Vol. 9, No 1/2020, 83-87

DOI: 10.17512/bozpe.2020.1.10

Construction of optimized energy potential
Budownictwo o zoptymalizowanym potencjale energetycznym

ISSN 2299-8535 e-ISSN 2544-963X

Projecting energy-efficient residential buildings in the climatic conditions of the mountainous regions of Armenia

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Abstract: The article presents the results of studies aimed at clarifying the heat engineering calculations of energy-efficient residential buildings in the mountainous regions of Armenia. The regular changes in climatic factors of mountainous conditions at the altitudes of 800-1000 m above sea level were determined from the statistical and regulatory data of the Republic of Armenia using the method of statistical and correlation analysis and mathematical modelling. A quantitative evaluation of changes in climatic factors of the mountainous conditions was carried out which improved the accuracy of heat engineering calculations, to identify the costs of optimal energy consumption and to reduce the cost price of building energy-efficient houses. The coefficients of the dynamics of changing climatic conditions of the Republic of Armenia, given in the article, are recommended to be used in the heat engineering calculations of the buildings when reducing the energy capacity of houses, construction costs and increasing the energy potential of the Republic of Armenia.

Keywords: factors of mountainous conditions, energy-efficient residential buildings, optimal energy consumption, alternative energy sources, projecting, construction, construction cost

Please, quote this article as follows:

Tokmajyan H.V., Israyelyan R.G., Tavadyan M.A., Miqayelyan N.A., Projecting energy-efficient residential buildings in the climatic conditions of the mountainous regions of Armenia, BoZPE, Vol. 9, No 1/2020, 83-87, DOI: 10.17512/bozpe.2020.1.10

Introduction

The issue of saving energy worldwide is considered, not so much from the point of view of cost reduction, but rather from the point of view of increasing the energy security of the country. Even countries in Western Europe, which have a milder climate, are taking decisive and effective measures to accomplish this task. This includes energy savings in all sectors of the economy and also the use of alternative energy sources (solar, wind, biofuels etc.). The energy obtained from alternative sources is increasing in most countries. It should be noted that due to the measures taken, the demand for oil and gas in developed countries is decreasing. There are also examples of existing power plants stopping production as they become unnecessary (Tokmajyan, 2010).

1. Conflict setting

The problem of Armenia's energy dependence is deepening due to the absence of its own fuel resources and unfavourable geological position. This makes the construction of energy-efficient buildings a priority as the costs for central heating can be reduced by 7-10 times the current amount. Also, in general, energy independence, ecology of constructed buildings and energy security of countries are increasing.

The regular changes in the natural and climatic factors of mountainous conditions and the dynamics of their development are determined which improves the accuracy of heat calculations of energy-efficient residential buildings and so has a positive economic effect.

2. Research results

Determining the patterns of change in the climatic factors of mountainous regions in Armenia in order to improve the accuracy of heat engineering calculations of energy-efficient residential buildings, along with the use of non-traditional types of energy will reduce construction costs and increase the energy potential of the republic.

Based on the statistical processing of the data and shown below are: the results from long term observations of the hydro-meteorology of Armenia, guidebooks and normative documents (Construction Norms – Construction climatology, 2003; Construction Norms – Heat protection, 2003; Israelyan, 2015; Tokmajyan, 2010), and the patterns of changes of climatic factors of mountainous conditions at the altitudes of 800-2000 m above sea level (Israelyan, 2015).

– *Atmospheric precipitations, factor* $X_{2.1}$

Correlative dependence of the changes of average annual precipitations from the altitudes above sea level (h):

$$X_{1.2} = 33.56 + 472.56 \cdot 10^{-3}\, h - 80 \cdot 10^{-6}\, h^2 \ \text{[mm]} \tag{1}$$

– *Air temperature, factor* $X_{2.2}$

Correlative dependence of the changes of air temperature revealed by statistical processing of average annual normative and guideline data throughout the Republic of Armenia depending on the altitude above sea level (h) and expressed as:

$$X_{2.2} = 18.557 - 7.091 \cdot 10^{-3}\, h \ \ [°C] \tag{2}$$

– *Wind, factor* $X_{2.3}$

Essentially, winds are manifestations of intense currents in the atmosphere, seeking to equalize the different degrees of heating of various zones of the mountain relief. In the zone of the most heated mountain slopes the air density decreases and rises vertically moving towards the colder areas. Part of this air, cooled at high altitudes, descends to the surface of the earth.
The following types of winds prevail in mountainous areas: cold (boron), warm dry (hair dryer) and mountain-valley which are usually observed in the warm season of the year. Mountain-valley winds have a clearly recognisable daily change of direction: during the daytime they blow from the bottom of the valley, up along the mountain slope or along the edge of the gorge and at night the reverse is observed.
By statistical processing of average annual data the correlation dependence of the vertical change in average annual wind speed based on the altitude (h) above sea level was established which can be expressed as follows:

