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Proposition of Housing Construction with Solar Envelope Method in Renewal Area after Disaster

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A B S T R A C T

In this study, with using the method of solar envelope, general layout plans, building forms and building density values were obtained to ensure optimal utilization of the sun in mass housing area. Toki housing in İnonu Quarter of Bingöl city who faced constantly with the fact earthquakes and natural disasters throughout the history was selected as study area. In conclusion; assessments were carried out about current buildings situation and recommended building forms.

1. Introduction

The role of buildings which we design and we build is very large on the consumption of resources and the destruction of nature. 50% of the energy utilisation and the 42% of water consumption in the world are in building sector. 50% of greenhouse gases causing global warming, 24% of air pollution and 50% of the CFC and HCFC emissions are caused by activities related to building construction [1]. The increase of energy demand and consumption, the environmental problems due to energy consumption who began to manifest itself, have increased the importance of renewable energy sources. Due to economic reasons, inability of social development, drastic increase in population, incorrect site selection and natural disasters, our country and many cities in the world need today renovation, conversion, relocation, and improving project designs and applications. It should be approached with a new vision in this construction process where the transformation is inevitable. In this respect, it must be given environmentally sensitive architectural approach from the planning process to the stage of building design, construction and building use. When creating new residential areas, the development and the protection of natural resources, the use of renewable energy sources will have to contribute to a sustainable future. In energy efficient design, reduction of energy losses (isolation) and increase the energy gains (such as to take advantage of solar energy) are required [2].

Use a combination of climate energy and forms triple provide the basis of the solar energy utilization in building [3]. In this study, a research was carried out using the solar envelope method in residential buildings (social housing) constructed in an urban renewal area after disaster in city of Bingöl (Turkey). The aim of the study is firstly to analyse the potential of making shade of the existing buildings in the study area both in its own and towards the surrounding buildings located in the near environment. To achieve this objective, buildings proportions exceeding volumetric limit of solar envelopes were determined. The second aim is to develop multiple alternative proposals in the same area. In this proposition phase of the study, different general layout plans were obtained according to the number of buildings. The construction density of the new proposals and various arrangements were compared between them and with the current cases.

2. Solar Envelope Method

Solar Envelope is a geometric method which create buildings form to benefit optimally from the sun. This method was developed by Knowles during the energy crisis of the 1970s [4]. The "Solar Envelope" is defined as the boundaries of a construction volume that do not cast shadow on the neighboring buildings located in its close vicinity over a certain time span. Solar Envelope determines the maximum volume that can be built for a given area. This method is applicable in the dense urban areas as well as the only building (residential and multi-use) and it support at every stage of the design [5]. The formation of solar envelope depends on environmental properties and the periods of access to the sun. When these two factors are combined, it is possible to determine the form and the border size of the solar envelope [6]. During the year, all days of the specified time range to provide the sun, optimal solar Envelope is obtained with the optimization of solar shell of summer and the winter period[7]. A building designed within the boundaries of a solar envelope will not cast shadows on neighboring buildings located in the vicinity and therefore will not obstruct the insolation potential.

In order to produce a solar envelope, the basic parameters of space and time should be well defined:

1-Space Factor: This is the base area of solar envelope in ground level. It is defined as the boundaries of the area in which the shadows extend from all directions.

2-Time Factor: The time parameter is defined as the time interval in which insolation is desired.

The start (before noon) and finish (afternoon) times of the insolation are defined by taking "12" as a reference on the basis of a sundial. It is possible to define different insolation durations for winter and for summer. In this work only the winter solar envelope was used.

The book by Knowles R. L. entitled, "Sun Rhythm Form" provides all details about the principles of the solar envelope method [8].

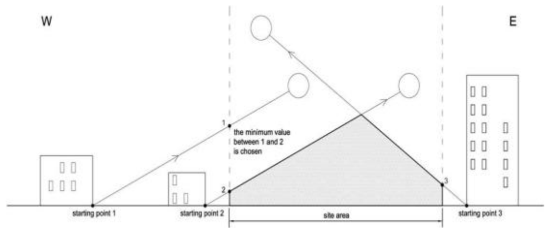


Figure 1: Schematic representation of the spatial limits of the solar shell [4].

