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Determination of insolation conditions and selection of the optimal orientation of residential buildings

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The project is devoted to the determination of insolation conditions and the choice of optimal orientation of residential buildings, considering the latitude of the terrain of Poltava. Presently, there is a change from construction according to standard designs to individual design and the process of consolidation of residential construction in cities continues by new construction in the historic built-up areas. Compacting and increasing the number of floors inevitably worsens insolation in the living rooms of existing houses due to the additional shading of their windows, which leads to a decrease in the duration of insolation. The factor of rational planning of the territory and the optimal orientation of the house on the cardinal points, the correct choice of floors and configuration in the plan get special significance.

Keywords: duration of insolation, optimal orientation of the residential building, insolation ruler.

Визначення умов інсоляції та вибір оптимальної орієнтації житлових будинків

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Виконання санітарно-гігієнічних вимог при проектуванні житла здійснюється відповідно до умов фізико-географічного районування території України і включає у себе вимоги до інсоляції, природного освітлення, провітрювання, іонізації та мікроклімату приміщень житлових будинків. Робота присвячена визначенню умов інсоляції та вибору оптимальної орієнтації житлових будинків з урахуванням широти місцевості м. Полтава. На сьогоднішній час відбувається перехід від будівництва за типовими проектами до індивідуального проектування та триває процес ущільнення житлової забудови у містах шляхом нового будівництва в історично сформованій забудові. При розміщенні нового будівництва в існуючій забудові слід забезпечити дотримання вимог чинних нормативних документів щодо інсоляції. Наявність природного світла в оселі є важливим параметром, добре інсольовані будинки та квартири користуються попитом. Ущільнення й збільшення поверховості забудови неминуче погіршує інсоляцію в житлових приміщеннях існуючих будинків через додаткове затінення їх вікон, що призводить до зменшення тривалості інсоляції. Тривалість інсоляції приміщення залежить від орієнтації вікон по сторонам світу, розмірів, товщини огороджувальних конструкцій і відстані від будівель, розташованих поблизу. Слід зазначити, що на тривалість (наявність) інсоляції впливають також інші архітектурно-планувальні елементи будівель: балкони, карнизи, лоджії, що затіняють вікна. Будівельні норми й правила для житлових приміщень регламентують тривалість інсоляції та кількість кімнат у квартирі, у яких має бути забезпечена нормативна тривалість інсоляції. Умови й час інсоляції приміщень в Україні встановлюються Санітарними нормами і правилами інсоляції, а також відповідними типологічними будівельними нормами й правилами. Особливого значення набуває фактор раціонального планування території й оптимальної орієнтації будинку за сторонами світу, правильний вибір поверховості та конфігурації у плані.

Ключові слова: тривалість інсоляції, оптимальна орієнтація житлового будинку, інсоляційна лінійка.

Introduction

Insolation of rooms along with their illumination, temperature-humidity, and noise conditions play a significant role in ensuring a comfortable mode of living.

Insolation regulation and calculation is the most acute lighting, economic and socio-legal problem, because these calculations restrain the desire of investors, landholders and tenants to overdensify urban development.

Review of the research sources and publications

Insolation in residential buildings should primarily take into account the requirements of national sanitary legislation, which is based on the study of natural and climatic conditions of different regions of Ukraine, to create the necessary living conditions and public health [1-3].

The determination process begins with the development of space-planning solutions for the new building. Then an insolation calculation is made using a solar map or an insolation ruler [4, 5, 6].

Issues of insolation rationing were dealt with by Dunaev B. A., Vernesku D., Zemtsov V. A., Skryl I.N., Haharin V. H., Pidhornyi O.L., Yehorchenkov V.O., Elahin B.T., Sergeychuk O., Martynov V. The results of their research are presented in the works [7-40].

Definition of unsolved aspects of the problem

Design of residential building standards do not allow apartments where all rooms orientation to the north side of building. Rooms with windows on the north facade of houses in cold weather are not insolated at all, and in summer they receive some morning and evening "sliding" sunlight, which almost does not enter to the room.

However, there is often a breach of insolation standards due to the orientation of the facades of houses to the north-west and north-east in urban planning practice (such situations are found when it is necessary to consider the existing road network), and when the insufficient distance is between the houses.

