The assessment of environmental sustainability of industrial buildings: implementation and issues in an industrial district

Maria Vittoria Santi

Highlights

The sustainability of industrial buildings is considered, in a selected industrial district, through the combined use of data, maps and assessment tools. The categorisation of buildings by types and constructive systems allows an estimation of the main issues in the district. Energy and environmental audits on sample buildings draw attention to specific issues, highlighted by the comparison between the energy performances of different types of building envelope. The procedure used for the study allows further development, which might imply the extension of the assessment to the whole Region.

Abstract

The research focuses on the sustainability of industrial buildings, providing a review of the main problems in terms of energy and environmental quality, through the application of the assessment tools in force in the territorial context. The general overview of industrial buildings in the region of Friuli Venezia Giulia is followed by the survey of the typological and constructive aspects of buildings in one industrial district (Maniago, PN). The identified building stock is analysed according to the sustainability criteria, on the basis of the energy and environmental audit of some sample buildings.

Keywords

Industrial building, Energy efficiency, Sustainability

1. INTRODUCTION

The research, carried out during the PhD programme, faces the main issues about prefabricated industrial architecture, seeking to document and analyse the past evolution and the current problems related to the use of precast concrete panels for the construction of large spaces for industry. Following a first phase of investigation on industrial architecture made by concrete and the use of precast elements for the building envelope, the research focuses on energetic and environmental aspects related to the sustainability of industrial buildings. This previous phase about industrial architecture has allowed to contextualise the phenomenon of prefabrication in relation to the development of industrial areas in Italy during the last century and to identify the peculiarities of this built heritage [1; 2]. The analysis of the constructive and detail features has therefore provided an opportunity for continuing the study toward the energy
and environment field, expanding upon the issues of quality and performance related to the typological and technological knowledge.

The aspect of sustainability for industrial buildings is still, in Italy, partly unexplored, and the construction standard is far from an environmental performance adequate for other building uses [3]; in addition, in the past, industrial buildings, excluded from many of the regulatory requirements until the 80s, were often designed and built with little consideration of the issue of energy saving, so that their opaque or transparent structures and heating systems have considerable energy performance deficits. Moreover, in Italy industrial buildings are also predominantly made by prefabricated building systems, very popular since the 50s and 60s due to their characteristics (such as the low cost of design and construction), respecting more the quantitative parameters than the overall architectural and environmental quality.

Nowadays, according to the growing interest in sustainability of the industrial sector and the prospect of an increasing need for reclamation of abandoned or underused areas, the problem of reuse and adaptation (functional, structural and energetic) of existing industrial buildings raises, especially regarding the most common types such as factories and warehouses constructed with prefabricated elements.

The aim of this part of the research is therefore the identification, with respect to the type of building considered in the study, of the major problems of energy and environmental quality, for a future critical synthesis of the possible refurbishment strategies, considering international best practices and available technologies. On this basis, the sustainability assessment through the energy and environmental audits prove vital, and the appropriate application of the latest tools and methods of certification is addressed in relation to the knowledge of the building stock of the recent past.

2. STATE OF THE ART

The interest in the issue of sustainability regarding industrial areas, followed by the spread of sustainable buildings and sites, however marginal, has grown in connection with several factors: the national and regional laws calling for new performance requirements for buildings and systems, the increasing use of renewable energy sources facilitated by public incentives, the specific regulations for the industrial sector and EU directives and legislation [4], the implementation of standards towards an integrated energy&environmental management of process and product (with the systems for environmental management ISO 14001, energy management ISO 50001, life cycle assessment ISO 14040, and carbon footprint ISO 14064), and, finally, the

1. INTRODUZIONE

La ricerca, svolta nell’ambito del corso di Dottorato, affronta i diversi temi dell’edilizia industriale prefabbricata, proponendosi di analizzare e documentare l’evoluzione passata e le problematiche attuali legate all’uso dei pannelli prefabbricati in calcestruzzo per la costruzione di grandi spazi produttivi.

Facendo seguito a una prima fase di indagine sull’architettura industriale in calcestruzzo e sulla diffusione degli elementi prefabbricati per l’impianto, la ricerca si è focalizzata sull’approfondimento degli aspetti energetico-ambientali legati alla sostenibilità degli edifici prefabbricati oggi, in Italia, in parte inesplorato e lo standard costruttivo è lontano da un livello di compatibilità ambientale considerato adeguato per altre destinazioni d’uso [3]; in particolare, si può notare come in passato gli edifici industriali, esclusi da molte delle prescrizioni normative fino agli anni ’80, siano stati spesso progettati e realizzati con scarsa considerazione del tema del risparmio energetico, tanto da presentare strutture opache e trasparenti di miseri costi di progettazione e realizzazione nel rispetto dei parametri quantitativi, ma meno della complessiva qualità architettonica e ambientale.

