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Traditional Houses with Stone Walls in Temperate Climates: The Impact of Various Insulation Strategies

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1. Introduction

The European Directive 2010/31/EU states that the measures to improve the energy performance of new and existing buildings should take into account climatic and local conditions as well as indoor climate environment giving the priority to the summer period. The Directive introduces the concept of thermal capacity that is very important in temperate climates during the summer phase.

The adoption of North-European super-insulated structures, characterised by low transmittance, involves the use of considerably thick thermal insulation both when designing new developments and when energy retrofitting existing traditional buildings.

The introduction of external insulation coatings has led to a change in the relationship between architecture and climate, resulting in an "international" envelope and the loss of local features; also, in temperate climates, because of indoor overheating it has led to various problems as regards summertime comfort.

The deeply rooted link between regional traditional architecture and specific climates has been underlined by many researchers (Givoni, 1998; Grosso 1998).

Many authors have carried out quantitative studies on the behaviour of traditional buildings in different seasons, showing the capacity of these buildings to secure indoor comfort by means of passive control systems. Experimental studies carried out on traditional houses in India (Dili et al., 2010) Korea (Youngryel et al., 2009), northern China (Wang & Liu, 2002), Japan (Ryozo, 2002), Nepal (Rijal & Yoshida, 2002), and Italy (Cardinale et al., 2010) are of particular interest.

Some authors have experimentally compared the behaviour of traditional and modern buildings, not only showing how the former are preferable both from the point of view of comfort and in terms of energy saving (Martin et al., 2010) but also identifying the limitations of energy saving legislation which tends to encourage the latter (Yilmaz, 2007; C. Di Perna et al., 2009).

Few authors have assessed the impact of energy saving strategies on traditional architecture (Fuller et al., 2009).

The present chapter focuses on the yearly behaviour of a traditional farmhouse in a temperate Italian climate and analyses the impact of alternative energy saving strategies on summer comfort and winter consumptions.

The aim of the current study was to:

- identify combinations of thermal insulation interventions which: optimise winter energy saving and summer internal comfort without modifying the close relationship between architecture and specific climate typical of traditional buildings; respect the building material consistency and the façades aesthetic appearance.
- compare the performance of this traditional architecture (after the retrofit intervention) with that of a modern building, of the type encouraged by new energy saving legislation (lightweight and super-insulated).

To that aim a series of monitoring activities in summer and in winter were carried out to investigate the internal environmental conditions and to calibrate a simulation model with the software Energyplus. This model was used to assess the impact of various energy-saving strategies on winter energy consumptions and summer comfort with the method of Percentage outside the comfort range (EN 15251:2007-08).

2. Research methods

This research study involved an experimental campaign to analyze the behaviour of a traditional building in different seasons and sunlight conditions as well as a series of simulations in order to extend the comparison to other types of walls representing either alternative energy retrofit solutions or newly built envelopes. The study was carried out in the following stages:

- Experimental campaign
- Dynamic simulation using Energyplus software
- Calibration of the simulation model by comparing the calculated and measured values
- Parametric analysis so as to assess different retrofit scenarios.

2.1 The case study

The building is located between the Apennines and the Adriatic Sea. The traditional rural architecture is characterized by passive control elements such as stone walls with high thermal inertia and small windows: these characteristic features represent the main elements of architectural quality. However, these buildings often have problems during the summertime due to low temperatures for considerable heat loss to the ground.

This study focused on a traditional Italian farmhouse (fig.1) in the city of Fabriano situated 325 m above sea level and with 2198 degree days (longitude 13°37′; latitude 43°62′). The farmhouse has two floors above ground level and is characterized by a surface area to volume ratio of 0.60; it is oriented with its longitudinal axis rotated 45° clockwise with respect to the north-south direction. The building is currently used as a private residence with one apartment on the ground floor and two apartments on the first floor. The load-bearing structure is built in plastered masonry consisting of local stone and crushed bricks bound together by sand and lime mortar. These walls are 60 cm thick at ground floor level



Fig. 1. External view of the building

and 40 cm thick on the first floor. Both the walls have high thermal inertia. The cement floor slab is about 15 cm thick and lies directly on the ground, while the recently replaced intermediate floor is made up with brick and concrete. The roof is made of wood and is covered with tiles.

2.2 Experimental study

Monitoring of the building was carried out both during the summertime (23-30 July 2008) and in the winter (8-14 January 2009), in order to analyze the performance of the external stonework in two different weather conditions. The monitoring involved (fig. 2 and table 1):

1. Analysis of the outdoor environmental conditions by means of a weather station which measured the speed and direction of the wind, the solar radiation, the temperature and the relative humidity.
2. Analysis of the indoor environmental conditions by means of two data systems (one located in the southeast side and one in the north-west side) which recorded: the mean radiant temperature, the temperature and the relative humidity of the air.
3. Analysis of the thermal performance of the vertical cladding using thermo-resistances to measure the indoor and outdoor surface temperatures of the masonry.
4. Analysis of the heat transfer through the walls using a flow-meter.

During the summertime monitoring period the householders agreed to regulate the ventilation keeping the windows open in the morning (8:00– 10:00) and in the evening (18:00– 23:00). Some rooms were monitored with the windows always closed so as to determine the impact of natural ventilation on indoor comfort.

During the winter monitoring period heating was turned on from 7:00 to 9:00 and from 13:00 to 14:00 and from 19:00 to 23:00 (temperature set-point 20°C). Some unused rooms on the north side of the building were never heated.