Therefore, the choice of optimal orientation of the house on the cardinal points is quite relevant task.

Problem statement

The purpose of the work is to research the insolation of the rooms of a residential house.

Tasks of research are:
- analysis of insolation conditions in the rooms of a residential building with different orientation to the cardinal points;
- choosing the optimal orientation for the house.

Basic material and results

Insolation is an important health factor, so the standards of insolation must be satisfied in the rooms of residential and public buildings and in the area of residential development. The optimal effectiveness of insolation is achieved by providing a daily continuous 2.5-3-hour exposure to direct sunlight to premises and territories. Insolation provides a health-improving, psychophysiological, bactericidal, thermal effect. The normalization is conducted in the spring and autumn period of the year, taking into account the light and climate characteristics of different areas of the country and the characteristics of the building. The requirements of the standards are achieved by the appropriate placement, orientation and layout of the buildings.

The standardized duration of insolation should be provided not less than in one living room of 1-, 2-, 3-room apartments and not less than in two living rooms of 4- to 5-room apartments. In multistory buildings (9 or more floors) allowed a single interruption of insolation of residential and public buildings (except as listed above) on condition of increasing the total duration of insolation during the day by 0.5 hours respectively for each zone.

Limitation of the excessive thermal effect of insolation in rooms and areas during the hot season should be ensured by appropriate planning and orientation of buildings, landscaping, using sun protection devices, and, if necessary, air conditioning and indoor cooling systems. Limiting the thermal effects of insolation areas should be provided by shading from buildings, special shading devices, and rational landscaping.

The year-round shading of the facades of buildings and residential areas is not allowed. Mid-year shadows (from September 22 to March 22) shall not exceed 40% of the total area of the housing areas free from housing development.

The duration of insolation of the room is calculated on the ground floor of the building through the central point of the lighting penetration, the dimensions of which meet the requirements of the norms of natural lighting of the premises. It is necessary to keep in mind the location and size of the building elements shading the lighting penetrations (shading houses, canopies, balconies, loggias, porticos, shutters, etc.).

Calculation of the duration of insolation is made for the premises in which it is normalized in accordance with the requirements of the norms [2,3].

During the analysis of insolation norms in multistory residential buildings, if apartments located under each other have the same layout on all floors, the calculated apartments are taken on the lowest residential floor. The duration of insolation on all other floors of the corresponding rooms will not be less.

If the ground floor has apartments with the same layout and orientation, the calculation of the duration of insolation of these apartments is advisable to start with the apartment that is most shaded by the opposite buildings and the relief of the area (in the absence of a shading building). If this apartment meets the standards, all other similar apartments will have a satisfactory insolation regime.

It is advisable to start calculating the duration of insolation with the living room that has the best insolation conditions in multi-room apartments according to the following attributes:
– favorable orientation;
– absence of summer facilities;
– the largest geometric dimensions of a window;
– the longest distance from neighboring houses.

If the insolation standards are met in this room, and the apartment consists of at most three living rooms, the insolation standards are also met for the apartment as a whole. It is necessary to check insolation of the next room according to the probability of meeting the standards for 4-, 5-room apartments, and checking of two rooms for apartments consisting of six or more rooms.

The degree of suitability of window orientation for insolation conditions is determined (Fig. 1), depending on the requirements for insolation mode of the premises.

It is advisable to calculate using an insolation ruler for calculating the duration of insolation of the territory of residential buildings.
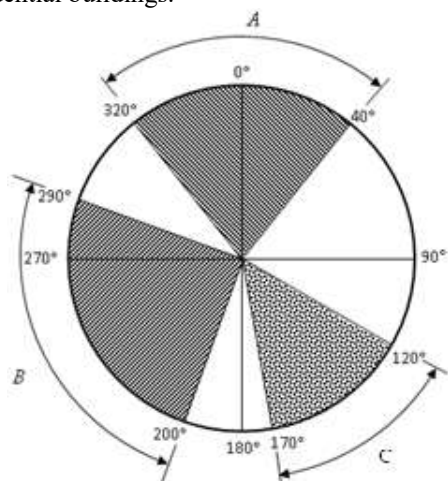
Figure 1 – Insolation characteristics of the horizon sectors on the territory of Ukraine.
A – insolation deficiency sector;
B – overheating sector
(for III and IV building-climatic regions);
C – sector of highest effect of ultraviolet radiation

Ukraine uses insolation rulers constructed for each whole degree from 45° to 52° north latitude. The nearest insolation ruler, depending on the geographic latitude, is taken for a particular calculation site. The scale of the insolation ruler should coincide with the scale of the general plan.

