Optimal orientation for a typical Italian residential building and its urban context

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ABSTRACT: Several studies have been performed about the optimal orientation, from energetic point of view, of specific building's typologies; however real urban tissues are normally composed by different types of buildings with different orientation. This work takes in consideration a building type called "palazzina in linea", that is particularly representative of Italian medium density expanding areas, and its typical urban context. Dominating building's orientation has been investigated in order to find its optimal value. The orientation that minimise the total annual primary energy demand, for lighting and climatisation, is assumed as the optimal one. The case study is situated in an expanding area of a small town in Venetian region. This work is based on computer simulations. Two main softwares have been used in an integrated way: *Ener_lux* and *TRNSYS*. Building's volume has been divided in thermal zones, corresponding less or more to the flats. *Ener_lux* calculates, with hourly step, energy and luminous solar radiation impinging on each external surface, taking into account the surrounding buildings shading effects. *TRNSYS* executes the energy balance of each thermal zone and calculates energy demand related to climatisation and artificial lighting. Inhabitants behaviour patterns are carried out by means of interview and statistic data.

Keywords: dwellings, orientation, energy

1. INTRODUCTION

The greater part of new Italian dwellings is located in medium density expanding areas of small towns. In these areas the dominant building typology is the so called "palazzina in linea", that is a three-four storey building, with a longitudinal layout equipped by one or more staircases connecting two or more flats at each storey.

Actually this typology is used without any particular care respect to orientation, the only criterion is to exploit in the more economic way the available ground surface.

In the resulting urban tissue the buildings are disposed in parallel and/or in orthogonal way. Sometime a dominant orientation of the built volume could be observed.

Distances between two building's facades are defined by local regulations. Generally these distances have to be superior or equal to the height of the higher building. In the examined area this criterion is respected.

In hour medium latitudes and temperate climates the energy demand due to climatisation represents the main quota of total building's energy requirement, and relatively to this kind of building it is commonly accepted that the East-West main axis orientation is the most convenient from energetic point of view [1,2]

However, taking in consideration a part of the above described urban tissue, it is more difficult to individuate an optimal orientation, and it is not obvious that this orientation exists.

In general the total energy demand of a group of buildings depends from many variables such as:

- shape and orientation of urban tissue,
- distances between buildings,
- building's technology, or rather: U-values, thermal masses localisation inside the building and in its envelope,
- internal gains and patterns of utilisation (inhabitants behaviour).

Solar gains are related to the first three factors.

In this work the usual building technology is fixed, whereas various tissue's orientations are explored.

Energy saving due to optimal orientation is compared with energy savings obtained by means of other actions such as substitution of normal lamps with low consumption models and substitution of normal glazing with low-emissive ones.

2. THE CASE-STUDY

2.1 The area

The case-study consists in a group of recent buildings located in an expanding area of a small town in Venetian region (Fig.1). This area is representative of Italian new edification.

This urban tissue is composed mainly by "palazzine in linea" with two-three storey, their main axis are disposed along two directions, the one orthogonal to the other. Inside this tissue it is possible to individuate a kind of repeating module.

In figure n. 2 it is evidenced in black the built volume of this module, that is considered in energy balance, while the hatched area define the volume considered in shading simulation.

Figure 1: Aerial view of examined area.