3. Applying Solar Envelope Method in İnönü Quarter of Bingöl City

Social housing in a urban regeneration zone in İnönü quarter of Bingöl (Turkey) city was selected as a study area (Figure 2). The permanent disasters in the city and the development of new urban renewal project in almost every area of the city after each disaster, were the most important reason to do the study in Bingöl city. These regeneration projects being carried out by Toki (*Turkey's Mass Housing* Administration).

Figure 2: Location of Bingöl in Turkey.

The housings located in area are the Toki housings project type C which is often used in many province of Turkey. C-type housings used in practice have a compact form similar to square or rectangular form. They are applied in each climatic region of Turkey. Designed as an 8 story housing, each floor have four apartments. Floor height of the apartments is 2.60 meters and the height of the basement is 0.50 meters.

When it comes to organize a large urban space once by a single designer, it is possible to make appropriate decisions for buildings in the layout plan regarding sunshine and energy efficiency. Because in the layout plan, it is possible to determine the location of buildings between them in order to benefit sufficiently from the sun and also to apply energy efficiently design principles. By this way, in practice, it is possible to determine the consideration or not of solar energy by designers in the area.

Figure 3: General view of the site.

Figure 4: Overview of the social houses.

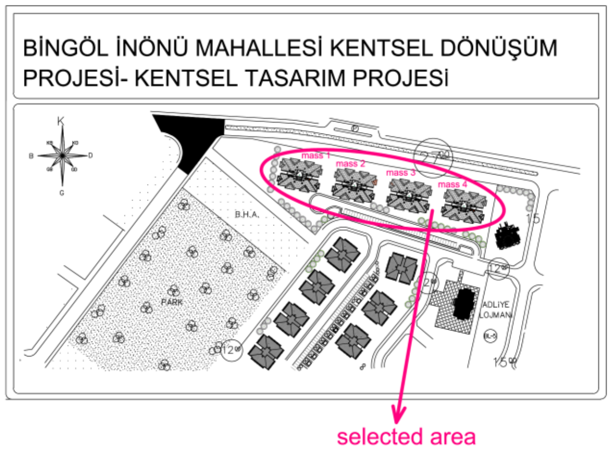
3.1. Analysis Studies

In the phase of analysis of the current case, solar envelopes were created according the localisation of housing buildings in the predetermined site. Firstly, the space factor was determined. The space factor is the ground area of the solar envelope. It was determined which take into account all the surrounding building emplacement for each building. It was established to be the largest in terms of volume and height for each building located on the site (figure 6). Secondly time parameters was determined. The time parameters consist to determine the sunshine duration in order to obtain optimal energy gain from the sun for a day. 4 hours of interrupted daily sunshine was accepted. This is the optimal duration when the solar energy gain is calculated for this region. For Bingöl solar envelopes were produced for the December 21 between 10:00 AM and 2:00 PM. The solar envelope volume that was produced for the shortest day of the year will ensure uninterrupted insolation on all the other days of the year. The sun's azimuth and elevation angle values were calculated depending on sun start and end times for the day of December 21 (table 1).

The solar envelopes produced for analyses and existing buildings are superimposed (figure 7). Building volumes which exceed the volume limit of the solar envelope create shade depending on the size of the overflow quantity on surrounding buildings in specified period of time. The rectification of the existing buildings according solar envelopes was shown in figure 8. The quantitative results are in table 2.