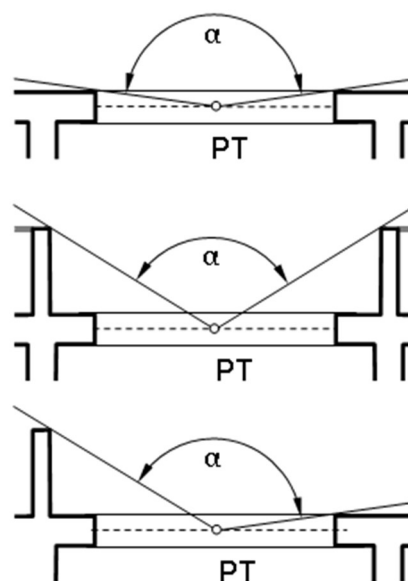Calculation of the duration of insolation with the insolation ruler is performed in this sequence:

- the horizontal angle of insolation is determined α: in calculating the duration of insolation of the room – is on the plan of the room, considering the vertical screening elements of the lighting aperture (Fig. 2), in calculating the duration of insolation of the territory α = 180°;

- insolation ruler is oriented on the sides of the horizon according to the orientation of the general plan and aligned in such a way that the pole of the graph (the point where the sun's rays coincide), coincides with calculation point;

- the sectors of shading by the opposite buildings and the surface of the terrain are defined within the horizontal angle of insolation;

- the calculated duration of insolation is determined from 7^{00} to 17^{00} as the difference between the duration

of insolation within the horizontal angle of insolation and the duration of shading by opposite houses and relief.

Figure 2 – Determination of the horizontal angle of insolation in rectangular windows

The method using the insolation ruler is used in the following calculations to calculate the duration of insolation of the premises for two days of the year, which is March 22 and September 22. Complying with regulatory requirements on these days usually guarantees their fulfillment throughout the entire calculation period.

A group of radial lines is conducted, an insolation graph is constructed using an additional graph, taking into account the latitude of Poltava (Fig. 3).

We used the plan of the apartment house with dimensions in the axes 16,2*32,1 m to perform the calculations.

The structural plan of the building is designed rigid, with longitudinal load-bearing and transverse non-bearing walls throughout the height of the building.

There are three two-bedroom apartments and one three-bedroom apartment on each floor (Fig. 4). The apartments include loggias.

The first calculation of the insolation of the rooms was performed with the longitudinal axis of the house in the direction of North-South (Fig 5.).

As the location of the rooms relative to the longitudinal axis of the house in the direction of the world and the size of the window openings in the rooms of different apartments are the same, so it is possible to determine the duration of insolation for only one case.

Apartment №2.

If the house is located with its longitudinal axis in the North-South direction, the insolation duration will be: - in room №3 of apartment №2 is the same as in room №2 of apartment №1;

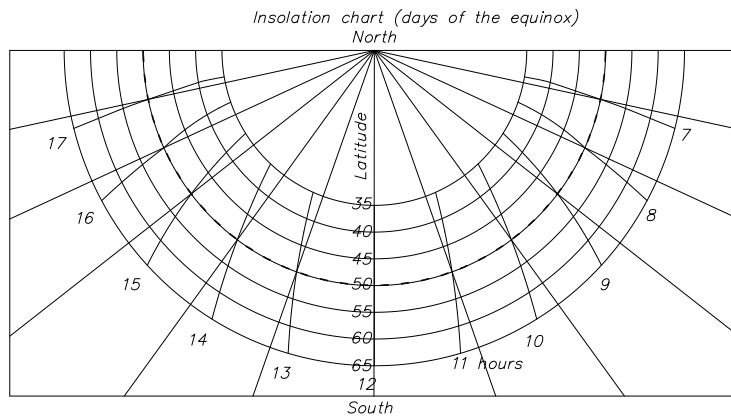- in room №4 of apartment №2 is the same as in room №1 of apartment №1.

