minimum values for GAC' shares on land and buildings are determined. The following formulas have been developed.

$$GAC = GAC_{SAmin} + GAC_{Bmin} \quad (11)$$

$$GAC_{SAmin} = CGUB_{SAmin} \text{ x } FAR \quad (12)$$

$$GAC_{Bmin} = CGUB_{Bmin} \text{ x } FAR \quad (13)$$

From formulas (3) and (13):

$$GAC_{SAmin} = 0.80\ (1\text{-}GCR) \quad (14)$$

From the formula (11):

$$GAC_{Bmin} = GAC - GAC_{SAmin},$$

$$GAC_{Bmin} = GAC + 0.80(GCR\text{-}1) \quad (15)$$

relations can be written.

Practically for GAC_{Bmin} in practice;

$$GAC_{Bmin} = GAC – GAC_{SAmin} \quad (16)$$

relation can be used.

The coefficients GAC_{SAmin} and GAC_{Bmin} are the numerators of the GAC coefficient. GAC_{SAmin} share is the coefficient that determines the amount of green space in the land area outside the building seating area. As can be seen from the formula; It is a construction condition that is independent of the total construction area of the building and varies only according to GCR.

GAC_{Bmin} is the other share of GAC and is the coefficient that determines the minimum amount of green space in the building. As can be seen from relations (10) and (15), it is dependent on both GAC and GCR. Therefore, GAC is affiliated with; it will vary depending on the region types with different FAR and CGUB values.

GAC_{SAmin}, which varies according to GCR values, and GAC_{Bmin}, which varies according to GCR and FAR values, were calculated according to the equations (14), (15) and (16) and are shown in Table 3 and Table 4.

Since the construction condition of GAC_{Bmin} is a rule that determines the total vegetated areas on the interior and exterior surfaces of the building;

$$\text{The relation } GAC_{Bmin} = GAC_{Ob} + GAC_{Ib} \quad (17)$$

can be written.

This relationship reveals the shares of GAC_{Ob} and GAC_{Ib}, which determine the green area sizes of GAC_{Bmin} inside and outside the building. However, it has been deemed appropriate to evaluate these coefficients, which determine the size of green areas inside and outside the building, in building design.

Regarding how much of the total vegetated area on the building should be on the exterior surfaces of the building and how much should be on the interior surfaces of the building; in case of high FAR values >3, or high total construction areas (TFA), $GAC_{Ib} > GAC_{Bmin}/2$; In other cases, it may be recommended to accept $GAC_{Ob} > GAC_{Bmin}/2$. This recommendation is put forward by taking into account the assumptions [4] determined for the shares of the Green Use Coefficient (GAC) at the building level.

In the thesis study [4], which is the basis of this article, the total vegetative areas at the building level, on the building and on the land are considered as the minimum required amounts. For this reason, in the article, the GAC_{SA} and GAC_B coefficients used in the calculation of the vegetative areas on the land and the building are stated as GAC_{SAmin} and GAC_{Bmin}, and it is accepted that they can exceed these values when necessary.

Table 3. GAC_{SAmin} Values Changing According to GCR Values

GCR	0.05	0.10	0.20	0.25	0.33	0.50	0.75	1.00
GAC_{SAmin}	0.76	0.72	0.64	0.60	0.53	0.40	0.20	0.00

Table 4. Changing GAC_{Bmin} Values for GAC and GCR Values

GAC \ GCR	0.05	0.10	0.20	0.25	0.33	0.50	0.75	1
0.20	0	-	-	-	-	-	0	0.20
0.30	0	-	-	-	-	-	0.10	0.30
0.40	0	-	-	-	-	0	0.20	0.40
0.50	0	-	-	-	0.03	0.10	0.30	0.50
0.60	0	-	-	0	0.07	0.20	0.40	0.60
0.80	0.04	0.08	0.16	0.20	0.27	0.40	0.60	0.80
0.90	0.14	0.18	0.26	0.30	0.37	0.50	0.70	0.90
1.00	0.24	0.28	0.36	0.40	0.47	0.60	0.80	1.00
1.20	0.44	0.48	0.56	0.60	0.67	0.80	1.00	1.20
1.50	0.74	0.78	0.86	0.90	0.97	1.10	1.30	1.50
1.60	0.84	0.88	0.96	1.00	1.07	1.20	1.40	1.60
1.80	1.04	1.08	1.16	1.20	1.27	1.40	1.60	1.80
2.00	1.24	1.28	1.36	1.40	1.47	1.60	1.80	2.00
2.40	1.64	1.68	1.76	1.80	1.87	2.00	2.20	2.40
2.50	1.74	1.78	1.86	1.90	1.97	2.10	2.30	2.50
3.00	2.24	2.28	2.36	2.40	2.47	2.60	2.80	3.00