Table 1: Angular coordinates of the sun for December 21

Bingöl, geographic latitude: 38.22 °		Solar elevation angle	Azimuth
Winter period December 21	Start of period time: 10:00 AM	22.0 °	30°
	End of period sunbathing time: 2:00 PM	22.0 °	30°



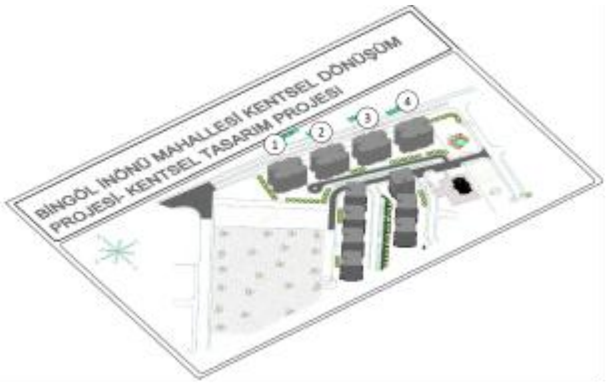


Figure 5: The determined study area and the three-dimensional model of the study area.

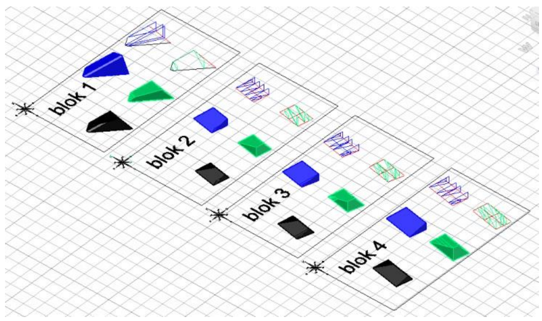
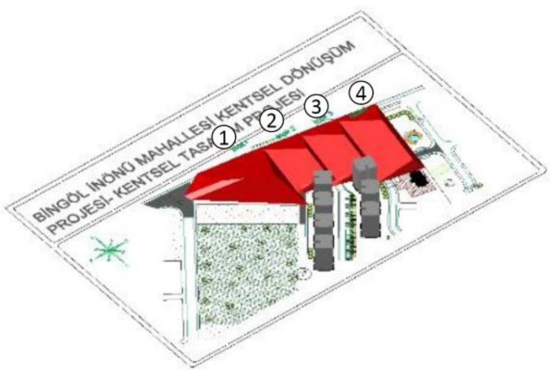


Figure 6: Solar envelope generation for the analyse of the current case.



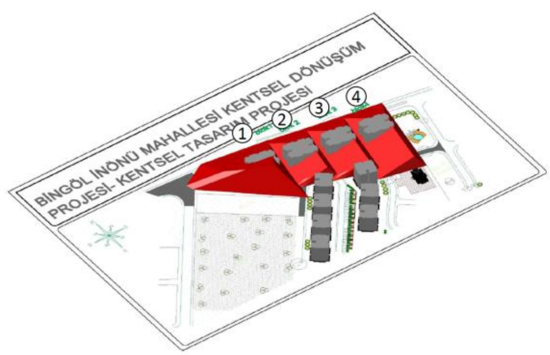


Figure 7: The obtained solar envelopes for the current case and their superposition with existing buildings.

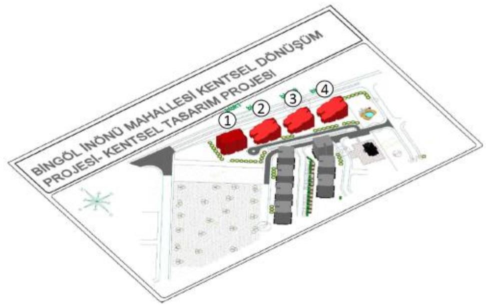


Figure 8: Rectification of the existing buildings with using solar envelopes.

Table 2: The amount and rate corrections in the buildings.

Mass No.	Current mass volume V (m3)	Revised mass volume V (m3) (obtained by solar envelope)	Difference V (m3)	Rate of reduction %
1	19864,72	18357,55	1507,17	7,58
2	19864,72	12363.59	7501,12	37,76
3	19864,72	12372.72	7491,99	37,71
4	19864,72	12491.15	7373,56	37,11
Total	79458,88	55585,01	23873,84	30,04

In study area, in total, there is an excess of 30% of construction volume that prevent sunshine in the area and in the near environment. The minimum excess is in the mass1 with a rate of 7, 58 %. This is due to the immediate environment in which the buildings are quite far (figure 7).