Insolation chart (days of the equinox)

Figure 3 – Construction of the insolation diagram, taking into account the latitude of Poltava
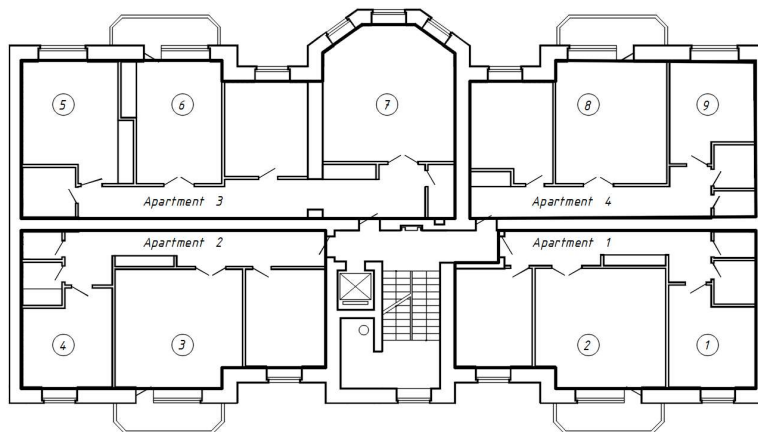

Figure 4 – Calculation scheme of the house. 1-9 – numbers of rooms, which can be calculated

Apartment №4.

If the house is located with its longitudinal axis in the North-South direction, the insolation duration will be: - in room №8 of apartment №4 is the same as in room №6 of apartment №3;

- in room №9 of apartment №4 is the same as in room №5 of apartment №3.

The results of the calculations are summarized in Table 1.

Table 1 – Duration of insolation of the rooms of the house from North-South direction