$$X_{2.3} = 0.8236 + 0.836 \cdot 10^{-3}\, h \ \ [m/s] \tag{3}$$

– *Barometric pressure, factor* $X_{2.4}$

The change of barometric pressure depends on the height of mountain relief (h) and has the following expression:

$$X_{2.4} = 1000 - 0.11\, h + 0.41 \cdot 10^{-5}\, h^2 \ \ [G/Ps] \tag{4}$$

– *Number of days with snow covering, factor* $X_{2.5}$

The period of stable snow cover in mountainous regions depends on the altitude from sea level, the form of the relief and exposition of the slopes. The statistical processing of average annual data on the number of days with snow cover depends on the altitude above sea level (h) and has the following expression:

$$X_{2.5} = 81.689 - 118.631 \cdot 10^{-3}\, h + 75.128 \cdot 10^{-6}\, h^2 \ \ [days] \tag{5}$$

– *Air humidity, factor* $X_{2.6}$

Water evaporation is not a stable component of atmosphere, its content changes depending on physical and geographical conditions of mountainous regions, seasons of the year, circular peculiarities of atmosphere, and the conditions of surface soil etc.

Depending on the season of the year, the distribution of the relative humidity of air in mountainous areas differs both in size and distribution patterns. In summer the relative humidity of the air increases in mountainous areas with altitude and reaches the highest points at 2000 m above sea level. In wintertime, the distribution of relative humidity in these areas has almost the opposite character compared with the summer months.

By statistical processing of average annual data the correlation dependence of the change in average annual relative humidity of air is determined dependant on the altitude (h) above sea level which has the following expression:

$$X_{2.6} = 60.68 + 4.45 \cdot 10^{-3}\, h \ [\%] \quad (6)$$

The relative humidity of the air determines the possible speed of evaporation. In the case of high relative humidity (about 85%) evaporation is limited.

– *Solar radiation, factor* $X_{2.7}$

Solar radiation is defined as: the energy of the sun received by the Earth in the form of electromagnetic waves. Direct solar radiation is defined as: the part of the solar radiation entering the surface in the form of direct sunlight and diffused solar radiation as: the part of the solar radiation entering the surface from the entire sky after diffusing in the atmosphere. The spectral distribution of solar energy in mountainous areas decreases vertically downwards with a weakening coefficient from 0.2 to 0.7.

Such factors such as cloud cover and pollution of the atmosphere cause local fluctuations in the amount of radiation hitting the earth. Therefore, the identification of patterns of changes in solar radiation in mountain conditions is a difficult and practically impossible task.

– *Number of foggy days, factor* $X_{2.8}$

The distribution of fog in mountain conditions is complex and has significant recurrence with no regulation of vertical development. The average number of foggy days in some areas is about 35% per year. This is due to the diversity of physical-geographical conditions and features of the atmospheric circulation.

The natural, climatic factors of mountain conditions that tend to increase with altitude include: precipitation and wind speed up to 1.8 times; the number of days with snow cover up to 4 times and relative air humidity 1.1 times. The air temperature and barometric pressure in terms of the increasing height of the mountain relief decrease from 2.9 and 1.2 times respectively (Israelyan, 2015).

The changing dynamics in climatic factors of the mountain conditions in Armenia in relation to an altitude of 800 m above sea level is given in Table 1.

Table 1. The changing dynamics of factors of mountain conditions in the Republic of Armenia (*own research*)

No	Factors	Altitude from sea level [m]						
		800	1000	1200	1400	1600	1800	2000
1	Atmospheric precipitations	1	1.18	1.34	1.49	1.62	1.73	1.82
2	Air temperature	1	–1.32	–1.64	–1.97	–2.29	–2.62	–2.90
3	Barometric pressure	1	–1.02	–1.04	–1.07	–1.09	–1.12	–1.15
4	Number of days with snow cover	1	1.29	–1.70	–2.10	3.05	3.70	4.10
5	Air humidity	1	1.01	1.03	1.04	1.05	1.06	1.10

Conclusion

1. Heat engineering calculations of energy-efficient houses in the mountainous conditions of the Republic of Armenia are recommended to be carried out taking into account the above coefficients (Table 1).
2. Research results have a practical value and their application in projecting will result in the final calculation, rise of economic potential of the republic and reduced costs of constructing energy-efficient houses.

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