Proceedings

of the

International Conference on
"Changing Cities"
Spatial, morphological, formal & socio-economic dimensions

Organized by

Department of Planning and Regional Development, University of Thessaly

Under the aegis of

THE GREEK MINISTRY OF ENVIRONMENT, ENERGY & CLIMATE CHANGE

&

THE FINANCING OF THE GREEN FUND

EDITOR: Aspa Gospodini

Skiathos, June 18-21, 2013

TITLE **Proceedings of the International Conference on "Changing Cities": Spatial, morphological, formal & socio-economic dimensions**

ISBN **978-960-6865-65-7**

Grafima Publ.

D. Gounari 62-68

54635 Thessaloniki, Greece

Tel/Fax: 2310-248272

www.grafima.com.gr,

E-mail: grafima@grafima.com.gr

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Scientific Board

The heavy review tasks of the International Scientific Board have entailed the expansion of the Board and the inclusion of new members:

FORWARD

The international conference on *'Changing Cities'* started as an idea a year ago. The initial concept was to organise something *creative, inspiring, stimulating,* and above all, *international.* There was a belief that such an academic event may contribute in revitalizing academia and tourism in Greece, and motivate, and give hope to all those - social groups, societal structures and people in Greece - hit by the economic crisis of public dept in the Eurozone.

Among the above, one should note in particular

- First, *Greek people* that has been witnessing a break of its morale caused by lack of employment, economic frustration, and demolishing of the social benefits system - including public health, public education, social security – due to austerity measures;
- Second, the great majority of *practicing urban planners, designers and architects* in Greece who have been suffering a great loss of jobs as a result of the recession;
- Third, *university teachers and researchers* in Greece who have been experiencing unprecedented salary cuts due to austerity measures while research funds are extremely low and rare;
- Finally, *Greek cities* which in the last 4 years have been shrinking in economic, spatial and demographic terms.

From the latter, derives the theme of this conference – *Changing Cities.*

The conference aspired to bring together architects, urban designers, landscape designers, urban planners, urban geographers, urban economists, urban sociologists and demographers, to investigate new challenges; and it aimed to become an international forum of transaction of ideas on cities. This goal appears becoming a reality since the conference has gained strong interest of academics and researchers in many countries and regions around the world; Greece and the Balkans, south Europe and Mediterranean countries, northwest Europe, Middle East and Asia, Far East, North America, Latin America and Africa. A total of about 450 abstracts and 300 papers were submitted in the conference; and among them, there have been about 165 Greek academics and researchers. This indicates that despite shortage of research funds, salary cuts, and broken morale, university teachers and researchers in Greek state universities try hard to keep a high-level academic status.

The strong interest for this conference allows us to have thoughts about organising *a series of Changing Cities conferences every two years,* spatially hosted on different Greek islands. This may offer to the conference participants a chance to visit, experience, and enjoy various attractive places in the Aegean Sea and the Ionian Sea.

I would like first to thank the Organising Committee, the key-note speakers, and the members of the international scientific board who supported enthusiastically the academic organization of this conference. I would especially like to thank those academic colleagues who have also pre-organized special thematic sessions in this conference.

Finally, I would like to thank all the academic, political and scientific organisations which financially supported this conference: University of Thessaly; the Greek Ministry of Environment & Climate Change; the Green Fund; Region of Thessaly; The Greek National Tourism Organization; The Municipality of Skiathos; The association of Skiathos hotels; The

Technical Chamber of Greece – Branches of central and west Thessaly and Magnesia; The Geotechnical Chamber of Greece – Branch of Thessaly.

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Urban identity:
heritage protection and comfort regulations in Geneva's current housing

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Abstract
This contribution proposes a comparative analysis of how legislation on built heritage protection and regulations on energy demands affect current 19th century housing buildings in the city of Geneva. Four measures of protection are analysed, looking at how comfort legislation and heritage protection come together in the recent renovation of roofs, walls and windows. The aim is to identify possibilities for good compromise or possible conflicts when renovating these elements in current 19th century housing ensembles. Their key value – which might sometimes be disregarded – often lies in the repetition of proportion, layout and detail, forming ensembles that contribute to the definition of urban identity in many cities[1].
Keywords: 19th century current housing; Geneva; built heritage protection; energy demands; legislation;

1. INTRODUCTION

Renovation of current historic housing is a necessity to avoid the loss of historic values, to address changes in family life and comfort demands, and to ensure building safety. Contemporary interventions in this patrimony have the potential to contribute to richer spaces by valuing the qualities of the original domestic spaces, while simultaneously responding to these new concerns. Inhabitants increasingly value distinctive historic features of buildings, while at the same time wanting the added comfort that comes with present-day infrastructure and insulation. These issues are often expressed in a series of legal binding measures at national and regional level. Increasing measures in both fields might be contradictory, especially in the case of current housing, which often constitutes built ensembles with a variable degree of protection.