№ of the apartment	№ room	Beginning of insolation	End of insolation	Duration of insolation, hour.	Fulfillment of standards for insolation of the room	Fulfillment of the standards for insolation of the apartment
1	1	13 h 15 m	17 h 00 m	3 h 45 m	+	+
	2	12 h 38 m	17 h 00 m	4 h 22 m	+	
2	3	12 h 38 m	17 h 00 m	4 h 22 m	+	+
	4	13 h 15 m	17 h 00 m	3 h 45 m	+	
3	5	7 h 00 m	10 h 28 m	3 h 28 m	+	+
	6	7 h 00 m	11 h 21 m	4 h 21 m	+	
	7	7 h 00 m / 7 h 00 m / 7 h 00 m (7 h 00 m)	8 h 2 m / 10 h 45 m / 12 h 20 m (12 h 20 m)	5 h 20 m.	+	
4	8	7 h 00 m	11 h 21 m.	4 h 21 m	+	+
	9	7 h 00 m	10 h 28 m	3 h 28 m	+	
Duration of insolation in the rooms of the house (per floor)						37 h 12 m
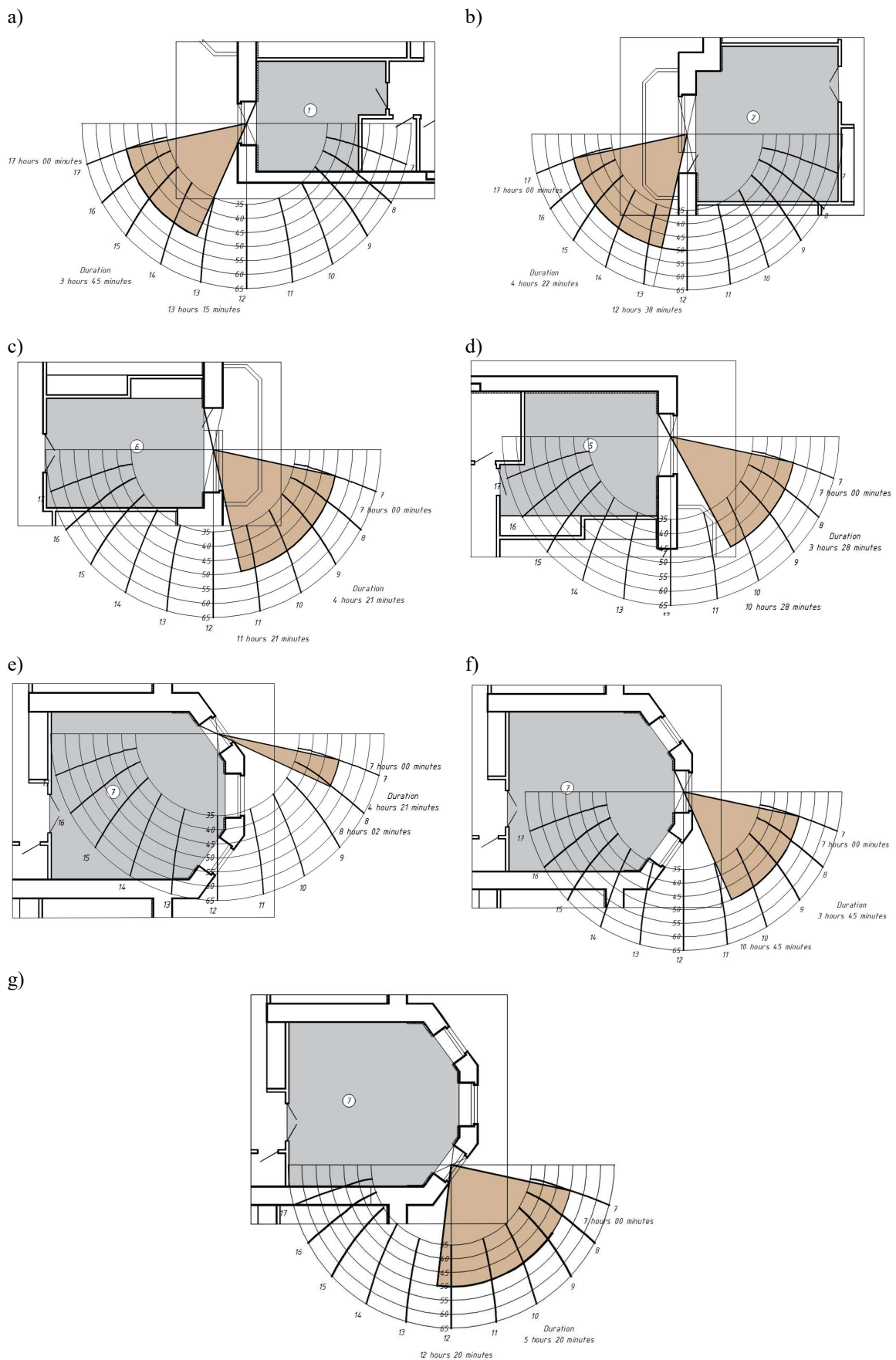
Figure 5 – Determining the duration of insolation in:
a) room №1 of apartment №1; b) room №2 of apartment №1; c) room №6 of apartment №3;
d) room №5 of apartment №3; e) room №7(window №1) of apartment №3;
f) room №7(window №2) of apartment №3; g) room №7(window №3) of apartment №3
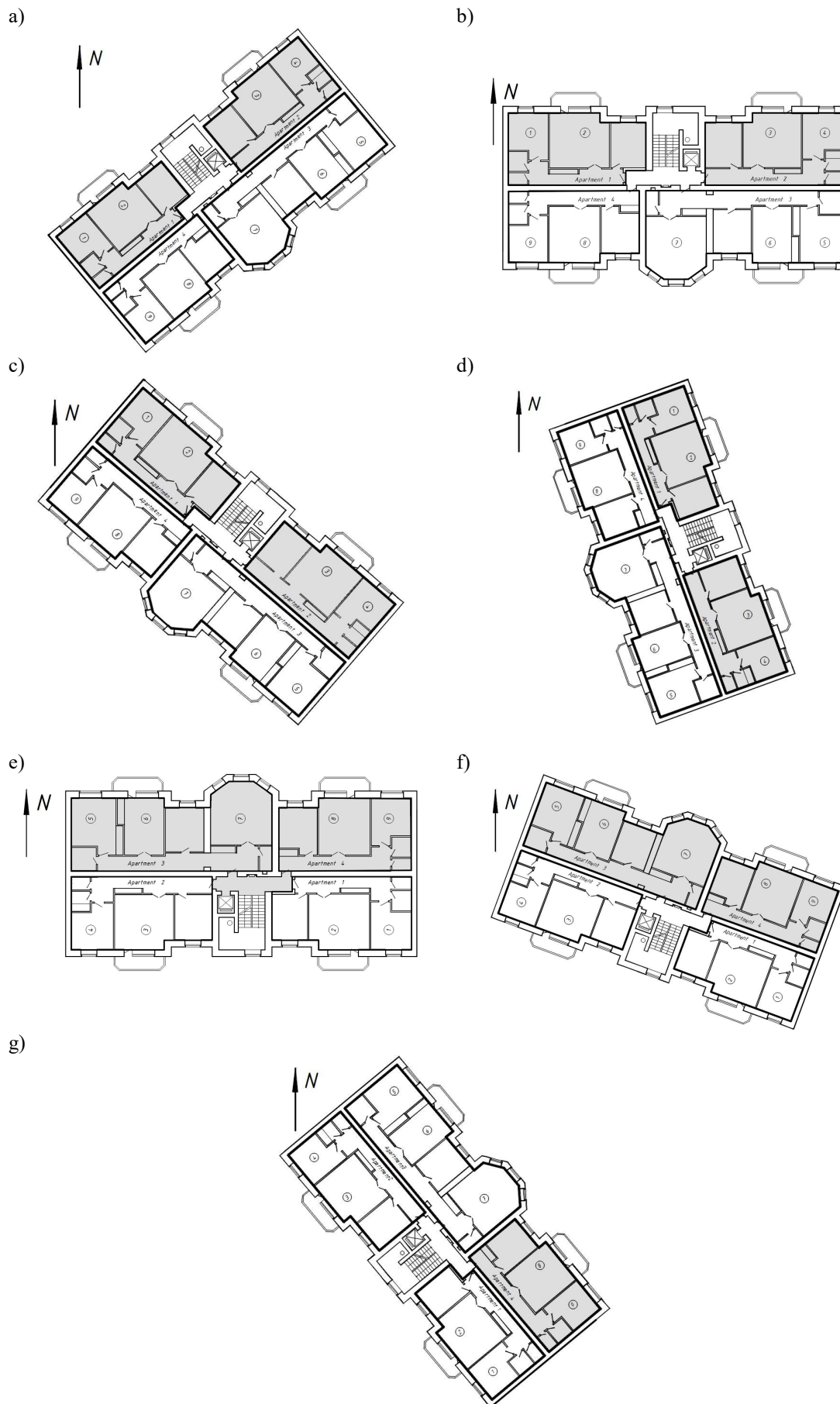
Figure 6 – Rooms where insolation standards are not met depending on the rotation of the longitudinal axis of the house from North-South direction:
a) by 60°; b) by 90°; c) by 120°; d) by 150° e) by 240°; f) by 270°; g) by 300°