3.3. Calculation of GAC Construction Rule

In order to calculate the GAC, GAC_{SA} and GAC_B values to be used in an urban planning area, it must first be determined which of the zone types in Table 1 to which different CGUB values are applied is suitable for that area. For this purpose, the qualities of the planning area are evaluated according to the qualities in Table 1. Thus, the CGUB value to be used for that field is determined. The next steps are according to the known or required GCR and FAR values; It is to find the GAC, GAC_{SA} and GAC_B values of the planning area by using Table 2, Table 3, and Table 4 or the formulas (10) (14) and (15).

As shown in the flow chart in Figure 1, which was prepared in accordance with the formulation determined in Section 2.2; All found coefficients are multiplied by the land area. Thus, the total amount of green space in the building (TPAB) and its share on the land ($TPAB_{SA}$) and its share on the building ($TPAB_B$) are determined as minimum values. Additionally, where necessary, the minimum values of GAC_{Ob} and GAC_{IB} can be determined in Section 2.2. By determining as explained at the end, their total can be selected as the minimum value of GAC_B.

As a result, the GAC construction condition is added to the GCR and FAR construction conditions given on a parcel or parcels in the zoning plan, as briefly shown below, and the plant area sizes that need to be planned at the building level explained in Figure 2 come into effect. The required planted area sizes are put into practice. These construction conditions are stated below, depending on the site area (SA):

Construction Rules:

GCR determines the “Building Sitting Area” BFA = GCR x SA

FAR determines the “Total Construction Area” TFA= FAR x SA

GAC determines the “Total Planted Area at Building Level” TPAB = GAC x SA

Shares of GAC:

GAC_{SA} determines the “Total Planted Area on the Site Area” $TPAB_{SA} = GAC_{SA}$ x SA

GAC_B determines the “Total Planted Area on the Building” $TPAB_B = GAC_B$ x SA

GAC_{Ob} determines the “Total Planted Area on Building Exteriors” $TPBA_{Ob} = GAC_{Ob}$ x SA

GAC_{Ib}” determines the “Total Planted Area on the Interior of the Building” $TPBA_{Ib} = GAC_{Ib}$ x SA

GCR and FAR are independent of each other from the above construction conditions. As can be seen from the formula (12), GAC varies depending on the "Building Level Green Use Coefficient" (CGUB), which determines the FAR and zone type. Therefore, GAC_{SA}, which is the share of GAC, is dependent on GCR, as can be seen from formula (14); GAC_B, on the other hand, is dependent on both GAC and GCR, as can be seen from formula (15). Therefore, while giving the construction conditions that must be followed on a building parcel, the values of GAC and its shares are: the given GCR must be given in accordance with the FAR and Region Type (CGUB coefficient of the region type). This issue will be explained concretely using the examples given in Chapter 4.