Legislation and plans for built heritage protection in Switzerland are essentially of cantonal responsibility, based on some common principles delineated by a federal legal basis. This regional specificity means in turn that protection and comfort demands might vary significantly between Swiss cantons. The city of Geneva's 19th century ensembles are an example of coherent large-scale developments where housing apartment buildings play a fundamental role. This is especially true in the so-called *ceinture fazyste*, a planned area built around the medieval city centre through the demolishing of the old fortification walls in mid 19th-century. Highly demanding cantonal legislation exists in terms of energy standards, with a particular focus on the promotion of a sustainable low-energy consumption society. However, heritage protection in the canton of Geneva is also quite exceptional, as it promotes the conservation of both individual and current 19th and early 20th century buildings, reinforcing their value as ensembles. For the above-mentioned reasons, Geneva represents a positive and coherent example combining reasonable[2] protection measures and technical up-to-date transformations.

[1] I would like to thank my colleagues Pierre Zurbrügg (EPFL) and Nicolas Galiotto (AAU) for their advice on calculating and evaluating thermal resistances, and my thesis advisors Luca Ortelli (EPFL) and Ana Tostões (IST) for their input on my work.
[2] By reasonable measures we mean those that seek a good compromise between different fundamental aspects while nevertheless defending their goal.

2. METHODS

The first objective of our work was to analyse the key protection measures and thermal insulation standards for building renovation that apply to current 19th century housing buildings in the Geneva canton. We then specifically examined how the adaptation of some frequently renovated building components – roofs, walls and windows – to energy regulations affects historic elements. We also identified some design solutions for compromise[3] and possible conflicts between the protection and thermal insulation of these elements. These solutions were identified through the in-depth analysis of ten recent 19th century house renovations in Geneva.

Legal research was undertaken by analysing the pieces of legislation that enforce built heritage protection and the pieces of legislation and regulations on thermal insulation in the Geneva canton. These are, for heritage protection, the *Loi d'application de la loi sur l'aménagement du territoire* (LaLAT), the *Loi sur la protection des monuments, de la nature et des sites* (LPMNS) and the *Loi sur la construction et les installations diverses* (LCI) [1, 2, 3]. The two main pieces of legislation that define energy demands are the *Loi sur l'énergie* (LEn) and the *Règlement d'application de la loi sur l'énergie* (REn) [4, 5], which defines rules for the application of the LEn. The LEn and the REn then refer to regulations by the Swiss society of engineers and architects[4] (SIA) on more specific topics. Of these regulations we focused our attention mainly on the SIA 380/1 *L'énergie thermique dans le bâtiment* [7].

3. BUILT HERITAGE PROTECTION MEASURES

Built heritage protection in the canton of Geneva is quite exceptional, as it promotes the conservation of both individual monuments and current 19th century buildings, reinforcing their value as ensembles. While monument protection is generally enforced through listing (*classement*), protection of more current buildings takes place by individual addition to the register (*inventaire*) or, most often, by inclusion in protected perimeters: conservation areas (*zones protégées*), site plans (*plans de site*), and special regulations (*réglements spéciaux*). Protected perimeters are one of the main strengths of heritage protection in the canton, as they are enforced through the instruments of urban planning. As such, their basis is defined in the piece of legislation on land-use planning, the LaLAT, which defines the procedure for the elaboration of the land-use plans (*plans d'affectation*). The most general of these land-use plans is the zoning plan (*plan de zones*), which maybe of 3 different types: ordinary areas (*zones ordinaires*), development areas (*zones de développement*) and conservation areas. The conservation areas "form delimited perimeters and have the objective of protecting the organisation and the architectural character of those neighbourhoods and places" [8]. Most buildings of our time of study are in areas considered building areas (*zones à bâtir*), included in the ordinary areas. Part of these areas overlap protected perimeters, such as the conservation areas or the site plans, and some buildings in these areas are included in the register or are listed. However, there is also a large number of buildings that fall outside these protection measures.

The building regulations that affect different types of areas are further defined in the LCI, including the conservation areas. In an article on the chronological evolution of protection measures in Geneva[5] Sabine Nemec-Piguet [10], current head of the Geneva *Office du patrimoine et des sites*, underlines how this measure shifted part of the perspective on built heritage protection from the individual to the urban character of each place. Amongst the conservation areas, two are of particular interest to our study: the *Vieille Ville et secteur sud des anciennes fortifications* and the

[3] The word compromise is used in a positive sense to refer to critical design solutions that achieve a non-conflicting balance between equally important issues.
[4] The SIA is a "professional association for construction, technology and environment specialists. (...) It develops, updates and publishes numerous standards, regulations, guidelines, recommendations and documentation (...) for the Swiss construction industry" [6].
[5] Another important reference regarding this issue is the work of lawyer Gabriel Aubert on the legal measures of built heritage protection at a crucial stage of their development. His findings are described in the article *La protection du patrimoine architectural en droit genevois* [9].