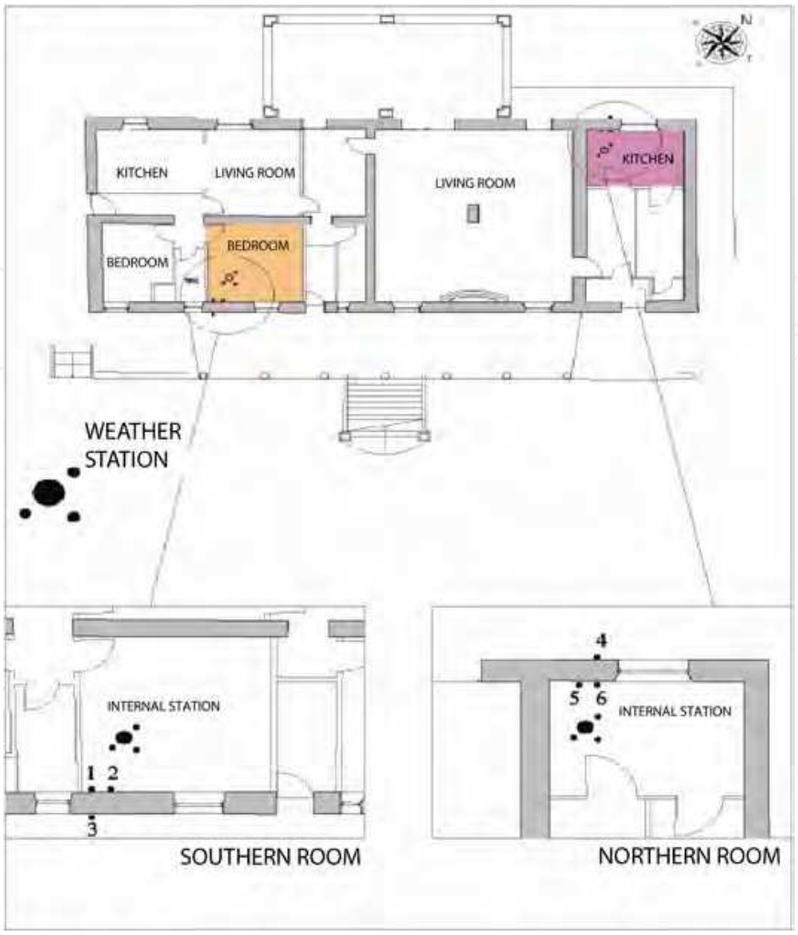


Fig. 2. Plan of the building with the instruments' position

SUMMER	23 July	24 July	25 July	26 July	27 July	28 July	29 July	30 July
MAX Temp	25,2 °C	28,8 °C	32,2 °C	32,7 °C	29,0 °C	31,2 °C	31,6 °C	27,1 °C
MAX REL. HUMIDITY	45%	46%	46%	46%	46%	46%	46%	45%
MIN Temp	19,1 °C	19,2 °C	21,8 °C	24,1 °C	23,5 °C	22,5 °C	21,0 °C	22,3 °C
MIN REL. HUMIDITY	44%	39%	38%	38%	39%	39%	38%	39%
DAY	SUNNY	SUNNY	SUNNY	SUNNY	SUNNY	CLOUDY	SUNNY	SUNNY
MAX WIND SPEED	1,5 m/s	3,1 m/s	2,7 m/s	2,1 m/s	2,8 m/s	1,8 m/s	2,0 m/s	0,8 m/s
WINTER	8 January	9 January	10 January	11 January	12 January	13 January	14 January	
MAX Temp	4,7°C	4,8 °C	5,1 °C	10,1°	9,2°C	4,5°C	6,7°C	
MAX REL. HUMIDITY	100%	100%	89%	75%	65%	100%	100%	
MIN Temp	0,8 °C	1,9 °C	1,0 °C	-1,1°C	-2,2°C	3,0 °C	4,1 °C	
MIN REL. HUMIDITY	93%	88%	55%	37%	23%	56%	92%	
DAY	RAINY	SNOWY	CLOUDY	SUNNY	CLOUDY	FOGGY	FOGGY	
MAX WIND SPEED	2,1 m/s	3,3 m/s	3,2 m/s	3,5 m/s	3,1 m/s	4,8 m/s	6,0 m/s	

Table 1. Weather scheme of the monitored weeks

Uncertainty is evaluated as a percentage of accuracy and a percentage of resolution declared by the manufacturers. For the thermometric probes the acquired data had a tolerance of ±0.15 °C distributed equally for all the values measured, while in the case of the flow-meter the accuracy was determined by the formula 5%VL + 1 W/m^{-2} (VL = read value) and results in a mean square error which fluctuates over time.

2.3 Analytic study

Simulation of the case study in the real "as-built" state was performed using dynamic software (Energy Plus). Calibration of the virtual model developed in the dynamic state was carried out by comparing the indoor and outdoor surface temperatures and the air temperature recorded during the monitoring. This calibration involved the preparation of a weather file using the real weather condition data. It was subsequently necessary to take steps to modify the input values of the software (above all regarding the infiltration model) so as to reflect the real occupancy, ventilation and heating.

Parametric analyses were carried out on this corrected model, in order to analyse the relative impact of different types of energy saving solutions on summer comfort and winter consumptions. The retrofit interventions were identified according to the Italian standard (legislative decree 192/05), implementing Directive 2002/91/EC on the energy performance of buildings, and subsequent corrective decrees: for the climatic zone of interest, the regulation set a limit of 0,34 W/m^2K for the vertical opaque envelope, a value of 0,30 W/m^2K for the roof and a value of 0,33 W/m^2K for the ground floor. The following scenarios were compared (tab.2):

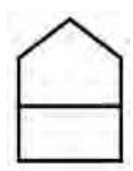
- Scheme A regards the "as built" state
- Scheme B regards the visible interventions, i.e. insulation of the vertical walls with an external 10cm thick low-transmittance "coating" of high density rock wool
- Scheme C regards the interventions that are not visible such as the thermal insulation of the intermediate and ground floor, with panels of high density rock wool: 3 cm thick for the intermediate floor and 4 cm thick for the ground floor; the thermal insulation of the roof (with panels of high density rock wool 11 cm thick); the replacement of single panes with low-e double glazing units (4/12/4), keeping the same window frames and wooden shutters;
- Scheme D regards the combination of the previous interventions (scheme B and C)
- Scheme E regards a newly built super-insulated lightweight building realized according to Italian legislation on energy saving (wooden structure and external single layer envelope of insulation material).

The energy consumption, the surface temperatures and the HOURS OF DISCOMFORT, calculated using the Method of Percentage outside the comfort range (Method A- Annex F-ISO EN 15251) were compared for the different simulated solutions.