Oggi, in funzione della crescente sensibilità per il tema della sostenibilità delle realtà produttive e nell’ottica di una sempre maggiore necessità di recuperare delle aree dismesse o sottoutilizzate, emerge il problema del rischio e dell’adeguamento (funzionale, strutturale ed energetico) degli edifici industriali esistenti, in particolare delle tipologie più diffuse come i “capannoni” realizzati con sistemi costruttivi prefabbricati, molto diffusi a partire dagli anni ‘50 e ‘60 per le loro caratteristiche (fra cui i basi costi di progettazione e realizzazione) nel rispetto dei parametri quantitativi, ma meno della complessiva qualità architettonica e ambientale.

L’obiettivo di questo passaggio della ricerca è stato quindi l’individuazione, rispetto alla tipologia edilizia oggetto di studio, delle criticità maggiori dal punto di vista della qualità energetico-ambientale, in funzione di una futura sintesi critica delle strategie e delle possibilità di riquadramento, considerando le best practices internazionali e le soluzioni tecnologiche attualmente disponibili. Date queste premesse, si è dimostrato centrale il ruolo della valutazione della sostenibilità attraverso l’audit energetico-ambientale e della più
design and certification tools for the energy and environmental sustainability at international (LEED) and national level (ITACA).

In this context, the design and refurbishment of industrial buildings implies, in general, the application of energy and environmental strategies aimed at rationalising consumption, optimising systems and reducing pollutant emissions. The energy and environmental sustainability of buildings has taken a leading role also for the evaluation of the existing building stock and, as a multidisciplinary theme, is oriented to the industrial site as a whole, according to international research (SIAM Project, Life Programme, 2004-2007 [5]; MEID project, Mediterranean Eco-Industrial Development, 2010-2013 [6]; Factories of the Future, Horizon2020 [7]). Moreover, in Italy there has been much research on the transformation of industrial heritage, and, in recent years, several studies have paid special attention to the relationship between sustainability and typological and technological characteristics of buildings [8; 9; 10; 11].

The topic of the renovation and improvement of the existing industrial facilities is, in fact, the practical aspect of interest related to the sustainability of industrial buildings, and it involves the architectural issue of the restoration of the built heritage. In particular, the architecture of industrial buildings has favoured considerations on the themes of structure, building envelope and prefabrication by many authors [12; 13], while only recently the issue of energy and environmental quality has been investigated [3; 14; 15; 16].

This articulated framework has implied different trends in research and methodologies, at national and international level, on the specific issue of energy and environmental quality of the industrial building stock; only a few compositions refer to buildings of the recent past (50s - 70s), and application examples and documentation are rare. This has suggested to analyse, as the first point, the topic of the energy and environmental assessment or audit (following the example of the European project already concluded Energy VillILAB, funded under the Cross-border Cooperation Operational Programme Italy - Slovenia 2007-2013 [16]). The energy and environmental audit, through the definition of a specific strategy for the assessment of the industries in the region, could also be a good basis for further developments of the study.

3. METHODOLOGY AND CASE STUDY

The research has been developed during a period of study and training at ARES-FVG (Regional Agency for Sustainable Building of Friuli Venezia Giulia [17]), dedicated to the theme of energy and environmental assessment and refurbishment of industrial buildings and areas. The topic is further
developed in relation to the regional context and with the aim of documenting the current condition of the industrial building stock, providing its assessment on the basis of energy and environmental parameters and finally envisaging proposals for future redevelopment of industrial areas and districts. The study is organised in a series of consecutive phases and is characterised by a change of scale, starting from a general overview on the regional scale, to get to the analysis of some particular applications on the building scale.

The first phase has involved an overview of the general features of industrial building in the regional area of Friuli Venezia Giulia, through the collection and analysis of the available data and documents. A first evaluation of the industrial building stock has been possible thanks to the cartography on land use in the region [18], which summarise the evolution of industrial buildings and areas from the 50s to the 2000s. Then the information on the eight industrial districts in the Region have been added to the cartography [19]; in particular, to address the analysis to a limited field of study, the reference is the current organisation of the ten Consortia for industrial development and their sites [20].

The second phase expands upon the typological and constructive characteristics of the buildings in the industrial district chosen as a case study (fig. 1): it is the industrial district in Maniago (PN), pertaining to the NIP Consortium [21].