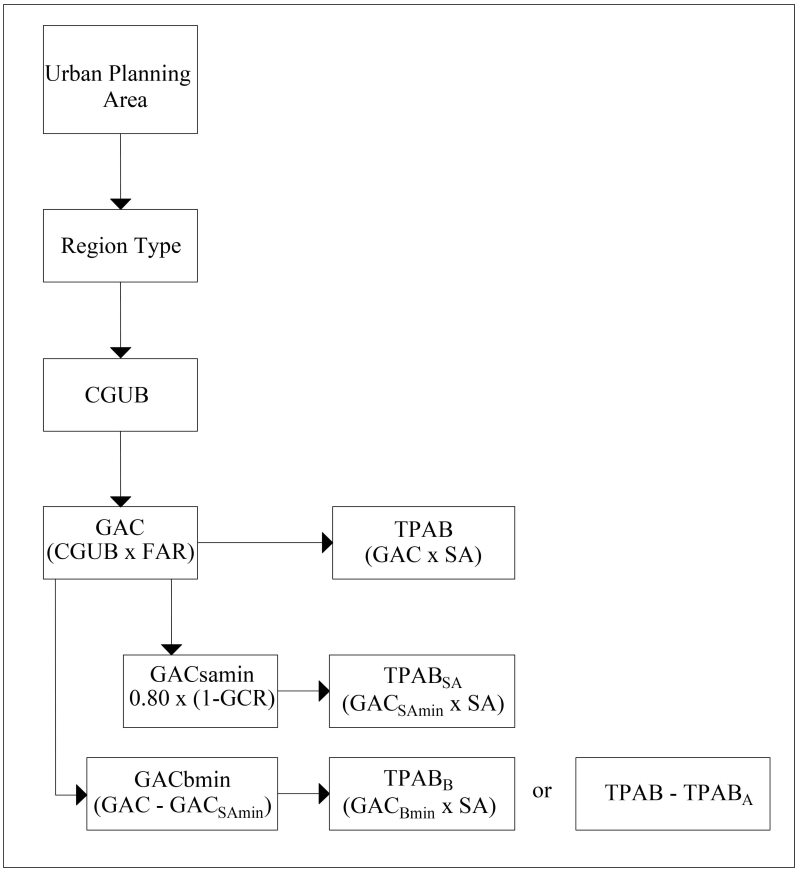

Figure 1. Flow Chart of Calculation of Green Area Amounts at the Building Level to Which the Green Area Coefficients Depend

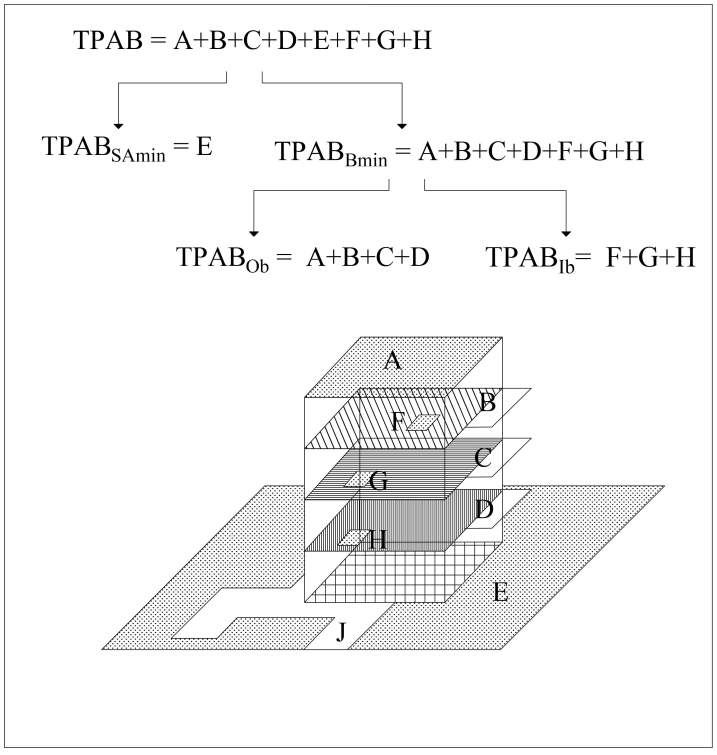

Figure 2. Schematic Representation of Planted Area Size at Building Level on the Building Plot. ((J) means Hard Ground.)

4. Sample Explanations

In this section, sample explanations regarding the determination of GAC and its shares and Planted Areas at Building Level (TPAB and its shares) are included.