The insulation standards for all apartments are complied when the longitudinal axis of buildings is oriented in the North-South direction.

Similarly, we calculate the insolation of the rooms when the longitudinal axis of the house is turned by 30º, 60º, 90º, 120º, 150º, 180º, 210º, 240º, 270º, 300º and 330º from North-South direction.

The norms of insolation are not met in apartments when the longitudinal axis of the house is turned by 60º, 90º, 120º, 150º, 240º, 270º and 300º (Fig. 6).

The choice of the optimal orientation of the residential building was made according to the following indicators:

- the value of total insolation of apartments in a residential building (per typical floor) (Fig. 7);
- the number of rooms where the insolation requirements are met (Fig. 8);
- the number of rooms where the insolation requirements are met (Fig. 9);
- the number of rooms where the insolation requirements are met (Fig.10).

Table 2 summarizes the indicators shown in the graphs of Figures 7 - 10.
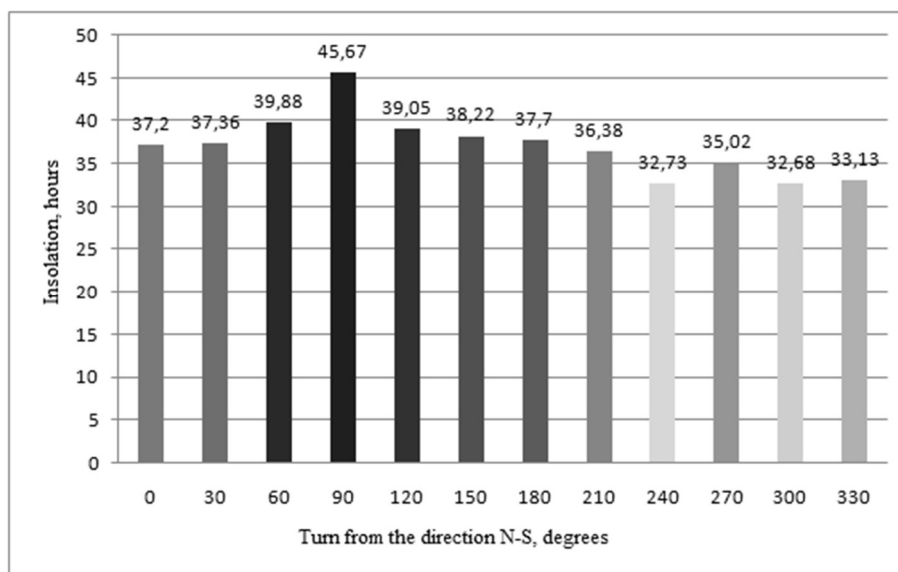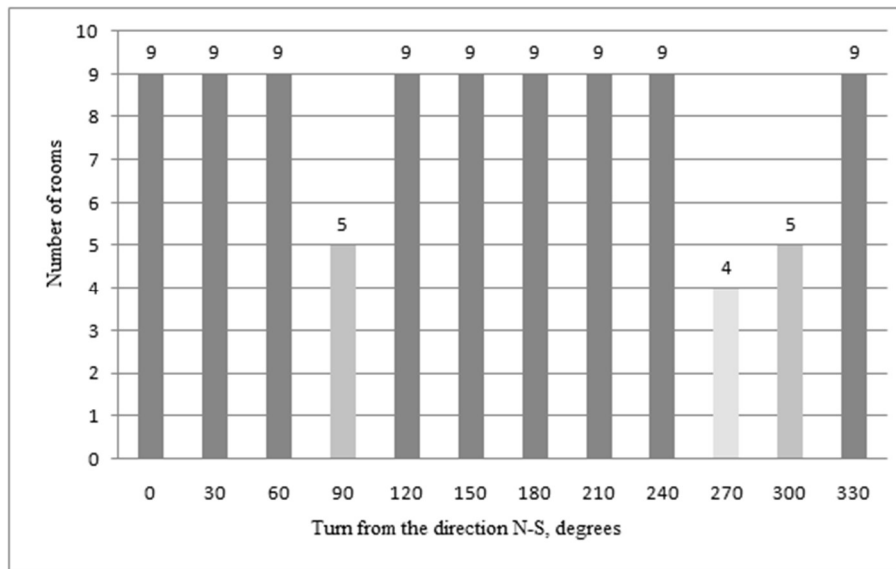