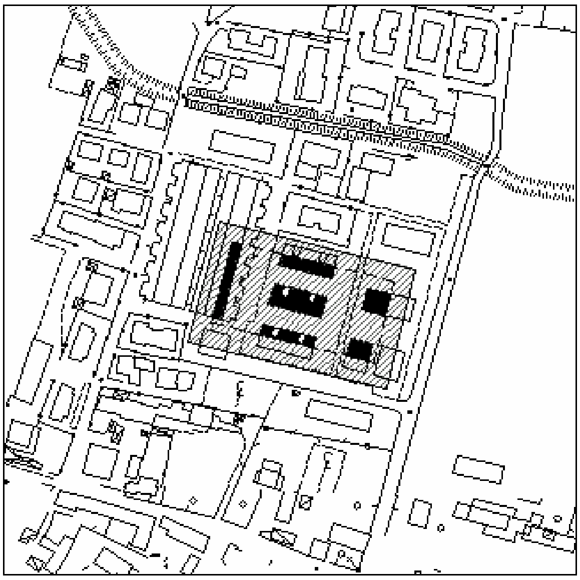

Figure 2: The sample of urban tissue

2.2 The building

A typical palazzina in linea has been examined, it has three storey and it is not symmetric respect to its principal axis, because all the staircases and main entrances are situated on the same side. The front on the opposite side contains the more extended dwelling's glazed surface. This front is defined here as the "main facade". In the following the examined orientations are referred to this front.

Inside the module it is possible to individuate a main facade's dominant orientation, representative less or more of the 80% of the built volume.

The sample-building contains twelve flats of various sizes, their total floor area is about 868 m^2, whereas the total floor area of all the buildings included in the considered urban module is 3472 m^2, equivalent to four sample-buildings

Average U-values of external walls and double glazed windows with plastic frame (PVC), are respectively 0.56 and 2.75 [$W/(m^2\ K)$].

The building is equipped by a centralised plant providing to winter heating, while summer cooling is obtained by means of multi-zone split coolers in each flat. Efficiency of different plants and global efficiency of Italian electric system (35%) are taken into account to calculate primary energy demand.

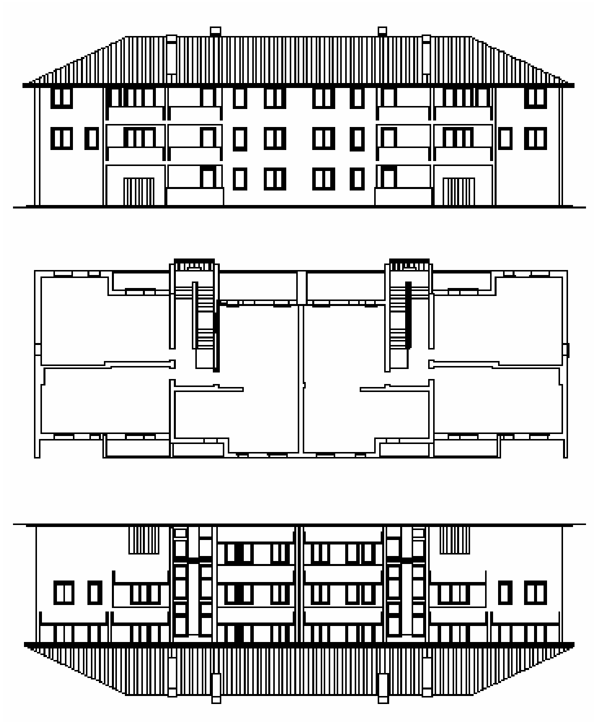

Figure 3: The examined building, plan of a typical floor and elevation of two principal facades.

Not particular devices are present to control the solar radiation. Only an internal diffusing curtain is used to intercept the direct radiation, when it is present, to avoid glare phenomena. The curtain reduces only the entering luminous flux, not solar gain.

Eight principal orientations have been explored: one every 45° from the South direction.

In order to reduce computational time and building's modelling effort only buildings belonging to the same typology are considered.

3. THE CALCULATION'S PROCESS

3.1 Calculations and software

This work is based on computer simulations. Two main softwares have been used in an integrated way: *Ener_lux* and *TRNSYS*. [3,4]

Building's volumes have been divided in thermal zones, approximately corresponding to the flats. The first program calculates, with hourly step, energy and luminous solar radiation impinging on each external surface, glazed or not, of each thermal zone, taking into account of shading effects of surrounding buildings. In case of glazed surfaces the degree of internal daylighting of the room is calculated too, using the method of circulating luminous flux. When internal average illumination is not sufficient (less than 300 lx) the thermal flux of lamps is calculated.

Hourly values of solar and internal gains from lamps in output from Ener_lux are passed as input to TRNSYS by data files.

The second program performs the energy balance of the thermal zone considering all other internal gains and calculates energy demand related to climatisation and artificial lighting.