Ensembles du XIX^e siècle et du début du XX^e siècle. The first area is the most protected, and includes the medieval city centre and a large part of the 19th century planned building area on previous fortification land. Protection of this area aims foremost to preserve its urban layout and architectural character. According to the LCI, existing buildings ought to be kept in place and, in case of transformation, their structure and characteristic elements should be kept. All architecture ought to match neighbourhood character. Furthermore, all permissions are submitted to the *commision des monuments, de la nature et des sites* for evaluation.

The *Ensembles du XIXe siècle et du début du XXe siècle* are not a single area as such but rather allow for the protection of groups of buildings that define a set outside protected perimeters. This mechanism is based on the specificity of current 19th century buildings: their value as ensembles with repeated elements that contribute to urban identity. Historians Armand Brulhart and Erica Deuber-Ziegler called this measure "a giant step towards the recognition of the quality of urban ensembles" [11]. An indicative list of characteristic elements of the *Ensembles du XIXe et début du XXe siècle* that are worthy of protection is presented in the *Office du patrimoine et des sites'* website[6]. This extensive list includes most building and decorative elements, and even plan typology.

The LPMNS aims to preserve Geneva's monuments as well as important natural and built sites and buildings. Three main protection measures are in force: listing, registration, and the inclusion in a site plan. Listing is less applicable to our study as it focuses on individual monuments. The register includes both monuments as well as individual buildings that are worthy of interest. Buildings that are registered should be kept and their characteristic elements preserved, using as reference the list of elements in place for the *Ensembles du XIXe et début du XXe siècle*. The site plan is a specific type of land-use plan that is detailed in the LPMNS. It is a fundamental measure, as it also allows for the protection of important built areas, including large current 19th century ensembles. Site plans and the special regulations where current 19th century buildings exist focus mainly on areas that are particularly important to mark the image of the city. Most of them include a map and specific regulations with the aim of preserving the urban identity of the area. Three main types of buildings are usually identified. The first ones should be maintained in place, as well as their main architectural elements. The second type includes buildings that present some interesting elements, and their transformation or demolition is appraised on a case-by-case basis. Other buildings can be transformed or rebuilt according to site integration and to an established height limitation.

4. THERMAL INSULATION REQUIREMENTS

The main pieces of legislation that specify energy requirements for buildings in the Geneva canton are the *loi sur l'énergie* (LEn) and the *règlement d'application de la loi sur l'énergie* (REn), that often refer to more specific SIA regulations. The REn considers that whenever existing buildings are submitted to renovation work, the modified elements or building areas are required to respect the minimal energy demands on several topics. Renovation work occurs "whenever the buildings or the building elements are affected by work that changes the energy performance of the building" [13]. Demands on thermal insulation follow SIA 180 *Isolation thermique et protection contre l'humidité dans les bâtiments* [14] and SIA 380/1 *L'énergie thermique dans le bâtiment* regulations.

The SIA 380/1 regulation is the main defining element for prescriptions on buildings' energy performance as well as the most demanding. Its aim is the "rational and economic energy use for heating and sanitary hot water production in buildings" [15]. In 2009, SIA requirements for thermal insulation in winter became stricter, following a new model defined by cantonal energy services [16]. Global requirements on renovation now roughly correspond to the ones that previously existed

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[6] A list of listed, registered buildings and protected perimeters and the indicative list of characteristic elements can be found in the *Office des Monuments et Sites* website [12].

for new buildings. In general terms, whenever a building is transformed including interventions that improve its energy performance, it should comply with the regulation's minimal energy requirements. If opaque building elements are completely replaced, standards for new buildings apply; if not, renovations must follow standards on transformed buildings, which are a bit less demanding. Two procedures can be followed to justify a building's compliance with the regulations: localised performances (*performances ponctuelles requises*) or global performances (*performances globales requises*). In the case of localised performances, the coefficients of heat transmission - *U* values[7] - that should be respected for each element of a building's thermal envelope are defined. When the global performances procedure is applied, the thermal quality of the envelope is compared with the buildings' yearly heating requirements, Q_h in MJ/m^2. In this case, localised performances should comply with the section of the SIA 180 regulation on *U* values, which is far less demanding.