3.2. Suggestions for Rehabilitation

For rehabilitation purpose, the general layout plan propositions were developed with multiple mass (Figure 9). This approach was necessary in order to obtain results in a systematic way and to remain as objective. In the rehabilitation study, four different arrangements were examined. The number of the building mass was significant for the site arrangement.

The floor areas geometric dimensions of the proposed buildings at ground level were determined approximately in line with the proportions of the dimensions of the surfaces obtained after the systematic division of the plot. Setback distances were also taking into account according the current situation. For each suggestion, the ground floor area density in the parcel (floor area coefficient in ground level) was the same (0.20). This approach was considered significant to obtain consistent results for comparison. Creating building masses in different numbers and properties provides the production of different alternatives. By this way, the designer can evaluate different options and may have the possibility to choose the suitable.

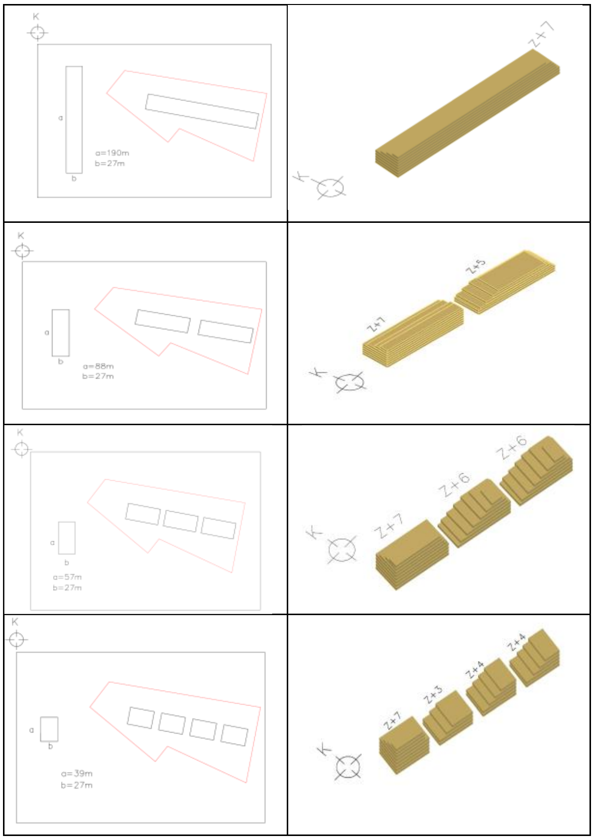


Figure 9: Different building masses suggestions for rehabilitation.

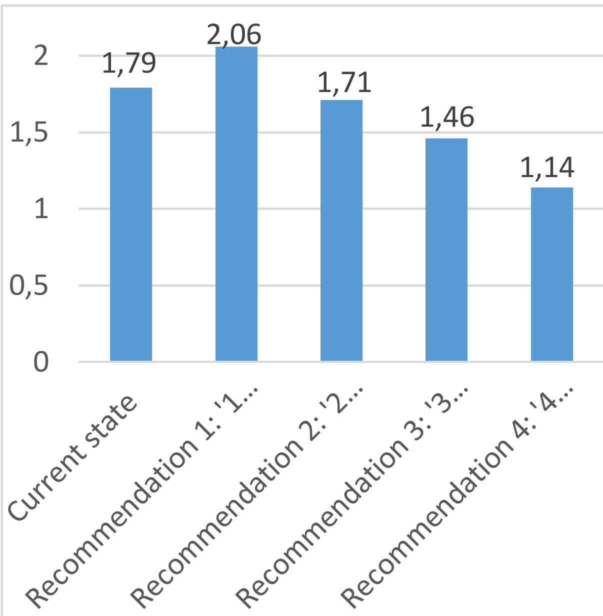


Figure 10: Comparison of the floor area coefficient in the current situation and suggestions.

In Figure 10 it is possible to see the variation of the floor area ration (FAR) for each suggestions. FAR is obtained from the division of the total construction area (total area of each floor) to the parcel area.