EXAMPLE 1: If a building parcel is located in zone 3, where air and noise pollution is high, population is dense, and vegetation is rich, it will be subject to a CGUB value of 0.40 from the Zone Types specified in Table 1. If the zoning plan construction conditions for this parcel with an area of 1500 m^2 are given as GCR= 0.50, FAR= 2, the following calculations can be made:

According to the given construction conditions, (from Table 2 or formula (10)):

- GAC = is determined as (2×0.40)= 0.80
- Shares of GAC with formulas (14) and (16);

  GAC_{SAmin} =0.40
  GAC_{Bmin} =0.40; It is determined as (0.80 - 0.40).
- These coefficients, which are determined as the ratios of the site area, are multiplied by the site area and the "Planted Area Values at Building Level", which must be complied with during the project, are obtained as follows:

Since TPAB =CGUB x SA, $TPAB_{Samin}$ = GAC_{SAmin} x SA and, $TPAB_{Bmin}$ = TPAB-$TPAB_{SAmin}$,

TPAB=0.80 x 1500 = **1200 m^2**

$TPAB_{Samin}$ = 0.40 x 1500 = **600 m^2**

$TPAB_{Bmin}$ = 1200-600 = **600 m^2**

To calculate $TPAB_{Ob}$ (planted area on the exterior of the building) and $TPAB_{Ib}$ (planted area on the interior of the building) values; GAC_{Ob} and GAC_{Ib} values, which are the shares of the GAC_{Bmin} value, are required. These values are due to the FAR construction condition on the site area (FAR=2) being less than 3;

Since GAC_{Ob} > $GACB_{Ib}$ /2, GAC_{Ob} = 0.25, GAC_{Ib} = 0.15 can be chosen.

Therefore;

$TPAB_{Ob}$ =GAC_{Ob} x SA, $TPAB_{Ob}$ = 0.25x1500 = **375 m^2**,

$BTBA_{Ib}$ = GAC_{Ib} x AA, $TPAB_{Bi}$ = 0.15x1500 = **225 m^2** (as 600-375).

In summary, the values of the construction conditions on this land can be stated as follows:

- Building Footed Are

  (BFA=GCR x SA) 0, 50 x 1500 = **750 m^2**
- Total Construction Area

  (T.F.A=FAR x SA) 2 x 1500 = **3000 m^2**
- Total Planted Area at Building Level

  (TPBA = GAC x SA) 0,80 x 1500 = **1200 m^2**
- Total Planted Area on the Land

  ($TPAB_{SA}$ = GAC_{SA} x SA) 0,40 x 1500 = **600 m^2**
- Total Planted Area on the Building

  ($TPAB_{B}$ = GAC_{B} x SA) 0,40 x 1500 = **600 m^2**
- Total Planted Area of Building Exterior Surfaces

  ($TPAB_{Ob}$ =GAC_{Ob} x SA) 0,25 x 1500 = **375 m^2**
- Total Planted Area of Building Interior Surfaces

  ($TPAB_{Ib}$ =GAC_{Ib} x SA) 0,15 x 1500 = **225 m^2**

or:

($TPAB_{Ib}$ = TPAB - $TPAB_{Ob}$) (600-375 = **225 m^2**)

Figure 3 shows the schematic drawing for this example.