3. Experimental results

3.1 Summertime monitoring

A comparison between the south-facing and north-facing walls (Fig.3) shows that the external surface temperature in the former reaches a maximum value at about 2 pm, while

Intervention	SCHEME A	SCHEME B	SCHEME C	SCHEME D	SCHEME E
					
Vertical walls	**P1= as built stone wall**	**P2= external insulation**	**P1= as built stone wall**	**P2= external insulation**	**P3=new wall**
Thermal transmittance (W/m²K)	1,92	0,33	1,92	0,33	0,13
Periodic thermal transmittance (W/m²K)	0,14	0,01	0,14	0,01	0,10
Internal areal heat capacity k1 (kJ/m²K)	206	201	206	201	27
Ground floor slab	**S1= as built floors**	**S1= as built floors**	**S2= insulation of the floors**	**S2= insulation of the floors**	**S3= new floors**
Thermal transmittance (W/m²K)	2,63	2,63	0,32	0,32	0,32
Periodic thermal transmittance (W/m²K)	0,86	0,86	0,01	0,01	0,01
Internal areal heat capacity k1 (kJ/m²K)	226	226	240	240	240
Roof slab	**T1= as built roof**	**T1= as built roof**	**T2= insulation of the roof**	**T2= insulation of the roof**	**T3= new roof**
Thermal transmittance (W/m²K)	4,49	4,49	0,29*	0,29	0,26
Periodic thermal transmittance (W/m²K)	4,39	4,39	0,18*	0,18	0,17
Internal areal heat capacity k1 (kJ/m²K)	30	30	88*	88	89
Glazing	**V1= as built single glazing**	**V1= as built single glazing**	**V2= double glazing**	**V2= double glazing**	**V3=double glazing**
Thermal transmittance (W/m²K)	5,5	5,5	2,27	2,27	2,27

*in the scheme C1 the insulation of the roof regards the introduction of an insulated horizontal attic slab with thermal transmittance U=0,30 W/m²K; periodic thermal transmittance Yie=0,30 W/m²K; internal areal heat capacity k_1=13 kJ/m²K. In that scheme the superior pitched roof slab has a thermal transmittance U=0,80 W/m²K

Table 2. The intervention analysed.

the latter always presents a maximum value of surface temperature in the evening at about 6 pm, exceeding the values recorded in the south side. This behaviour is because the north-west side is struck by sunlight with a low angle in the final hours of the day.

The thermal peaks that occur on the external side of the walls are not present on the internal side and the internal surface temperatures are low, leading to discomfort.

On the sunny day the maximum range in temperature between the internal and the external façade is about 6°C to the south and 10°C to the north; the indoor surface temperatures throughout the day are around 20°C to the north and 22°C to the south.

On the cloudy day (28th July) the maximum temperature difference between the indoor and outdoor surfaces is 3°C to the south and 5°C to the north and the indoor temperatures throughout the day are around 21°C to the north and 23°C to the south.

The inner surface temperature in the north-facing room is about 2 °C colder than the south-facing one, both on the cloudy and on the sunny day.

Therefore, the difference in temperature found for the south- and the north-facing walls is constant (about 2°C) in all types of weather conditions: this depends on the fact that the thick exterior wall strongly delay the heat transfer from the external to the internal side; also internal surface temperature's trend is influenced by the internal air temperature (Fig. 4) and by the contribution of internal heat gains due, for example, to the solar radiation entering through the windows, the presence of people and equipments. The north-facing part of the building is not inhabited thereby eliminating all the internal heat gains.

The graph on Fig.3 shows a progressive weekly increase in internal surface temperatures. This depends on the high thermal inertia of the walls that involves a high capacitive resistance and therefore a significant delay (around a week).

The internal surface temperatures (fig.5) were compared in two south-facing rooms, in such a way as to have cross ventilation throughout the day in one case and the windows closed in the other.

Opening the windows during the night leads to a slight increase in the indoor temperatures at night since the outdoor air is warmer. During the daytime, natural ventilation leads to a reduction of about 0.5°C in the internal surface temperatures, except between 15.00 and 17.00 when the outdoor temperature rises. Throughout the daytime, in both cases, whether the windows are closed or open, the recorded value is less than 23°C bringing about an operative temperature always lower than the optimal summertime temperature.

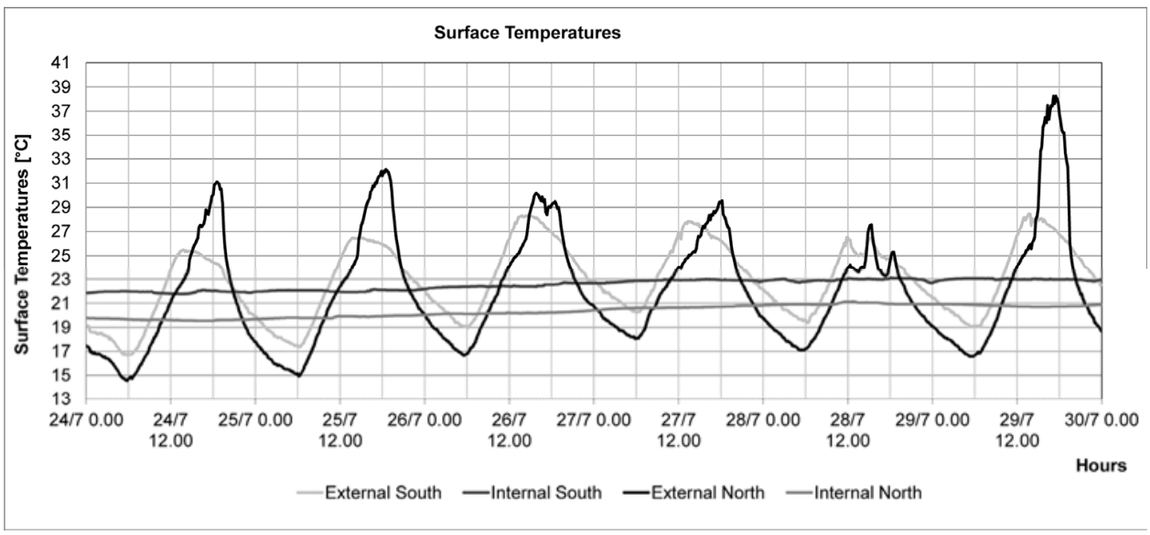


Fig. 3. Internal and external surface temperatures in northern and southern side during the summer period

