Quantifying lack of external shading within former soviet standard housing

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Abstract. In order to contribute to a strategy of future upgrades as to mass housing inherited by Russian cities from the previous Soviet epoch, the paper addresses a problem of outer shading devices absence that leads to summertime overheating in the dwellings (inhabitants’ opinion and Passive House criterion). By using the ratio of projections area (as a complex of shading elements) to windows area when estimating basic samples of the urban housing stock from the period 1950s – 70s in terms of their shading qualities, this study provides data on their potential inclination to be overheated. Thus, the model ratio is indicated. Finally, the Unshaded Windows Factor, described as the model ratio and divided by a current one, is introduced with the intention of making a preliminary assessing tool. The outcomes can be used in a process of sun-protections development during mass urban housing renovation.

1. Introduction

1.1. A brief retrospect to the Soviet standard housing

A post-war situation of acute housing shortage forced Soviet authorities to find ways to accelerate rates of the construction. Exceptional possibilities in decreasing terms of putting erecting houses into operation were seen in the application of rapid-flow construction method. Thus, the building industry was invariably aimed at conveyor-based principle to produce construction elements, and planning organizations were charged with the adaptation and developing standard designs of mass housing [1].

Prepared by a large number of standard buildings projects developed and approved earlier, Order No 193 was issued by the Committee for Architecture under Council of USSR Ministers in March 1948. It established a list of 200 projects that were obligatory for any residential construction in the USSR; additionally, according to the Order, State Organizations for Architectural and Construction Control were prohibited from issuing permits for the construction of houses based on non-standard projects. As a result, unconditional application of standard projects only approved by the Committee for Architecture was provided. By the end of 1948, 700 000 m² of floor space based on standard projects was erected about the country (52% of the total construction) [1].

An essential stage of the standard housing development process in the USSR is associated with a resolution "On the development of the production of prefabricated reinforced concrete structures and components for construction" issued by the Council of Ministers in August 1954 [2]. Launching of 402 factories within the USSR afterwards added to the standardized building stock a vast bulk of houses completely assembled from prefabricated structures on sites. For the next decades, standard
prefabricated housing transited through a number of generations, constantly increasing a variety of types and number of realization, and determined general features of the majority of modern urban residential areas, houses and apartments in the country: in Russia, approximately 60% of the existing residential floor spaces constructed from 1948 to 1990 belong to this kind of housing [3].

1.2. Thermal conditions and a need for renovation

By now, this dwelling stock needs for considerable renewal interventions to meet current requirements. At the same time, in terms of the renovation, this housing provides potentially wide opportunities for increasing quality of the urban areas occupied. First of all, despite their large quantity the houses are completely unified (according to the types) and a limited set of architectural solutions is enough for an immense effect just through its replication. Moreover, this set of solutions can be uncomplicated and, hence, easy to perform because of comparative simplicity of the houses building fabric: technically, such a typology of houses is reported to be easily adapted to comprehensive retrofit strategies (such as Passive House Standard) [4].

One of the housing vital problems is the inhabitants’ thermal discomfort. This is inferred from a questionnaire that was handed out to the inhabitants of relative housing in the context of local housing studies. In particular, 28 out of 34 respondents had experienced discomfort excess summertime indoor temperatures, and 15 out of 28 had carried out available measures to protect their apartments from the solar heat. Overheating in the dwellings due to lack of an adequate solar shading, while happening in short period, was supposed to be one of the primer factors of the microclimate dissatisfaction. At the same time, it is shading system in various types that form the basis of counter-overheat strategy and are necessary and, often, sufficient to minimize or prevent the increase of indoor temperatures due to solar gains [5,6].

All in all, the preliminary data obtained disclose a tendency within the dwellings to high temperatures excess as a consequence of unshaded windows during the hottest summer period, in July as a rule. Therefore, in order to form a set of compensative measures during prospective renovation, a need to determine the missing share of exterior shading for the housing arises.

2. Materials and method

A group of the housing samples is chosen to represent an urban dwelling stock of the sixties, seventies and eighties marked with the massive use of standard projects for residential development, with slight climate-adjusted modifications, throughout the USSR (the samples are drawn from a standard project list implemented in Chelyabinsk city, Figure 1, Table 1).

A pre-assessment using empirical values of the acceptable shares of glazed areas for different orientations (from the Annex 50 of the International Energy Agency [7]) within the samples shows that there are excesses over the values varying from 3 to 10 per cent, that especially critically for the most heating eastern/western orientation [8].

A further evaluating procedure is based on an earlier proposed approach [9] according to which the relationship between total area of exterior shading components and total windows area of a building can be expressed through the ratios that are able to be indicators of that whether the building is prone indoor temperature excesses caused by solar heat. This approach is underpinned by calculations of overheating frequency for various combinations of shading elements and windows areas of a case study carried out in Passive House Planning Package (PHPP) [9]. By means of PHPP a boundary value corresponding to Passive House criterion (25°C should be less than 10% of time [8]) is determined (under the South Ural climate) and it equals 2.5. This value enables to arrange the housing samples in terms of their tendency to overheating based upon greater or less than 2.5 their ratios of shading area to windows area are.