The method of localised performances is mostly applied to smaller renovations whenever only a few building elements are transformed. It does not require the calculation of global heating needs, but demands a very good performance of every transformed element. In buildings with extensive external and interior decorations, this method allows for their protection because only the renovated elements are required to attain certain values. In this case, the intervention might choose, for instance, not to insulate the walls and focus only on window renovation. The global performances method is generally applied to more significant renovations of entire buildings or of part of a building (for example, an attic transformation). Even though it requires further calculations, it allows for more flexibility when choosing which elements should be more or less insulated (each individual element follows SIA 180 regulations). This aspect can be used to apply a less demanding solution to some important elements if other insulated building components can make up the difference.

Table 2. *U* limit values for the SIA 380/1 localised performances method for transformed building elements considering an interior temperature of 20°C, and for the SIA 180 (simplified)

		SIA 380/1: Limit values U_{li} (W/m^2 K)		**SIA 180: U_{max} (W/m^2 K)**		
Building element against		The outside or less than 2m underground	Non heated places or more than 2m underground	The outside or less than 2m underground	Non heated places	More than 2m underground
Opaque elements	Roof	0.25	0.28	0.4	0.5	0.6
	Floor	0.25	0.30	0.4	0.6	0.6
	Walls	0.25	0.30	0.4	0.6	0.6
Windows		1.3	1.6	2.4	2.4	-

According to the SIA 380/1, built heritage protection does not immediately ensure fewer requirements as far energy demands are concerned, unless exemptions are granted: "whenever following the requirement implies technical feasibility problems, unsustainable economical investments or goes against heritage protection demands, disparities should be justified" [18]. This means that, in principle, any necessary deviations might be authorised on a case-by-case basis, depending on the dialogue between different building actors, the *Office du patrimoine et des sites* and the *Office cantonal de l'énergie*.

5. SOLUTIONS FOR COMPROMISE

Built heritage protection aims to ensure that the buildings and their important elements are preserved even if they are subject to changes, while energy saving regulations aim for more

[7] The coefficient of heat transmission or *U* value (W/m^2 K) is used to evaluate the thermal conductivity of given elements. It is the inverse of heat resistance *R* (m^2 K/W), meaning that the lower the *U* value, the better thermal insulation is. The SIA 380/1 defines it as the "quotient of the thermal flow by unity of surface of a building element, in a stationary regime, by the temperature difference between the surroundings that are contiguous to this element" [17].

comfortable living environments with sustainable energy consumption. In protected buildings, the conjugation between these instruments can push the design to go further – and apply varied techniques to achieve compromises. Nevertheless, it is important to consider the transformation of other 19th century housing buildings that are not protected. In these cases, renovations according to the most economic or to the most energy efficient solutions can lead to losses of important historic elements. Energy improvement of a building envelope typically focuses on elements such as façade openings, outside walls, and on a building's basement and attic insulation. We chose to focus on the improvement of the thermal performance of three building components – roofs, walls and windows – that can often affect protected elements, looking at some possible conflicts and at practical solutions for compromise that were observed in recent examples of building renovation.

5.1 Roofs

The original roofs of Geneva's 19th century houses were often covered with slate plates or clay tiles, directly placed over one layer of wooden battens that covered the roof rafters at a right angle. Structurally, as in many wooden roofs of this time, rafters often rested on purlins that were placed over the roof trusses. Trusses were quite varied, even though it is quite frequent to see two pitched roofs where trusses have high collar beams (usually attics used for storage), or mansard roofs known to serve as servant's dwellings[8]. On the inside, the rafters were usually covered in wooden lathes or battens, followed by a final coat of plaster of Paris. Skylights placed over staircases or internal courtyards were also quite common.

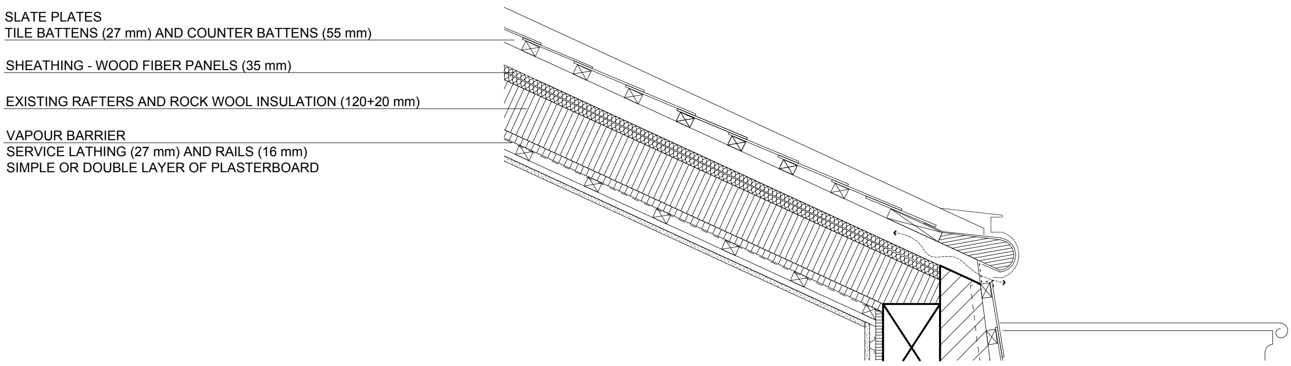

Figure 1. Example of roof insulation between existing rafters
(study drawing by *MVT Architectes* for the building on Rue Saint-Victor 8 - adapted)