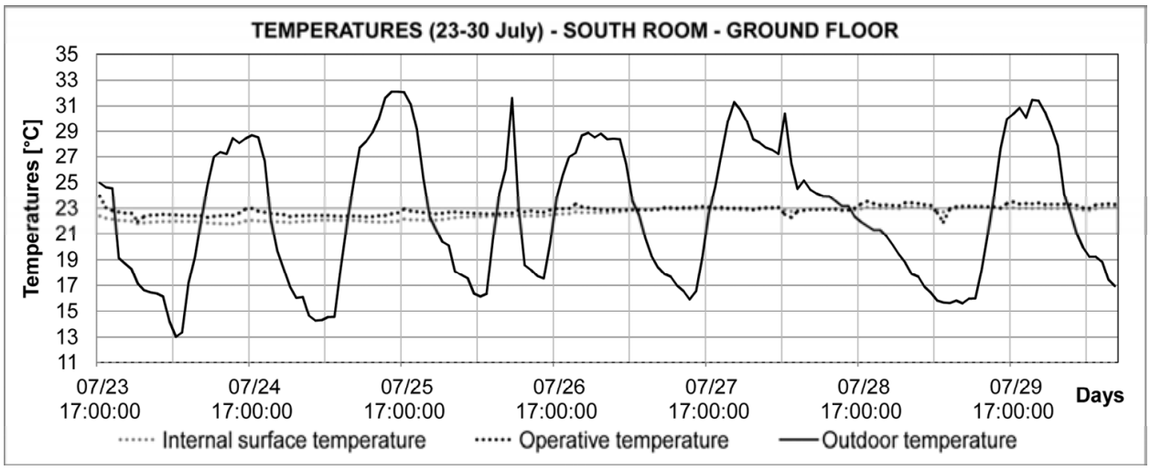


Fig. 4. Operative temperature on the southern room

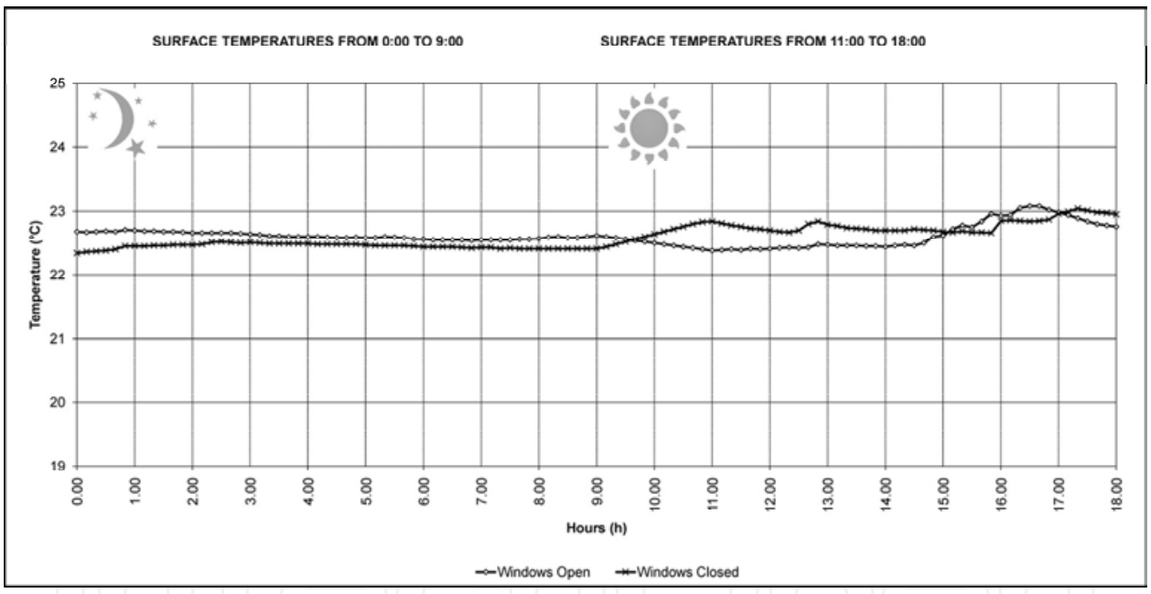


Fig. 5. Impact of ventilation on thermal inertia during the summertime. The graph shows the internal surface temperatures recorded in two rooms: one with windows opened and one with windows closed

3.2 Wintertime monitoring

The indoor and outdoor surface temperatures were compared for a north-facing and a south-facing wall (fig.6).

An analysis of the indoor surface temperatures shows that the south-facing room is about 15°C warmer than the north-facing one. This is due to the fact that the north-facing part of the building is not heated. In both cases (with heating on or off) the indoor surface temperatures have a very constant trend, without fluctuations.

As regards the temperatures of the south-facing wall, it can be observed that on both cloudy and sunny days, even with very different external surface temperatures, the indoor surface temperature is around 16° - 17°C: this value is very low and causes indoor discomfort.

The temperature variations in the south room are due to the influence of heating plants as it can be seen from operative temperature. (fig.7)