**Figure 7 – Cumulative insolation of apartments depending on the rotation
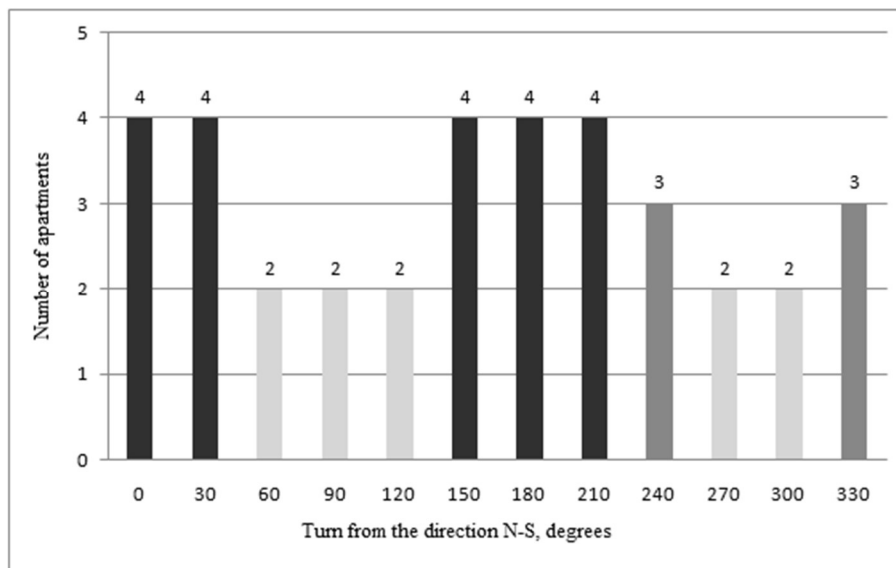of the longitudinal axis of the house from North-South direction**
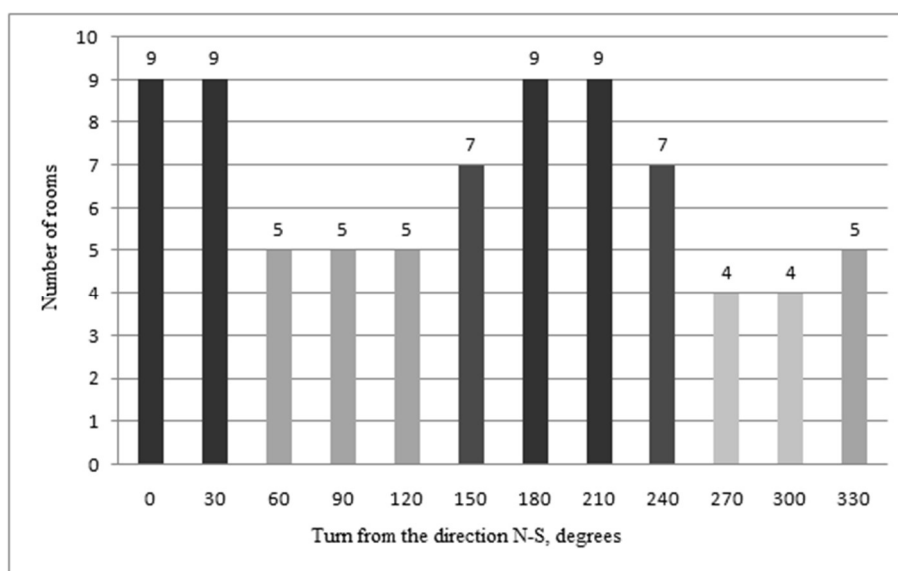
**Figure 8 – Number of rooms where insolation requirements are met depending
on the rotation of the longitudinal axis of the house from North-South direction**

Figure 9 – Number of rooms where insolation occurs depending on the rotation of the longitudinal axis of the house from North-South direction

Figure 10 – Number of apartments where insolation requirements are met depending on the rotation of the longitudinal axis of the house from North-South direction

Table 2 – Duration of insolation of the rooms of the house from North-South direction

Name of parameter	The value of the indicator when the longitudinal axis of the house is turned from North-South direction by											
	0°	30°	60°	90°	120°	150°	180°	210°	240	270°	300°	330°
Cumulative insolation of apartments in a residential building	7	6	2	1	3	4	5	8	12	9	11	10
Number of rooms where insolation requirements are met	1	1	3	3	3	2	1	1	2	4	4	3
Number of rooms where insolation occurs	1	1	1	2	1	1	1	1	1	3	2	1
Number of apartments where insolation requirements are met	1	1	3	3	3	1	1	1	2	3	3	2
Sum of the indicators	**10**	**9**	**9**	**9**	**10**	**8**	**8**	**11**	**17**	**17**	**20**	**16**

Conclusions

The total insolation in all rooms of the house (per typical floor) is greatest when the longitudinal axis of the house is turned from North-South direction by 90° and 60°.

The biggest number of rooms that meet the requirements of insolation when the longitudinal axis of the house is turned from North-South direction by 0°, 30°, 180° and 210°.

The biggest number of rooms where insolation occurs when the longitudinal axis of the house is turned from North-South direction by 0°, 30°, 60°, 120°, 150°, 180°, 210°, 240°,150°, 210° and 330°.

Insolation requirements in one of the apartments are not satisfied when the longitudinal axis of the house is turned from North-South direction by 60º,90º, 120º, 270º,300º,330º.

According to the sum of all indicators, the worst orientation is when the longitudinal axis of the house is returned from North-South direction by 300º.

The smallest sum of indicators when the longitudinal axis of the house is turned by 180° from the direction of North-South, as seen in Table 2, is the optimal orientation of the residential building.

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