A visible limitation of the method is that it unifies shading and translucent elements without differentiating variations of their locations about the surface of a building only drawing a basic tendency in a quantitative way.
Figure 1. Samples of the standard housing stock. (Additional elevations are put where there is a significant contrast between the façades).
Table 1. Properties of the housing samples.

| Type of a standard project | Project start year | Orientation\(^a\) of the principal façades | Exterior shading components total area\(^b\) (m²) | Windows total area\(^c\) (m²) |
|---------------------------|--------------------|-------------------------------------------|-----------------------------------------------|-----------------------------|
| 1-464-1                   | 1959               | South and north (SN)                      | 102                                           | 187                         |
|                           |                    | East and west (EW)                        | 205                                           | 344                         |
| 1-447C-19                 | 1960               | SN                                        | 54                                            | 82                          |
| 1-447C-6                  | 1958               | SN                                        | 48                                            | 59                          |
|                           |                    | EW                                        | 77                                            | 112                         |
| 1-464C-46                 | 1968               | EW                                        | 559                                           | 543                         |
| 1-464A-52                 | 1966               | SN                                        | 264                                           | 242                         |
|                           |                    | EW                                        | 528                                           | 454                         |
| 1-447C-49                 | 1968               | SN                                        | 1881                                          | 762                         |
|                           |                    | EW                                        | 1881                                          | 1262                        |
| 97.1-22/1.2               | 1987               | SN                                        | 230                                           | 89                          |
|                           |                    | EW                                        | 378                                           | 138                         |
| 85-06                     | 1973               | SN                                        | 179                                           | 62                          |
|                           |                    | EW                                        | 314                                           | 123                         |

\(^a\) In the method employed areas of the buildings windows and shading devices taken into account depend on the orientation of the most developed and fenestrated façades, therefore the southern-northern and eastern-western orientation (two from the chiefly occurring ones) have different values of the areas (under the eastern-western orientation they are greater than under the other).

Samples with single-facing apartments (1-447C-19, 1-447C-46) are only considered under eastern-western orientation due to insolation requirements for all dwellings (the requirement is that sun rays should directly illuminate living space through windows continuously during 2.5 hours).

\(^b\) Along with balconies/loggias slabs (providing overhang from 0.9 to 1.2 m) and parapets other components of the envelope that are able to produce extensive shadow when oriented south, east or west are taken into consideration: eaves, projecting of walls, and sheds.

\(^c\) Glazed area is only taken into account.

3. Results

The lack of the shading, and thereby the inclination to overheating, within the housing samples can be traced in the chart below (Figure 2): the lower the ratio the more the lack and the inclination.

No ratios turn out to fall below the minimum indicated – 0.5 (coincides with 26% of the time). But, exceedance of 25°C more than 15% of annual occupied hours (corresponds with the ratio equalling 1.2) is called ‘catastrophic’ [10]. This means that five types – 1-464-1, 1-447C-19, 1-447C-6, 1-464C-46 and 1-464A-52 – prove to be at significant risk of overheating. While 1-464A-52 oriented east/west meets the boundary, 1-464-1 is twice away from it, regardless of what the orientation is. In general, orientation plays an insignificant part for the most types except 1-447C-49, which, when oriented south, is able to meet the Passive House condition (10%/25°C) due to developed balconies and loggias only located on the southern façade. Three of eight types comply with or even exceed the threshold value with ratios varying from 2.5 (1-447C-49 with the only orientation) to 2.7 (97.1-22/1.2) and 2.9 (85-06).

Taken together, degree of shading lack revealed among the analyzed types approximately correlates with their age. The greatest degree is among types from the end of fifties to the middle of sixties, whereas the later types, up to 1987, have the least degree. The results point to both that the primary shading factor within the later types is exterior private spaces (balconies, loggias), which are more expanded comparing with the earlier ones, and that these spaces when developed enough for
Living conditions are able to meet sun-protection requirements under the local climate without additional measures.

Figure 2. The housing samples inclination to overheating through the comparison between the ratios (shading/windows areas) and PHPP calculations.

4. Conclusions
Since the connection between the ratio of external shading elements area to windows area and duration of indoor overheating has been indicated [9], the ratio is used as an independent assessing tool in the study. As the ratio equaling 2.5 tallies with acceptable value of overheating frequency (equals or less than 10%) in the South Ural climate it is interpreted as a model ratio. This generates Unshaded Windows Factor (UWF) that is introduced to simplify the assessment. UWF is expressed as $2.5/ R_{ES/W}$ (where $R_{ES/W}$ is the external shading/windows ratio of an assessed building) and should be less or equals 1; otherwise the building is assumed to be vulnerable to overheating. An attempt to apply UWF towards the most advantageous orientations of the housing samples is represented in table 2.

Table 2. Application of Unshaded Windows Factor for assessment the housing samples.

| Type of a standard project | Orientation | UWF |
|---------------------------|-------------|-----|
| 1-464-1                   | EW (SN)     | 4.2 |
| 1-447C-19                 | EW          | 4.2 |
| 1-447C-6                  | SN          | 3.1 |
| 1-464C-46                 | EW          | 2.5 |
| 1-464A-52                 | EW          | 2.1 |
| 1-447C-49                 | SN          | 1.0 |
| 97.1-22/1.2               | EW          | 0.9 |
| 85-06                     | SN          | 0.8 |
The other conclusion can be drawn regarding potential mass housing retrofitting. In the case of the analyzed houses, and their numerous modifications, shading is primarily provided by small balconies/loggias and this is insufficient for the most part, as detected above. In contrast, a developed shading system of modern conventional buildings can be complexly organized and consisted of structural components (floors or units projections, self-shading shape of the envelope, large-scale neighbored buildings or trees) and additional ones (exterior shutters, cantilevered components, overhangs of balcony slabs, interior blinds or curtains). While the former can hardly be altered when retrofitting of the houses which are under consideration, the latter would be relatively easy to install. And it is the additional part of shading system that should be in the focus to make up the above indicated lack during future mass housing renovation.

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