TRNSYS simulations are carried out by means of multizone routines, in order to correctly reproduce the mutual influences between the zones.

Internal gains, due to the presence of occupants and their activities, are related to house's occupancy patterns. This information has been carried out using a CNR's survey [5] about appliances and time utilisation profile of the dwellings and some interviews to the occupants.

4. ANALYSIS OF THE RESULTS

4.1 Building's optimal orientation.

Considering first a single building, the main facade optimal orientation seems to be the south one: it allows a total annual energy demand value 6.4% lower than the East orientation that is the worst one (the more consuming).

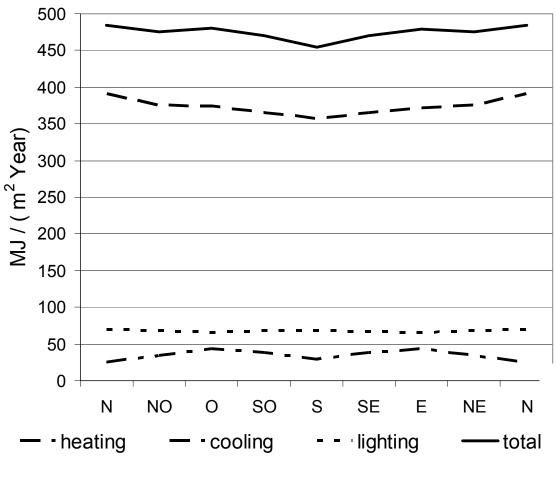

Figure 4: Building's specific annual primary energy demand as function of main facade orientation.

If the energy demand for cooling is excluded, the advantage grows to 7.5% (Fig. 4-5).

It could be noticed that differences in energy demand between various orientations are small, in particular between North, East and West ones. This is due to the partial building's symmetry respect the main axis, so the glazed area on two opposite sides is not significantly different.

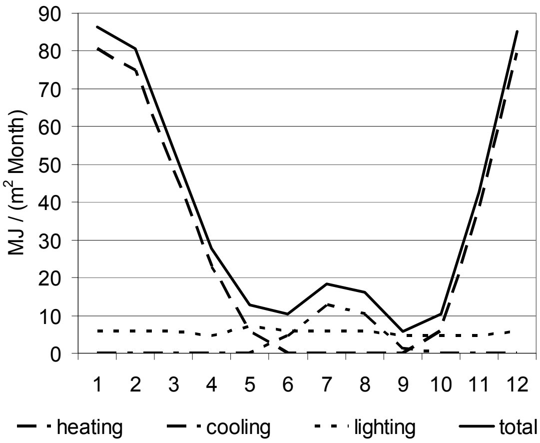

Figure 5: Annual profile of building's primary energy demand in case of optimal orientation.

4.2 Tissue's optimal orientation.

Considering the urban module, the results are not so different compared to the single building's ones. The best convenient dominant orientation remains always the south one: it allows an energy saving of 4.9% on the total demand that became 5.8% excluding cooling (Fig. 6).

The less convenient main facade dominant orientation is always the north one, but the west one is more consuming than the East.

In fact the dominant orientation in the examined sample is representative of 80% of the built volume, in this configuration when the bigger part of the buildings has the main façade facing West, a 20% of them has the main façade facing North. Consequently in this case the tissue's average specific energy demand is bigger.

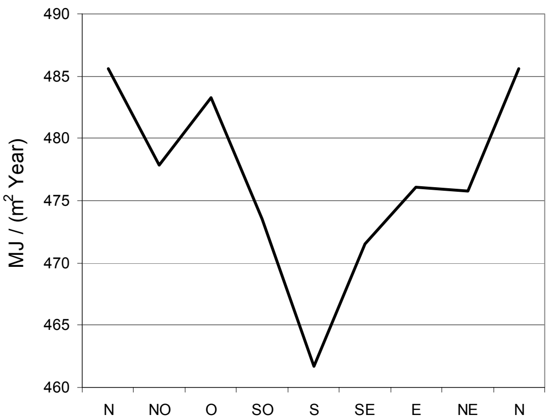

Figure 6: Tissue sample's total annual specific primary energy demand as function of main facade dominant orientation

It has to be remarked that the parameter "main orientation's representativeness" is quite variable, assuming values between 25% and 100%..