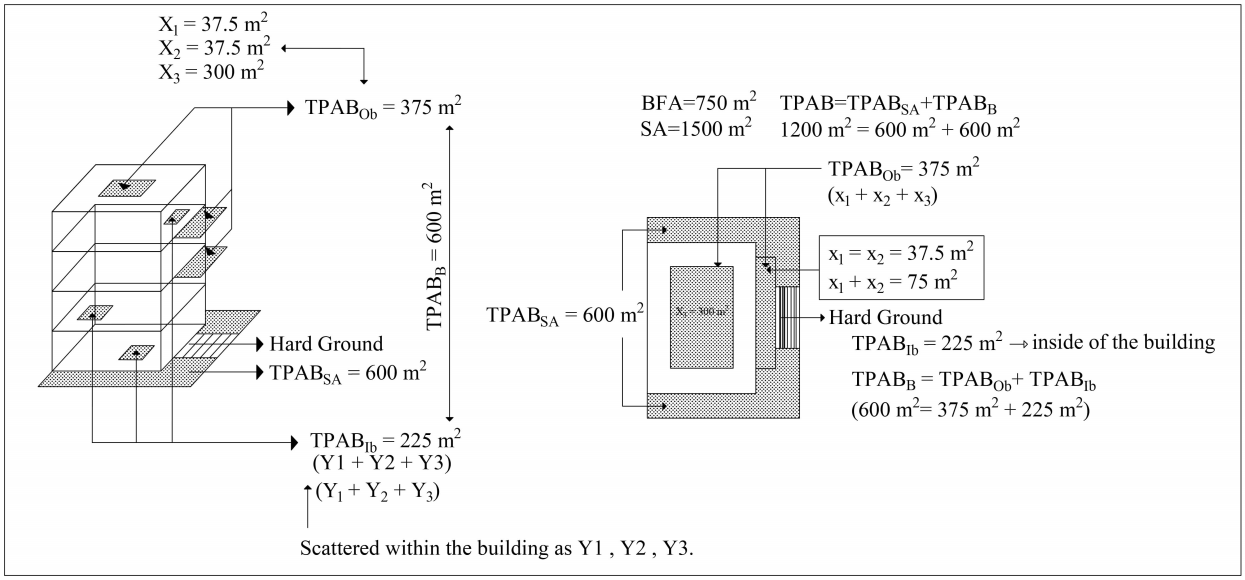

Figure 3. Schematic Representation of Example 1

EXAMPLE 2: It is stated in the zoning plan that this parcel is located in the Region Types with low air and noise pollution, low population density, weak vegetation and an area of 800 m^2, as indicated in Table 1; the CGUB value is 0.30. As given construction conditions; GCR= 0.20, FAR= 2.

According to the given construction conditions, from (Table 2.) or from the formula (10):

GAC is determined as (2 x 0.30) = 0.60

From GAC's shares in the land with formulas (14) and (16);

$$GAC_{SAmin} = 0.64.$$

In this case, since $GAC_{SAmin} > GAC$, $GAC_{Bmin} = 0$

In conclusion;

$$TPAB=GAC \times SA=0.60 \times 800=\mathbf{480\ m^2}$$

$$TPAB_{SAmin} = GAC_{SAmin} \times SA = 0.64 \times 800 = 512\ m^2 > 480\ m^2$$

Therefore,

$TPAB_{SAmin} > TPAB$, $TPAB_{Bmin} = 0$. Because only the vegetative area on the land is sufficient and it exceeds the total vegetal area value (TPAB) at the building level. In this case, vegetated area on the building is not mandatory. However, since the coefficients of GAC and its shares revealed in this study are given as minimum values, the architect can design a vegetated area on the building other than the one on the land. A schematic explanation of this example can be seen in Figure 4.

$$CGUB = 0.30$$

$$GCR = 0.20,\ BFA = 160\ m^2$$

$$FAR= 2\ TFA= 1600\ m^2\ 10\ floors.$$

$$SA= 800\ m^2,\ GAC = 2 \times 0.30= 0.60,\ TPAB= 800 \times 0.60 = \mathbf{480\ m^2}$$

$$TPAB_{SAmin}= 0.80\ (1\text{-}GCR) = \mathbf{512\ m^2}$$

$$TPAB \leq TPAB_{SAmin}\ \text{Result:}\ TPAB_{Bmin} = \mathbf{0}$$

As can be understood from Table 5., in regions with low CGUB values and parcels with low GCR values, there is a high probability that the planted area on the plot ($TPAB_{SAmin}$) is greater than the total planted area at the building level (TPAB), in other words, GAC_B=0. In Table 4 examined in this regard, it can be seen that for the values of the GAC construction rule between 0.20 and 0.60, the GAC_B values get closer to 0 or 0 as the GCR values decrease.