Single, double, triple, four divisions were made in the study area. As a result of this division following masses were emerged:

Proposal 1: The building intended to be a single mass and volume obtained by the solar envelope method has been taken in consideration. As a results, ground floor + seven-story building was obtained .Value of the floor area ratio (FAR: 2, 06) is higher than the current situation (1, 79). Floor area of the mass remained stable in the first and second level. The deformation begins from the third level.

Proposal 2: The building is intended to be two mass: The first mass has Ground floor+ seven and the second mass has ground floor + five- story. There is deformation from the fifth floor in the first mass. In the second mass, the ground floor and first floor remained stable, the deformation begins from the second floor. Value of the floor area ratio (FAR: 1, 71) is less than the current situation (1,79).

Proposal 3: The building is intended to be three mass: The first mass has ground floor +seven floor, the second mass has ground floor + six floor and the third mass has ground floor + six floor story. In the first mass, the area of the first five floor remained stable, deformation occurred in the sixth and seventh floors. In the second mass, only the ground floor remained stable, deformation occurred on other floors. In the third mass, ground floor area remained stable, deformation occurred on other floors. Value of the floor area ratio (FAR: 1, 46) is less than the current situation (1, 79).

Proposal 4: The building is intended to be four mass: The first mass has ground floor + seven floor, the second mass has ground floor + three floor, third mass has ground floor + four floor and the fourth mass has ground floor + four floors. In the first mass, ground floor area and the first five floors remained stable, deformation occurred in the sixth and seventh floors. In the second mass, the ground floor, first and second floor remained stable, deformation occurred in the third and fourth floor. The ground and first floor area of the third and fourth mass remained stable, deformation occurred in the second floor. Value of floor area ratio (FAR: 1, 14) is less than the current situation (1,79).

4. Conclusions and Suggestions

The creation of progressive and creative new approaches to effective use of solar energy in the design throughout the world is important for the sustainability of our habitat. Solar envelope method was developed as an alternative to energy efficient architectural design. In this study, to identify the solarization problems and to propose solutions, solar envelope method was used in the urban regeneration area in Bingöl province, which carried out by Toki. In this context; the study is composed of analysis of the current case and development of various rehabilitation alternatives. The findings showed that the potential benefit of the buildings from the sun is ignored in existing applications.

Designs should not be left to chance. The land must be used efficient while ensuring energy efficiency. Sustainability is a pillar of the economy, it cannot be ignored in any design. As a result of this method, it is observed that using pyramidal and gradual blocks instead of symmetric solutions and using of various story levels in the city context is a necessity. It is demonstrated that it is possible to use solar envelope method as a basement in design process of urban regeneration projects. It must be ensured that higher quality urban regeneration and renovation projects will be carried out by developing this study according to different climatic zones.

This study was carried out only in the small part of mass housing areas of Bingöl province. The results of this study revealed that in the current project the sun input data didn’t take into account. It was found that in the determined study area, there is excess volumetric construction of 30% in total. In the same parcel, four different general layout plan propositions were realized to demonstrate the built potential of the site according the sun data. All the proposal buildings produced with the solar envelope method will not create shadows to surrounding buildings. As a result of these proposals, differences appeared in the density value of the total constructible area. In the proposal study, it is possible to see clearly that the floor area ratio (FAR) values decreases as the number of the mass increases. In the first proposal, the result appears as a single mass, FAR value is higher than the current situation. But in this case problems may arise in the internal architectural solutions. Dark places may occur due to the deep interiors. To remedy this situation; in some places in the mass, voids can be designed so the light penetrates in the internal spaces. Another solution for this first proposal with the highest constructible area among the others, architects may recommend terraced house typology. In the second, third and fourth proposals FAR values were below the current situation. Floor area reductions appears on the upper floors. This situation requires bringing new perspectives to design. Generally, the method gives pyramidal volume. Different residential solutions are necessary especially on the higher floors. Reductions occurring in the upper floors can be assessed by solutions like Penthouses or duplex apartments.

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