In the first case the built volume is equally disposed along two main orthogonal directions, but the main façades can present four different orientations.

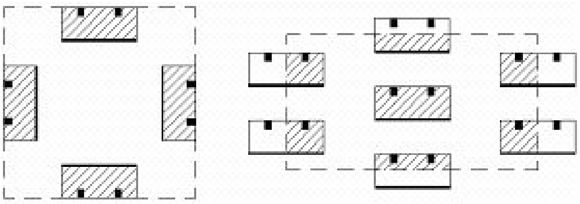

Figure 7: Tissue samples with main facade's dominant orientation's representativeness value equal to 25% on the left, and 100% on the right. The referring facade and staircases are evidenced

In this case the buildings are commonly disposed in a way to have the main facades looking towards an internal squared courtyard, while the opposite facades, with staircases and main entrances, are facing the surrounding roads.

In the second case all the considered buildings are disposed in parallel with the same orientation (Fig. 7).

With the aim to explore in a simplified way the influence of this parameter, the two extreme situations have been simulated, but without an accurate calculation of shading effects. Results are compared n figure 8.

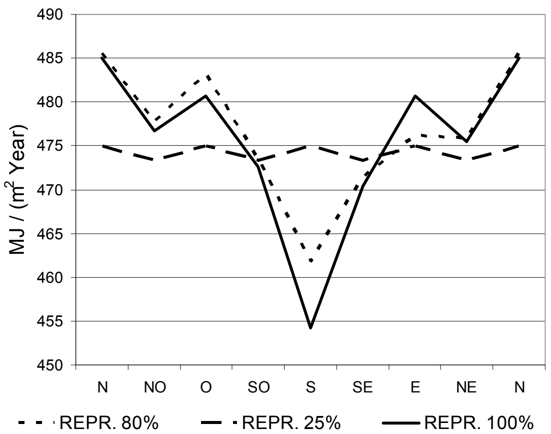

Figure 8: Total annual specific primary energy demand as function of main facade dominant orientation. Comparison between tissues with main facade dominant orientation's representativeness value equal to 25%, 80% and 100%.

If this parameter assumes the maximum value (100%) the results are not too different from these of the real case study, whose main orientation's representativeness value is 80%: the south dominant orientation allows an energy saving of 6.3% that became 7.4% excluding cooling demand.

Whereas when the representativeness is 25% an optimal orientation is not observable, in fact the differences in energy consumption determined by various orientations are very small: in general lower than 0.5%, and lower than 0.7% excluding cooling.

4.3 Comparison with other energy saving actions

As above illustrated, in the best convenient situation, energy consumption variation due to orientation are not bigger than 6.5% (7.5 excluding cooling). It is interesting to compare this entity with that ones obtainable by other actions finalised to an appropriate use of energy.

A complete substitution of windows normal glazing by low-emissive ones (U-value = 1.72 [W/(m^2 K)]) allows a reduction of 4.1% of total energy demand, and excluding the quota for cooling the reduction grows to 9.5% because this kind of glazing increase the sunspace effect.

A complete substitution of traditional lamps by low-consuming fluorescent models can reduce energy demand for lighting to 30% of actual value, consequently the building's total primary energy demand decreases more or less of 9.5% (16% excluding cooling).

5. CONCLUSION

This kind of investigation would require the analysis of several case-studies, in a way to analyse the influence of various parameters as the typology mix and dominant orientation.

But, as a first step, it was important to verify the existence of a tissue's optimal orientation in a typical urban situation.

In the examined case it could be said that an optimal tissue's orientation exists. However, if the buildings are not passive solar buildings or not equipped by solar collecting devices, the expected energy saving by optimising only the orientation is small. Its entity is similar to energy saving that we can obtain by substitution of glazing, while it is very smaller than energy saving obtainable by substitution of lamps.

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