Nowadays, the insulation of an existing roof is usually done at roof or slab level, often depending on whether the attic space is used for housing. However, if the roof is in bad condition, it might also be convenient to profit from its general renovation to insulate it. Depending on the solution, characteristic elements might be affected, such as the roof covering materials, the roof frame if it is submitted to additional weight, and the outside volume. Both for conservation and for practical reasons, the original roof framing is generally kept when insulating, replacing or reinforcing any elements that are structurally damaged[9]. Many insulation solutions are available, that we can easily observe in manufacturers catalogues or in building manuals [20]. In analysed renovations[10], when the insulation is placed at roof level, one of the best compromises is to place most of it between and below the rafters, depending on their height (Figure 1). This system avoids most of the increased rooftop thickness that comes with external insulation, which can induce connection problems with the gutter or with the eaves (even though it minimises thermal bridges). Insulation between rafters

[8] Observation based on the analysis of archive drawings of *ceinture fazyste* buildings, including elevations (which give us a general idea of roof shape) and roof framing drawings (building permissions found at the *Archives d'État de Genève* and at the *Direction des constructions et de l'aménagement* archives of the *Ville de Genève*).
[9] The *Refurbishment Manual* [19] presents different options as to the insulation of roofs where wooden framing needs reinforcing.
[10] This solution was or is going to be applied, with some variations, in projects by *MTV Architectes* at the Rue de la Servette 36 and Rue Saint-Victor 8 and 10 buildings, and by *SRA Architectes* at the Boulevard Helvétique 6 and Avenue Frontenex 5 buildings.

is often done with an averagely priced material of good thermal and fire resistance, such as rock wool[11] (λ value around 0.034-0.048 W/(m K)). In addition, flexible rather than rigid materials "compensate for the natural swelling and shrinkage behaviour of the timber roof structure" [21]. Above the rafters, a layer of sheathing often made out of wood fibber panels is placed to avoid any water leaking, but permeable to vapour. These panels are followed by a layer of wooden counter battens for ventilation, and by the wooden tile battens that support the ceramic tiles or slates (usually new to avoid irregularities). Inside, below the insulation, an airtight vapour barrier is added, followed by a service lathing to pass any necessary cables and prevent damage to the vapour barrier. The final coating is then placed, most frequently using a double layer of plasterboard.

If we recall that according to the SIA 380/1 localised performances method the limit U value for a roof is 0.25 W/(m^2 K), it is necessary to place a total of around 0.14m to 0.17m of rock wool paired with sheathing to fulfil this method's legal demands[12]. In addition, rafters often have inferior heights, around 0.12m. Hence, this insulation is usually composed of two layers: a main one between rafters, and an extra wood-battening layer paired with insulation of around 0.02m to 0.05m placed underneath. The possible disadvantage of this solution is the loss of ceiling height, which could become a problem if it is close to the legal limit for housing use. Even when the global performances method is applied, the roof is sometimes a place where insulation is reinforced to make up for places where most characteristic protected elements are present. Nevertheless, if ceiling height is an issue and if insulation can be reinforced elsewhere, SIA 180 performances with a U value of 0.4 W/(m^2 K) can easily be achieved with insulation placed only between rafters.

5.2 Walls

As was often the case in buildings from this time, façade walls were mostly built in rubble stone masonry with a varying thickness between floors. Drawings[13] where wall thickness is indicated put it around 0.60-0.65m on the ground floor, successively reducing it up to 0.50m on housing floors. Façades are generally rendered, with dressed stonework framing embrasures, façade corners and bases. In more exceptional cases, entire walls present visible stonework. On the inside, characteristic woodwork panelling often covers the window back and splays, which sometimes include folding inside shutters. In some cases, inside walls also have dados made up of finely worked wooden panels. In addition, the coved ceilings usually present simple or more elaborate plaster decorations. In less decorated buildings, shutters are often placed on the outside and, on the inside, a simpler wooden frame is placed around the inside of the rendered splay.

In these buildings, external walls are a key element of heat loss but are very difficult to insulate without damaging any of the historic elements outside and inside. This possibility naturally depends on the characteristics of each wall; in the rare cases where there is an available gable blind wall, it can be insulated uniformly from the outside and largely contribute to the building's thermal performance, reducing some thermal bridges[14]. Several materials can be adopted for compact external insulation. If, for instance, expanded polystyrene is applied (λ around 0.032-0.042 W/(m K)), about 0.11m to 0.14m are necessary to come to a U value of 0.25 W/(m^2 K) for a 0.50m rubble stone masonry wall, but more is sometimes applied to add to the buildings performance[15].