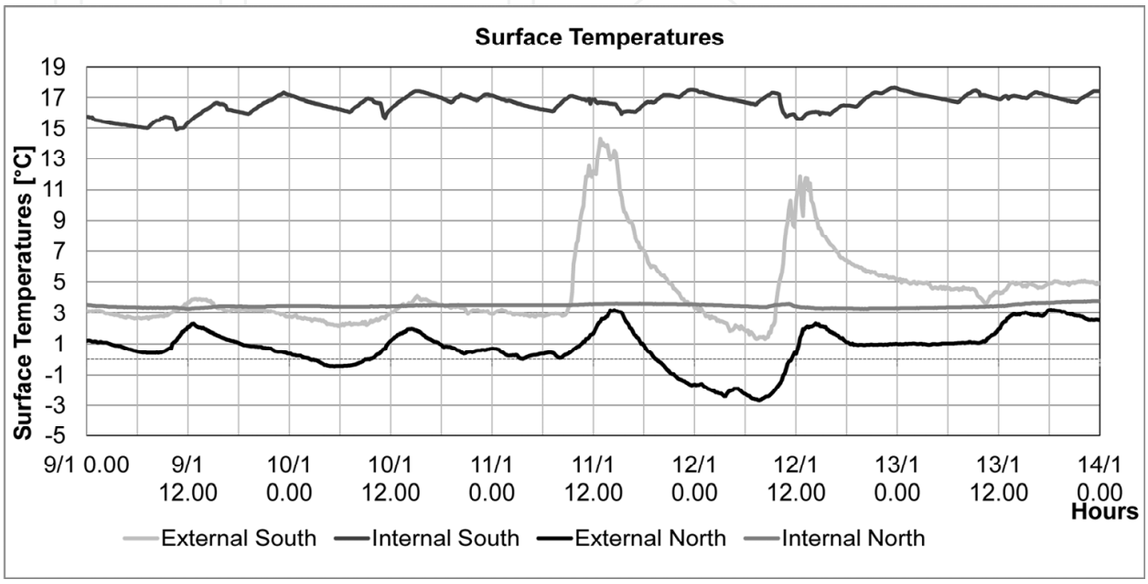


Fig. 6. Internal and external surface temperatures in northern and southern side during the winter period

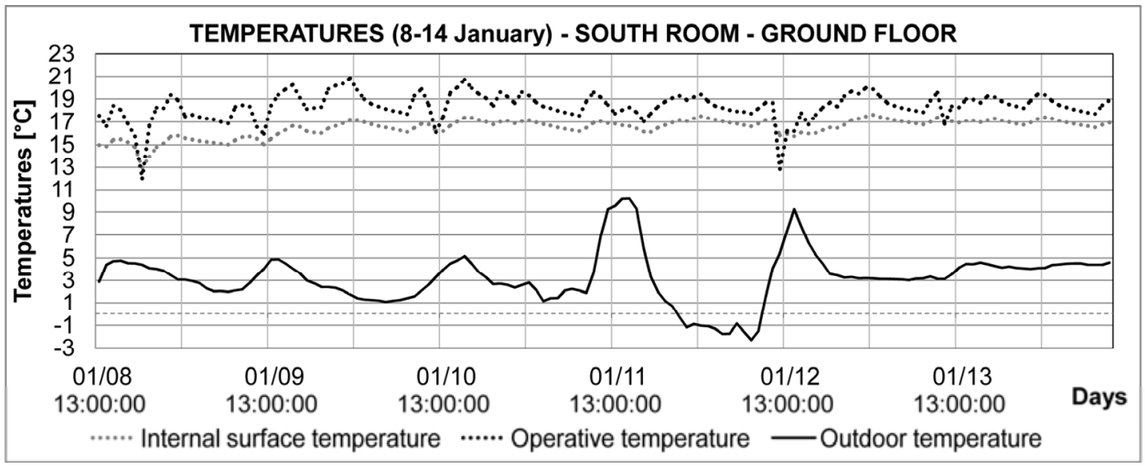


Fig. 7. Operative temperature in wintertime.

4. Analytic results

To analyze the relative impact of different types of energy saving solutions on summer comfort several simulation models were developed and compared.

We separated the interventions that do not affect the architectural image and the interventions that alter the architectural appearance of the building.

In the second stage the interventions on visible elements and interventions on the non-visible elements were combined and the building optimised according to the new regulations on energy saving was compared with a new lightweight super-insulated building.

The study of discomfort hours using the Method of Percentage outside the comfort range (Method A- Annex F- ISO EN 15251) gave the following results (Tab.3):

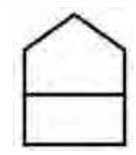
Interventions		**Scheme A**	**Scheme B**	**Scheme C**	**Scheme C1**	**Scheme D**	**Scheme E**
							
		As built state	*External coating*	*Insulation of floors and glazing*	*Scheme C+ attic floor insulation*	*Insulation of all constr. elements*	*New lightweight building*
Ground floor	overheating	0	0	0	0	0	0
	cooling	2928	2928	680	680	1886	259
	Total discomfort hours	**2928**	**2928**	**680**	**680**	**1886**	**259**
First floor	overheating	447	432	410	247	35	325
	cooling	748	697	407	435	469	386
	Total discomfort hours	**1195**	**1129**	**817**	**682**	**504**	**711**
CONSUMPTIONS kWh/m²anno		**134**	**102**	**91**	**83**	**61**	**44**

Table 3. Discomfort hours. The total amount of hours in the hot season is equal to 2928 (1 June – 30 September)

4.1 Scheme B: Visible interventions

The first solution analyzed is the external insulation of the vertical envelope. We neglected the insulation of the internal side of the wall because several authors demonstrated that it determines the problem of surface and interstitial condensation (Stazi et al., 2009).

The study of discomfort hours (see table 3) on the ground floor during the summer, shows that the external insulation of the wall does not bring the temperature in the comfort range: all the hours in the hot season (equal to 2928) are hours of discomfort. This problem is well illustrated by the graph of operative temperatures (Fig. 8). This is due to the fact that there is great heat loss through the ground floor slabs which determines a very cold indoor environment. Therefore the adoption of one type of wall rather than another is of little importance.

Although slightly different, the figure show how, the retrofitting solution analyzed (scheme B) worsen the initial "as-built" condition (scheme A). In fact, insulation of the walls, by impeding the heat transfer from outdoors, further lowers the indoor temperatures and is therefore a disadvantage in terms of comfort.