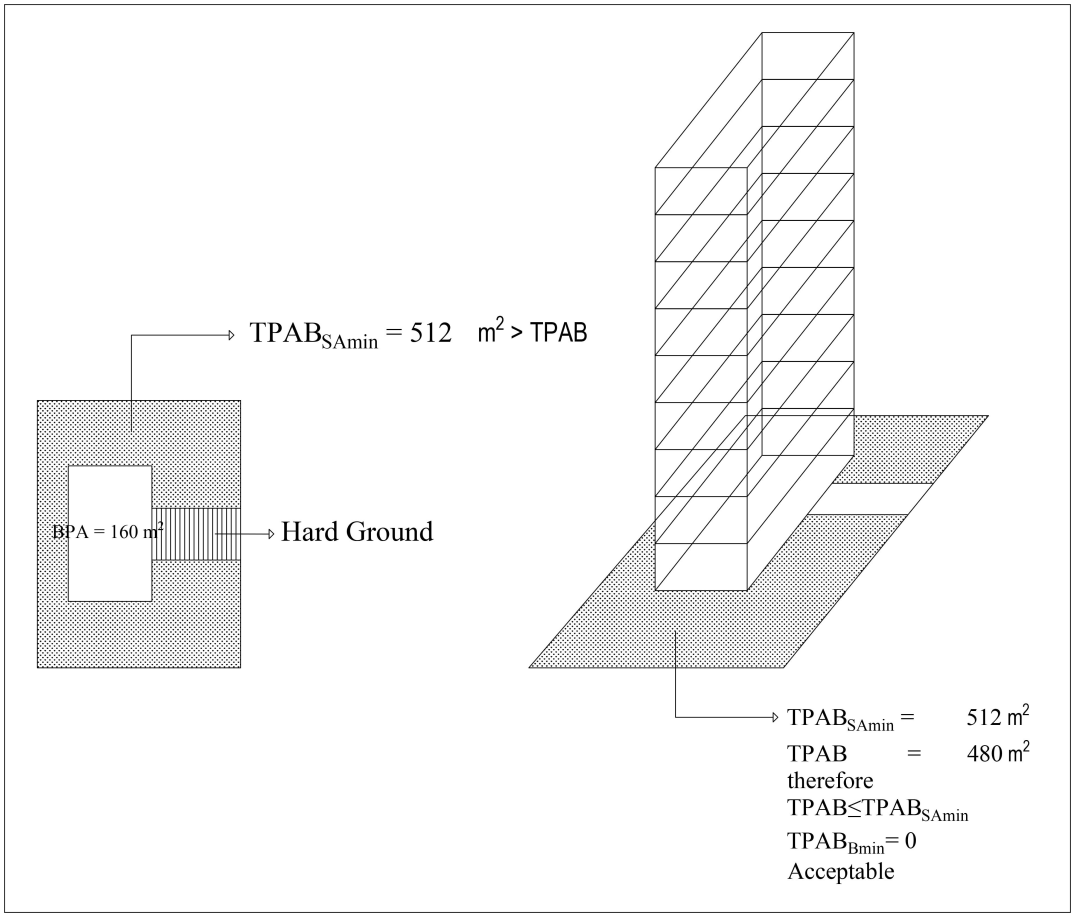

Figure 4. Schematic Representation of Example 2

Table 5. Comparative interpretation of examples

VALUES		Example 1.	Example 2.	COMPERATİVE INTERPRETATION
ATAS	Region Type	-High Air and Noise Pollution -Dense population -Vegetation is rich	-Low air and Noise Pollution -Low population -Poor Vegetation	(The Second Example's region has better conditions, Therefore less vegetated area will be required in Example 2)
	CGUB	0.40	0.30	$CGUB_2 < CGUB_1$ (0.30 < 0.40) $GCR_2 < GCR_1$ (0.20 < 0.50) Therefore less vegetated area will be required in example 2
	SA	1500 m^2	800 m^2	
	GCR	0.50	0.20	
	BFA	750 m^2	160 m^2	
	FAR	2	2	
	TFA	3000 m^2	1600 m^2	
NEW CONSTRUCTION RULES	GAC	0.80	0.60	In example 2, Since the GAC_{Samin} > GAC, GAC_B=0 Because GAC_{Samin} will provide more vegetated area than the total required vegetated area at the building level.
	GAC_{Smin}	0.40	0.64	
	GAC_B	0.40	0	
	GAC_{Ob}	0.15	0	
	GAC_{Ib}	0.25	0	
PLANTED AREAS ON BUILDING LEVEL	TPAB	1200 m^2	480 m^2	In example 2, TPBA < $TPBA_{Samin}$ Planted area on the plot will more than meet the planted area required at the entire building level. There will be no need for a planted area on the building. ($TPAB_B$)
	$TPAB_{SAmin}$	600 m^2	512m^2>480	
	$TPAB_B$	600 m^2	0	
	$TPAB_{Ob}$	375 m^2	0	
	$TPAB_{Ib}$	275 m^2	0	