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[11] We also studied a project for Rue de l'Athénée 4 by *AFM Architectes* where expanded polystyrene with added graphite will probably be applied (λ=0.031 W/(m K)). This solution can be interesting as it substantially reduces the charges to the rafters and has a good thermal insulation, but it more rigid and requires increased attention to fire protection.

[12] This estimation of thermal resistance was done using the EN ISO 6949 [22] simplified method for heterogeneous layers.

[13] Observation based on the analysis of archive drawings of *ceinture fazyste* buildings (building permissions found at the *Archives d'État de Genève* and at the *Direction des constructions et de l'aménagement* archives of the *Ville de Genève*).

[14] This solution was applied at the Rue des Grottes 12-14 building by architects *Steeve Ray et Associés* using cellular concrete panels and is going to be applied by *MVT architectes* at the Rue de la Servette 36 (here an insulating rendering is also going to be applied on the remaining façades).

[15] The estimation of thermal resistance was done using the EN ISO 6949 method for homogeneous layers [22]. Thermal conductivity values were taken from the *Catalogue d'éléments de construction avec calcul de la valeur U* [23] unless specified otherwise. The value for a rubble masonry wall was taken from the Lesosai program values [24].

In façade walls, one of the possible interventions is to replace the rendering with an insulating one, which has a thermal conductivity (λ) of around 0.08 W/(m K) rather than 0.87 W/(m K) for a normal rendering. Nevertheless, the few centimetres that are applied (generally around 0.03m) can only do so much for thermal insulation, from an approximate *U* value of around 1.2 W/(m^2 K) for a non-insulated masonry wall to 0.84 W/(m^2 K)). It is also important to make sure that the rendering remains slightly behind the stonework limit from a conservation point of view, and to choose a mineral rendering that remains permeable to water vapour. New developments have recently been made in very efficient insulating aerogel rendering (λ of 0.028 W/(m K))[16] where, for the same thickness, a *U* value of 0.53 W/(m^2 K) could be achieved. This solution can be interesting, especially in cases where no other wall insulation is possible and where cost is less of an issue.

Interior wall insulation is usually part of more general building renovation work. This solution allows for the preservation of the façades. However, the interruption of the insulation at slab level can induce condensation problems that affect the wooden joists due to low temperature paired with humidity. Excessive interior insulation can contribute to this kind of problem, as the temperature on the cold side of the insulation will be even lower, further away from the warm interior. In the cases where insulation thickness is reduced, global heating demands might be easier to satisfy than localised ones [26]. The work on *Energy-Efficient Upgrades* [27] suggests that humidity around timber joist ends can be minimised by exposing them as well as the joist supports, and filling voids with PUR spray foam. This solution aims to establish a certain continuity of the insulation system, even though a complete continuity seems hard to achieve.

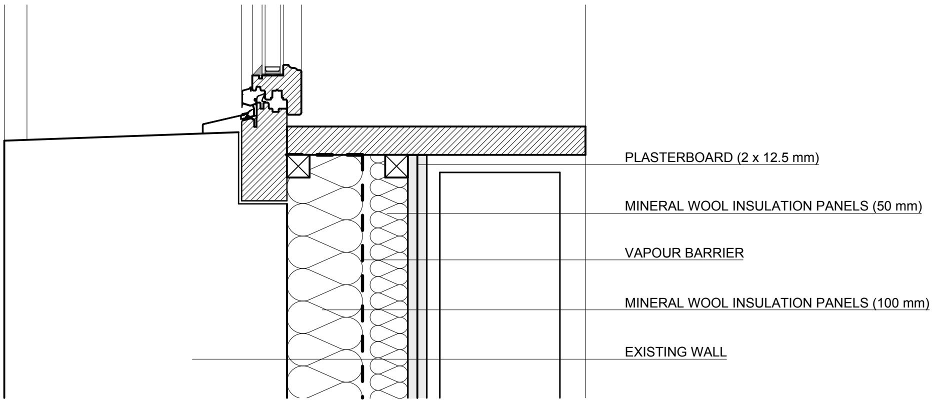

Figure 2. Example of the interior insulation of a back wall
(study drawing by *DLV Architectes* for the building on Rue Rousseau 7 - adapted)