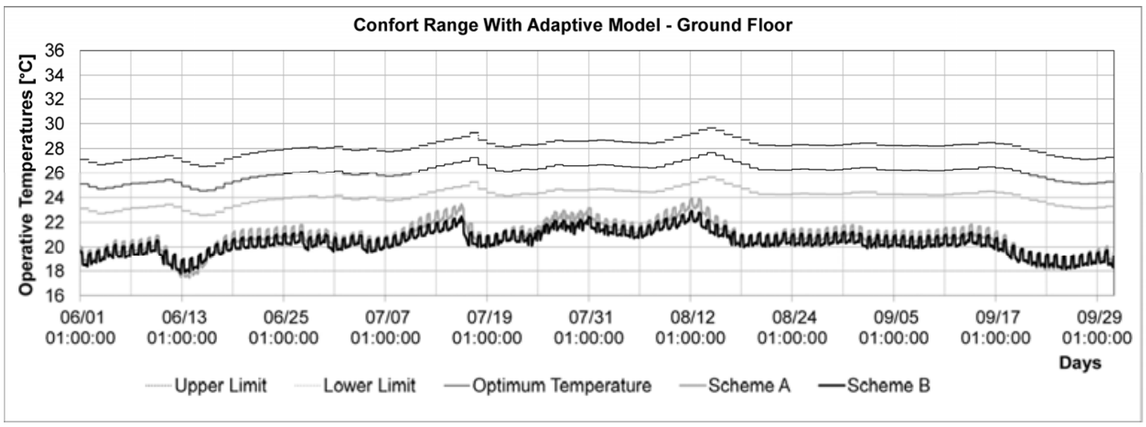


Fig. 8. Operative temperatures on the ground floor for scheme A ("as built" situation) and scheme B (external insulation of the vertical envelope)

A similar comparison was made on the first floor: the impact of external insulation of the walls was assessed, with no modifications being made to the other parts of the building.

In this case there is no problem of heat dispersion through the floor slabs and, together with the night time temperatures which are too low there is also the opposite problem of overheating during the daytime.

The graph of the operative temperatures (fig. 9) and the hours of discomfort (table 3) show that the insulated wall behaves better than the as built wall, with smaller fluctuations and temperatures which are closer to the comfort range. There is a reduction of both hours of nighttime discomfort as a result of cooling (from 447 to 432) and hours of daytime discomfort due to overheating (from 748 to 697).

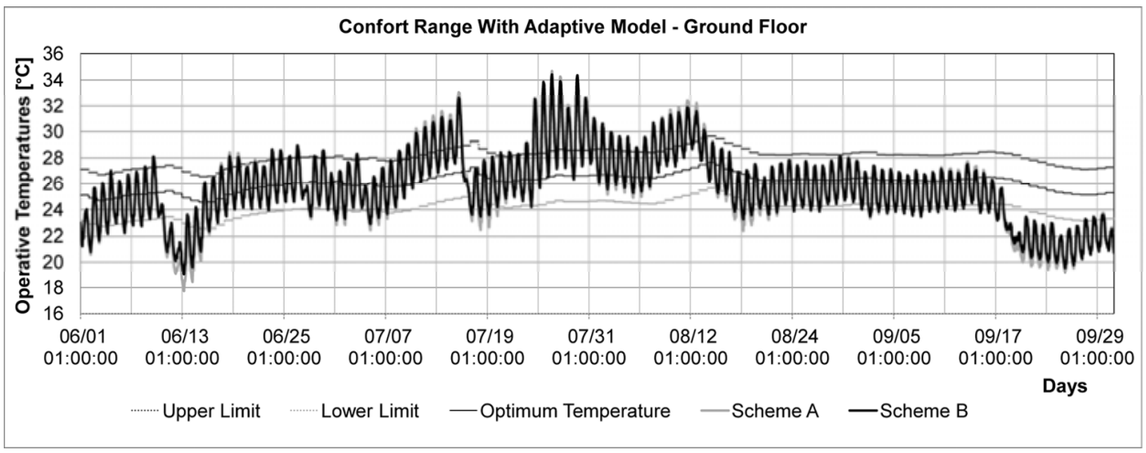


Fig. 9. Operative temperatures on the first floor for scheme A ("as built" situation) and scheme B (external insulation of the vertical envelope)

4.2 Scheme C: Not visible interventions

Interventions that do not affect the exterior image of the building regard the insulation of the ground floor slabs and intermediate floors (in relation to the fact that each floor has different apartment owners), insulation of the roof, introduction of double glazing.

From the figure showing the operative temperatures on the ground floor (Fig.10) it can be seen that the insulation of the ground floor slab and the introduction of double glazing determine a great reduction in the discomfort caused by the very low temperatures since this solution brings the temperature back within the comfort range (impact of 4 – 5°C on operative temperatures). This is clearly visible even from discomfort hours (see table 3) with a 77% reduction in dissatisfaction levels, from an initial value of 2928 to a value of 680 (the percentage is calculated on the total discomfort hours in the as built scheme=2928).

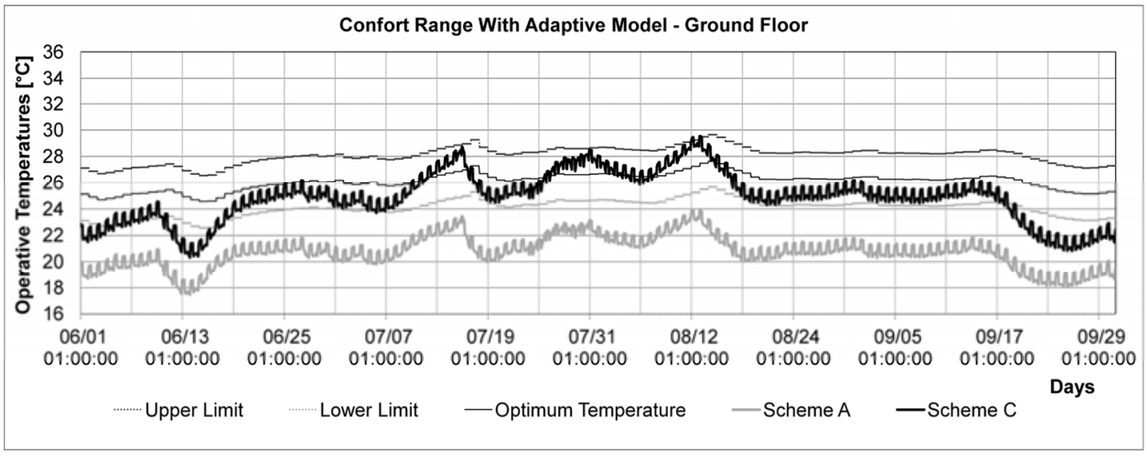


Fig. 10. Operative temperatures on the ground floor for scheme A ("as built" situation) and scheme C (insulation of the floors, insulation of the roof and introduction of double glazing)