5. Evaluation

The GAC construction rules and shares explained in this article are expressed as a percentage of the land area. It determines the total planted area size (TPAB) on the building and its plot and the size of the shares of this size on the plot and building ($TPAB_{SA}$ and $TPAB_B$). GAC varies according to different zone types and FAR construction conditions.

The GAC_{Ob} and GAC_{Ib} coefficients, which are the shares of the GAC_{Bmin} coefficient, also determine the total planted area sizes ($TPAB_{Ob}$ and $BTBA_{Ib}$) inside the building and on the external surfaces of the building.

GAC construction rule and shares are found through the formulas explained in the article or tables prepared according to these formulas (Tables 1, 2, 3, 4).

The shares of GAC vary FAR and GCR construction rule.

Total Planted Areas at Building Level determined according to GAC coefficient and shares are minimum values and will not be included in Total Construction Area (TFA).

GAC ratio presented in this article is a construction rule indicating the total vegetated areas on the building and its plot in addition to GCR, which indicates the building seating area in the zoning status on the plot of a building, and FAR, which indicates the total construction area. The important issue to be stated for these construction conditions is that "GCR and FAR construction rules are maximum values, while the construction rules of GAC and its shares are minimum values. Unless a special reason is shown in the plan notes in the zoning plans, it may be possible for the application to exceed these minimum values. The Total Planted Areas in Buildings that will not be included in total construction area is an important determinant in this regard.

In zoning plans, the GAC value must be given by the planner in accordance with the "Region Type". The multiplication of this value with the plot area will give the total planted area (TPAB) to be designed at the building level (on the plot and building). The GAC_{SAmin} and GAC_{Bmin} shares of this GAC value given as a zoning construction rule in the Zoning Plan will be calculated by the architect who designed the plot in accordance with the flow chart and multiplied by the plot areas to determine the minimum planted area sizes to be created on the plot and building. Therefore, it will be necessary for both zoning plan makers and architects who design buildings in accordance with the plan to know what the GAC construction rule means and how it is calculated.

6. Conclusions

The GAC construction condition has been put forward as a construction condition to be included in the zoning plans of densely populated cities and settlements where green areas are not sufficient. This condition will play a positive role in eliminating the inadequacy of green areas by using plants on buildings.

The benefits of planting on buildings are many and varied. The most obvious benefits of plants are providing visual appeal in buildings, controlling sun rays and radiation, screening wind, noise and unwanted images, providing privacy and security, emphasizing space perception and view, preserving bioclimatic balance, getting closer to nature and psychological satisfaction. In addition, if the savings to be obtained from the artificial energy spent in providing most of these benefits through the use of plants are considered, it is seen that the use of plants on buildings will provide significant energy control in achieving different purposes, especially natural lighting, heating and cooling. Thus, its role in making the building economical and sustainable will be better understood. Therefore, with the GAC construction condition, buildings will generally gain the characteristics of using natural energy, being economical and sustainable.

The share of the total planted area in the building on the plot ($TPAB_{SA}$) is significantly effective in controlling wind, noise and sunlight, especially on the lower floors of the buildings, in accordance with the seasons. While the benefits such as ensuring privacy and security, perception of space, providing visual appeal and emphasizing the view, getting closer to nature and psychological satisfaction can be provided by the total planted area (TPAB) in the entire building; the role of the share of the total planted area on the building ($TPAB_B$) will be quite high in achieving these benefits. "Protection of Bioclimatic Balance" in improving indoor air conditions can be provided by the total planted area inside the building ($BTBA_{Ib}$).

When the benefits of green areas to the city are considered; it is seen that the plantings brought at the building level with the GAC construction rule will also contribute to the improvement of the ecology of the building's surroundings and the entire city. The mentioned benefits; improving the city climate, eliminating air, noise and visual pollution; and also, it can be stated as increasing the level of social life by providing socio-psychological satisfaction such as getting closer to nature and turning to the human scale. The $TPAB_B$ value will be quite effective in this regard.