In protected buildings, interior insulation can be applied in places where wooden panelling or particular plaster of Paris ceiling decorations near the walls do not exist. Unprotected buildings are, naturally, more exposed to interventions that affect important elements, especially inside, where they are less visible. In cases where wooden panelling does not exist, it is also possible to place insulation on wall surfaces and against the wall underneath the windowsills and on splays[17] (Figure 2). If the objective is to achieve localised performances demands with *U* value of 0.25 W/m^2 K it would be necessary to add roughly around 0.11m to 0.16m of rock wool to 0.50m thick masonry walls, if this thickness is feasible from a building physics point of view. Interior insulation should be paired with a vapour barrier on the inside to avoid vapour condensing on the cold side of the insulation. In a global performances calculation (*U* value of 0.40 W/m^2 K) it would be necessary to place much less, around 0.06m to 0.08m. In cases were interventions on window splays are possible, insulation is beneficial to minimise surface condensation. As excessive thickness may

[16] We refer to the insulating rendering of high performance developed by Empa and Fixit AG and that is being marketed by the latter [25].
[17] This solution is being applied to part of the less decorated back façade of a protected building on Rue Rousseau 7 by *DLV Architectes*.

affect windows and daylight, very performing materials might be worth considering if financially possible, such as aerogel panels (λ around 0.014 W/(m K))[18].

5.3 Windows

As is the case of most windows in French-speaking Swiss urban context, original windows in current 19th century housing buildings in Geneva were mostly casement windows with two casements and waist height sills or French windows, sometimes paired with balconies. Dressed stonework elements often framed the embrasures. In most cases, one simple glazed wooden window was placed on the inside of these stone elements or, otherwise, was paired with a storm window on the outside. This extra window is usually also a casement window made with simpler details, which would be placed as additional protection during the winter months. Each sash is then generally divided in two or three panes of glass with glazing bars in between; sometimes, there is also a fixed or opening fanlight above the window transom.

Legally, any work on a building's exterior that increases comfort conditions in the Geneva canton, such as window transformation, is subject to building permission [3]. In the case of buildings included in protected perimeters, the list of protected characteristic elements dedicates a paragraph to window renovation indicating that: "an improvement of the phonic and thermal conditions can be sought by adding a glass layer or a double window. It may also be achieved by changing the glazing of placing joints. Nevertheless, if the window condition should not allow for such an intervention, the rules and detail regarding the new windows (...) have to respect the look of the original windows" [12].

In addition to specifying the conditions for building permissions and transformations, the LCI and the RCI also define living standards that buildings in building areas can be required to meet regardless of their time of construction, including some energy saving measures. The RCI states that elements that comprise the façade openings that give onto heated rooms should be adapted to have a $U \leq 3.0$ W/(m^2 K) until 2016 [29]. This general rule is far less demanding than SIA regulations that need to be applied in case of transformation, but means that original single simple glazed windows may no longer be kept without changes, but that original double windows could still exist if they have not been renovated until then[19].

As we have seen, according to SIA 380/1 regulations, the localised performances method demands very high performance, as windows should abide by a U value of 1.3 W/(m^2 K). Nowadays, the most obvious solution to fulfil these demands is to replace the window with a single industrial one with triple glazing. These are very efficient from a thermal point of view, but the frames are much wider than the original ones to support the heavy glass, and without the fine detailing. Replacing windows for most currently available industrial ones is not authorised in protected buildings. In non-protected ones, a need for interior comfort might lead to the hasty disposal of original windows in good condition, which affects the logic of the building façade and the architectural character of ensembles. It is also worth mentioning that the replacement with double-glazed windows using detailing that is similar to the original ones[20] is in principle not acceptable using the localised performances method, with a U value of 1.44 W/(m^2 K)[21]. Nevertheless, when the objective is to abide by localised performances, there are some solutions for compromise that can be applied to improve interior comfort as well as keeping characteristic elements intact. Transposing the idea of the original double window system, it is possible to maintain the old window and place a new one

[18] Thermal conductivity value presented for Agitec's Spaceloft board [28].

[19] Recent studies on the renovation of historic windows in Switzerland have shown that the U value of one simple glazed window is around 4.50 to 4.95 W/(m^2 K), and that of a double simple glazed window around 2.26 to 2.42 W/(m^2 K). In addition, they have also calculated the U value of several renovation solutions [30, 31].

[20] This solution is often applied using the global performances method, as is the case of a building on Rue Lissignol 8 (project by Morten Gisselbaek).

[21] Comparative U values were extracted from the *ReHAB: Assainissement de fenêtres dans les immeubles d'habitation 1850-1920* [30] research in which we participated, conducted at the *Laboratoire de Construction et Conservation* of the EPFL.

with double glazing on the inside, thus keeping the external façade intact. Alternatively, a new window can also be placed on the outside[22], leaving the inside intact. As condensation problems might arise from this solution, it is important to insure minimal ventilation between windows [30]. In both cases, the fact that two windows exist increases thermal insulation so that the new window frame can have proportions that are more similar to the original ones by not supporting the triple glazing. However, the feasibility of this option at large scale would require an industrial production of profiles for double-glazing that are smaller than for triple glazing.