The analysis of the operative temperatures (fig. 11) and discomfort hours (see table 3) on the first floor, shows that the not visible interventions determine a reduction of dissatisfaction

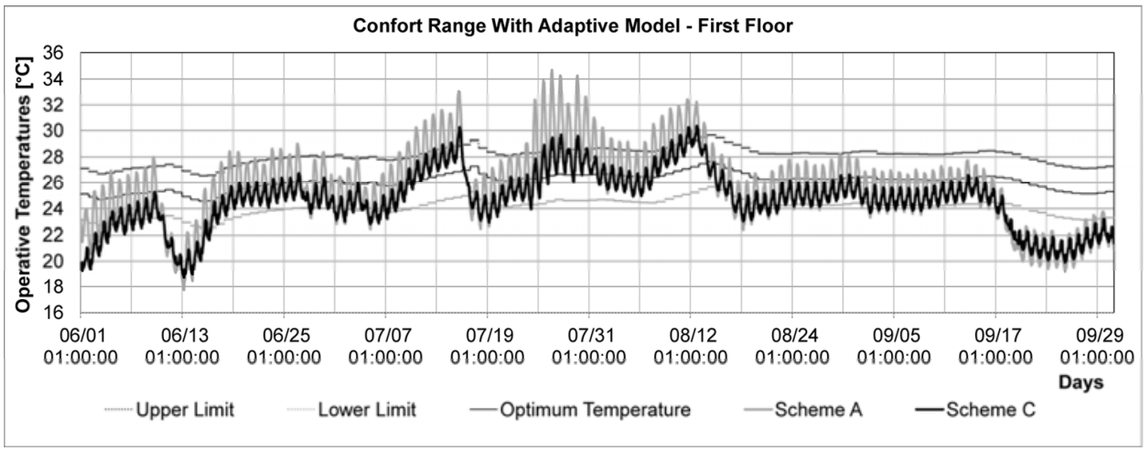


Fig. 11. Operative temperatures on the first floor for scheme A ("as built" situation) and scheme C (insulation of the floors, insulation of the roof and introduction of double glazing)

levels both for daytime overheating (discomfort hours from an initial value of 447 to a value of 410) and for nighttime cooling (discomfort hours from an initial value of 748 to a value of 407). So on the first floor there is a 30% decrease in the total hours of discomfort, from 1195 to 817 (the percentage is calculated on the total discomfort hours in the as built scheme=1195).

4.3 Scheme D and E: Combination of different interventions and comparison with a new lightweight building

Visible and not visible interventions were combined, considering an "optimized" building (scheme D= scheme B + scheme C). Said optimized scheme was compared with Scheme C (only interventions that are not visible) and with scheme E (building of new lightweight construction with low thermal transmittance).

The analysis of the operative temperatures (fig.12 and table 3) on the ground floor shows that the total discomfort hours in scheme D due to the cold environment increase substantially in relation to scheme C (from 680 to 1886) since the internal gains are very low and there is a great reduction of the thermal flows entering form the external envelope.

In the scheme E the hours of discomfort are low (259) if compared with other schemes. This scheme is slightly better because the most important problem on the ground floor is the discomfort for cooling and a wall with a low transmittance has to be preferred.

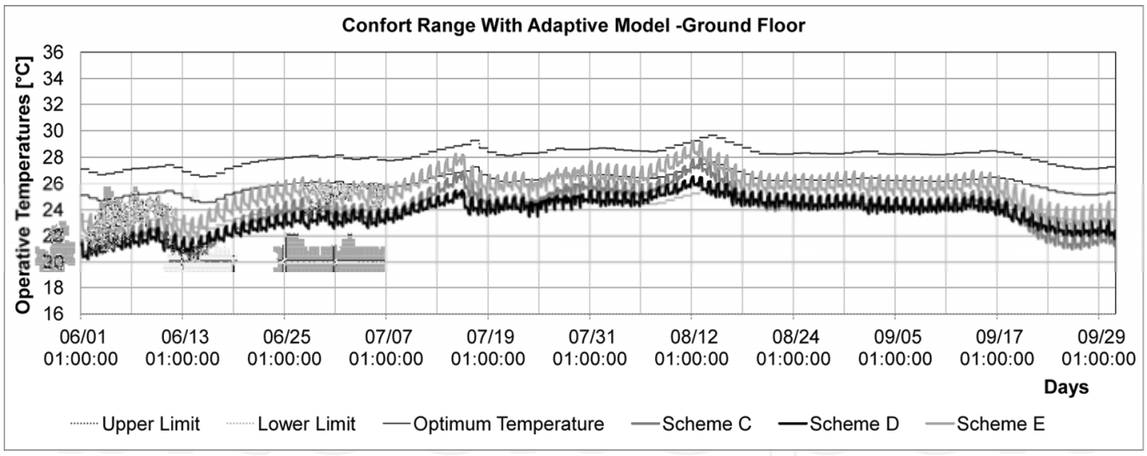


Fig. 12. Operative temperatures on the ground floor for scheme C (insulation of the floors, insulation of the roof and introduction of double glazing), scheme D (a combination of scheme B and C) and scheme E (new lightweight construction)

On the first floor together with the night time temperatures which are too low, there is also the opposite problem of overheating during the daytime.

In the scheme D the discomfort hours (fig. 13 and table3) for heating substantially decrease from 410 to 35 because the external insulation greatly reduces the thermal flows entering from the outside and the internal mass absorbs the internal loads. The total discomfort hours are 504, lower than in the scheme C.

The lightweight building (scheme E) presents some problem of daytime overheating. The discomfort hours of that scheme (with respect to the scheme D) increase up to a value of 325. This solution is slightly better than the scheme C.