Therefore, the GAC construction rule will also contribute to increasing the quality of life, which is an important rule of sustainability, both on a building and city basis.

APPENDIX A

SA: Site Area (Plot area)
BFA: Building Footprint Area
TFA: Total Floor Area
GCR: Ground Coverage Ratio (BFA / SA)
FAR: Floor Area Ratio (TFA/SA)
TPAB: Total Planted Area on Building and Site
$TPAB_{SA}$: Total Planted Area on Around of the Building Site (as the component of TPAB)
$TPAB_B$: Total Planted Area on Building Surfaces (as building component of TPAB)
$TPAB_{Ob}$: Total Planted Area on Out Surfaces of Building (as out surfaces component of $TPAB_B$)
$TPAB_{Ib}$: Total Planted Area Inside of the Building (as inside component of $TPAB_B$)
CGUB: Coefficient of Green Usage of Building
$CGUB_{SA}$: Coefficient of Green Usage on Building Site (as site component of CGUB)
$CGUB_B$: Coefficient of Green Usage on Building (as building component of CGUB)
GAC: Green Area Coefficient (TPAB/ SA)
GAC_{SA}: The Share of GAC on Site
GAC_B: The Share of GAC on Building
GAC_{Ob}: The Share of GAC_B out Surfaces of Building
GAC_{Ib}: The Share of GAC_B Inside of Building

REFERENCES

[1] Tosun, E.K., "Analysis of the Compact City Model in the Sustainable Urban Development Process", Journal of Management and Economics, vol. 20, no. 1, pp. 31-46, March 1, 2013. https://dergipark.org.tr/en/pub/yonveek/issue/13698/165793

[2] Tefera, Y.; Soebarto, V.; Bishop, C.; Kandulu, J.; Williams, C. "A Scoping Review of Urban Planning Decision Support Tools and Processes That Account for the Health, Environment, and Economic Benefits of Trees and Greenspace," Int. J. Environ. Res. Public Health, vol. 21, no. 1, p. 48, 2024. https://doi.org/10.3390/ijerph21010048

[3] Şahin, Ü., "The Deadliest Overlooked Climate Disaster: Heat Waves," Istanbul Journal of Urban Research and Thought, pp: 116-119, 005-2022., ISSN:2757-797X.

[4] Karagüler, S., "Usage of Plants on the Buildings in order to Relief the Harms of Lessening the Green areas Because of Building", Ph.D thesis, Istanbul Technical University., Institute of Science and Technology, Istanbul., Thesis Number; 775206, 1994, pp. 1-289. https://tez.yok.gov.tr/UlusalTezMerkezi/tezSorguSonucYeni.jsp

[5] Markus, T.A., "Building Conversion and Rehabilitation: Designing for Change in Building Use", Cox and Wyman Ltd, Fakenham and Reading, London., 1979.

[6] Yeang, K., "Designing the Green Skyscraper": Landscape Architecture, Tall Buildings: 2000 and Beyond, Collected Papers, Council on Tall Buildings and Urban Habitat, 1990.

[7] Green Area Ratio Guide Book, Department of Energy and Environment Natural Resources Administration Regulatory Review Division 1200 First Street NE, 5th Floor Washington, DC 20002, November 2017. chrome-extension://efaidnbmnnnibpcajpcglclefindmkaj/https://doee.dc.gov/sites/default/files/dc/sites/ddoe/service_content/attachments/GARGuidebook_FINAL_November2017_0.pdf

[8] Anon., "Green Roof Policies, Washington DC's Green Area Ratio Rules," https://lpdd.org/resources/washington-dcs-green-area-ratio-rule/, LPDD, htpp://www.lpdd.org (accessed October 1, 2024).

[9] Keeley, Melissa., "The Green Area Ratio: an urban site sustainability metric", Journal of Environmental Planning and Management, vol. 54, no. 7, pp. 937-958, 2011. https://doi.org/10.1080/09640568.2010.547681