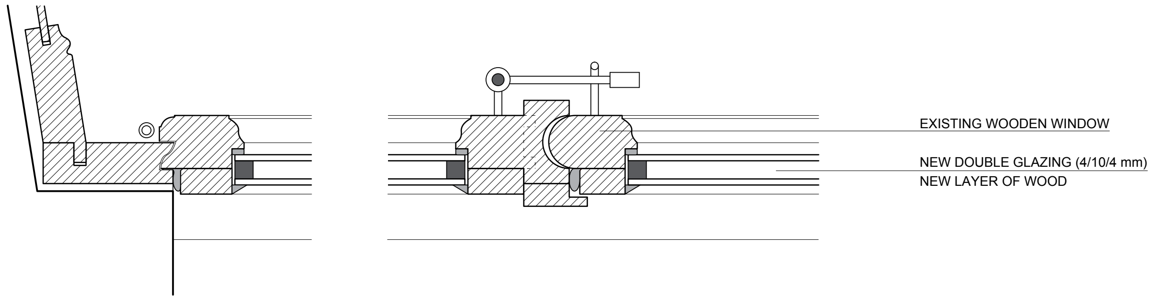

Figure 3. Example of a window renovation by replacing the single for double-glazing (drawing from the ReHAB project - adapted [30])

In case of the global performances method, window performances need to respect SIA 180 requirements, with a less demanding *U* value of 2.4 W/(m^2 K). Thus, if other elements are more insulated, window renovation can be more flexible. One of the most interesting examples that recent technical advances have perfected is the replacing of single for double-glazing in original old windows[23] (Figure 3). This can be done to windows in good condition by adding a layer of wood to the prepared external window surface, which is usually the most damaged. This type of intervention can change the *U* value to an average of 1.44 W/(m^2 K)[24].

6. CONCLUSIONS

This article looked into the example of the city of Geneva where 19th century housing ensembles have a fundamental role in defining urban identity, like in so many other European cities. Its specificity lies in important legislation on built heritage protection, based on the instruments of land-use planning, which allow for the protection of large city areas. The evolution of cantonal legislation has also enforced increasingly stricter regulations on energy efficiency demands. The necessary energy requirements can be achieved through a localised or global performances method. As discussed, using one method or another depends mostly on the amount of renovation work and on the interventions that can be done without compromising historic values.

Solutions for compromise have been found to exist for roofs, walls and windows, where an intervention can significantly affect characteristic elements. Demands in both fields tend to promote better design solutions, technological progress and research. However, we have also observed that some solutions that can significantly improve thermal performances cannot, in principle, be applied according to the localised performances method, making it necessary to adopt another strategy or carry out a global intervention that might not be adequate in buildings with many historic elements. This is the case of the replacement of simple for double-glazing in historic windows, or of placing very efficient new insulating rendering on the external face of masonry walls. In addition, some interventions that abide by regulations can also be hard to carry out for reasons relative to building physics, such as excessive interior insulation.

[22] New storm windows were or are going to be placed at Rue Saint Victor 8 and 10 (*MVT Architectes*), and at Boulevard Helvétique 6 and Avenue Frontenex 5 (*SRA Architectes*), even though in the last 3 examples simple glazed windows were applied, as the interventions were done before 2009.
[23] This technique is being increasingly applied, as in protected buildings on Rue Rousseau 7 (*DLV Architectes*) and Quai de l'Ile 15 (*SRA Architectes*).
[24] A publication by the Geneva *Office du patrimoine et des sites* [32] already mentions both solutions even though the new second window was most though of as a simple glazed one.

Unprotected buildings face other issues, such as the possible consequences to existing characteristic elements of the application of a high-efficiency energy model or the most inexpensive solution. In addition, legal measures necessarily depend on department resources, reasonable processing times, as well as knowing that requirements on heritage protection and thermal efficiency can only go as far as the technological advances of the time and the economic possibilities of the house owners. In protected buildings, exceptions to energy regulations can be granted on a case-by-case basis, depending on the dialogue between the different actors. This takes time and effort. This long drawn-out renovation process is one of the issues that could make it difficult to apply this model elsewhere. Another would be different pressure on energy demands due to climate differences, or the feasibility of some technically specialized solutions. As regulations apply to a given reality, it is never too much to mention that inhabitants increasingly want to be comfortable within certain limits, and to find defining techniques and elements of a building's past character. Demanding yet flexible legislation can contribute to better technical results and for dialog between actors, especially in cases where different interests could collide. As such, it is not surprising that comfort and memory go hand in hand, and, hence, that the everyday work of building actors is to collaborate, using legislation to achieve better results.

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