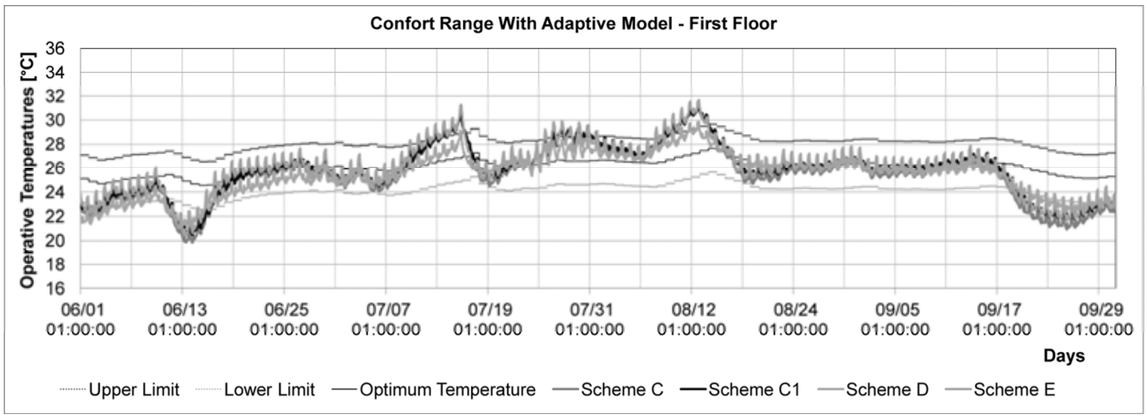


Fig. 13. Operative temperatures on the first floor for scheme C (insulation of the floors, insulation of the roof and introduction of double glazing), scheme D (a combination of scheme B and C) and scheme E (new lightweight construction)

4.4 The optimal configuration from the comfort point of view

The study shows that from the point of view of the summer comfort the most significant interventions are the thermal insulation of the floors and roof and the replacement of single panes with double glazing without intervening on the vertical walls (scheme C). As the matter of fact there is a great reduction of discomfort levels either with the scheme C (intervention on the not visible elements) or with the scheme D. In the first case the result show: in the ground floor a 77% reduction of discomfort hours; in the first floor a 30% reduction. In the scheme D the discomfort hours slightly decrease: 35% in the ground floor and 57% in the first floor. The scheme C present a total amount of discomfort hours of 1497 (680+817) while the scheme D present a total of 2393 (1886+507). Then it would be preferable to adopt the scheme C because it guarantees summer comfort and it does not alter the historic vertical walls.

The last phase of the study was to assess the impact of introducing in the scheme that proved to be the best (scheme C) an insulated ceiling (scheme C1). For the climatic zone of interest, the Italian standard imposes: a limit of 0.30 W/m²K for the thermal transmittance of the horizontal attic floor (that delimits the heated area); a limit of 0.80 W/m²K for the thermal transmittance of the superior pitched roof slab (separating an unheated room and the external environment).

The simulation (see table 3 and Fig.13) showed how the introduction of an insulated attic slab greatly reduces the hours of discomfort due to overheating (from 410 of scheme C to 247 of scheme C1).

This configuration resulted to be the optimal situation with respect to all the schemes studied.

4.5 Consumptions

We carried out a study on winter consumption to ensure that the identified optimal configuration does not lead to high winter consumptions (see table 3).

It resulted that the interventions on the elements that are not visible (scheme C) determine a reduction on winter consumption from an initial value of 134 to a value of 91 kWh/m²year. The introduction of an insulated attic floor (scheme C1) reduces the winter consumption to 83 kWh/m²year.

With the insulation of the external walls (scheme D) said value is further reduced to 61 kWh/m²year.

Even if the exclusion of the intervention on the external walls is not congruent with the Italian regulations on energy saving (that for the external walls set a limit of thermal transmittance), a consumption value of 83 kWh/m²year can be considered acceptable since it is slightly higher than the value obtained with the insulation of all structural components of the traditional building (61 kWh/m²year).

A lightweight building realized according to standards for energy saving reduces the winter consumption to 44 kWh/m²year.

5. Conclusion

An experimental and analytical study was carried out on a traditional farmhouse in central Italy. The study allowed the thermal behaviour of the building to be analysed according to different usage and weather conditions. It was also possible to identify the problems of summertime discomfort which, on the ground floor, are due to the considerable loss of heat through the floor slabs and, on the first floor, to the overheating of the rooms. In this regard retrofitting was proposed according to the new legislation on energy saving, and a comparison was made between various types of retrofit interventions carried out on the external walls in terms of both summer comfort and winter consumptions.

In particular (in consideration of the historical value of the stone walls) were distinguished the interventions on visible constructive elements (realization of an external insulation coating on the vertical walls) from interventions on the not visible elements (that do not alter the architectural image of the building: insulation of roof, insulation of intermediate and ground floors, introduction of double glazing).

Since discomfort due to cooling is of great importance, the insulation of the ground floor has a greater impact than the other interventions. The combination of said intervention with the insulation of the roof and the introduction of double glazing leads to a 77% decrease in discomfort hours. The insulation of the vertical walls with an external coating is too invasive for the image of the building and not very significant in terms of summer comfort and energy savings.

The intervention on the not visible elements has to be preferred since it determines adequate summer comfort and acceptable winter consumptions without altering the historic vertical walls.

The study also reports a comparison in terms of comfort and energy consumptions with a new building with low thermal capacity and low thermal transmittance.

The study could be useful to adjust the regulations on energy saving for traditional existing buildings of historic value in temperate climates.

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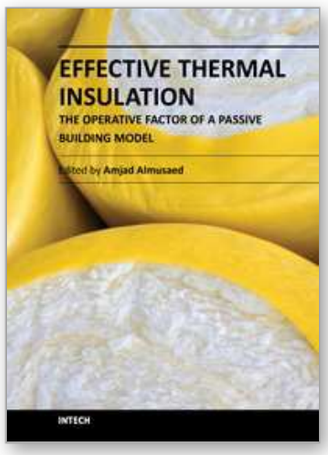
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This book has been written to present elementary practical and efficient applications in saving energy concept, as well as propose a solitary action for this category of topics. The book aims to illustrate various methods in treatment the concept of thermal insulation such as processes and the attempt to build an efficient passive building model.

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