The regional cartography concerning the municipality of Maniago and the maps of the Consortium have been used as a basis to categorise the buildings in the district; the functional and dimensional information on the buildings (use, date of construction, areas and volumes) have been deducted from the acquired data, while the typological and constructive information have been detected through surveys and observation on the field.

In the third and final phase, the aspects of performance of the building stock have been analysed, according to the main tools and methods for energy and environmental audit of buildings, including the tools for calculating the energy performance and the protocol for assessing the environmental sustainability.

Data on energy and environmental audits of the buildings in the district have been acquired from the documentation developed by the European Project Energy VillLab, of which ARES-FVG was a partner for the issues of energy efficiency in industrial areas [22].

The basic reference and tools used for the assessment of the energy efficiency of industrial buildings are: the certificate of energy performance of buildings (according to Legislative Decree 192/05, now updated by MD 26/06/2015 with the new guidelines for the energy certification of buildings [23]), and the technical regulations on energy saving and energy certification of
buildings (UNI TS 11300 [24]), taking into account the requirements for the “manufacturing building” category (E.8 - buildings used for industrial and similar activities). A further important reference, especially for the evaluation of possible interventions, has been identified in the ITACA Protocol - industrial Buildings [25], which added the factors of environmental sustainability to the energy efficiency aspects. Then the Green energy audit scheme has been used [26], in its two versions standard audit and walkthrough audit, for the assessment of individual buildings, as explained in the final report of the European project [22].

Figure 1. Industrial buildings in the district in Maniago (PN): types of building, building systems and materials: reinforced concrete structures and sandwich panels, reinforced concrete structures and masonry in brick or concrete blocks, precast concrete structures and panels.

4. RESULTS

There are eight industrial district recognised by the Autonomous Region of Friuli Venezia Giulia [19] and they are characterised by a building stock which is widespread in the industrial zones of several neighbouring municipalities and includes buildings built in different periods. The comparison, by overlaying, between the regional land use maps [18] and the data on the industrial districts and the Consortia for industrial development [20] has led to a first evaluation of the features of industrial buildings in the region. These industrial areas originated and consolidated in the period between the 50s and the 70s, while only a few developed (or expanded) in recent times (from the 80s). A first analysis has confirmed that these areas are also characterised by
The industrial area in Maniago (PN), chosen as a case study, is managed by the Consortium for industrial development of Pordenone (NIP), hosts about 70 companies whose activities are mainly related to the “knife district”, and covers a total area of 168 hectares, of which 165,220 m² are still available for new settlements [22].

The choice to study a specific industrial area, which is geographically confined, has facilitated the processing of data and has simplified the synthesis of the results, according to the research topics. This has allowed the census of all the buildings in the area and the organisation of the information acquired in a georeferenced database. This has also supported the development of a series of thematic maps on several characteristics of the industrial area, such as maps categorising buildings by the date of construction or otherwise by the building systems or even by energy performance, when available (Fig. 2).

Regarding the construction features of the buildings in this district, the analysis has shown that they were constructed since the 60s (indeed there are not buildings prior to the 50s), with the typical building systems for industrial sites. In detail, the walls are mainly made with precast concrete structures and panels, with cast-in-place concrete structures and masonry in brick or concrete blocks, with cast-in-place concrete structures and sandwich panels.
in metal sheet and insulation, or with steel-frame structures and curtain walls. The roofs are made with the same construction systems, such as prefabricated beams and shed elements, floors in concrete, metal trusses and framed structures and sandwich panels with metal sheet and insulation, sometimes with the addition of ceiling and insulating panels in mineral wool. The types of windows have more variety: iron frames and single glass or polycarbonate (often fixed-type), insulated aluminium doors and windows with double-glazing, combined double windows, or insulated windows with special glass [22]. Survey and observation on the field, in the area chosen for the study, have confirmed the presence of the types listed above and have allowed to determine the amount of each of these (Fig. 3).

<table>
<thead>
<tr>
<th>type of wall</th>
<th>panels</th>
<th>number</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>prefabricated structure, precast concrete panels</td>
<td>vertical</td>
<td>15</td>
<td>27</td>
</tr>
<tr>
<td></td>
<td>horizontal</td>
<td>16</td>
<td>29</td>
</tr>
<tr>
<td></td>
<td>other forms</td>
<td>6</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td></td>
<td>37</td>
<td>67</td>
</tr>
<tr>
<td>reinforced concrete structure and masonry with bricks or concrete blocks</td>
<td></td>
<td>6</td>
<td>11</td>
</tr>
<tr>
<td>reinforced concrete structure completed with sandwich panels in metal sheet and insulation</td>
<td></td>
<td>5</td>
<td>9</td>
</tr>
<tr>
<td>reinforced concrete or metal structure and wall in concrete blocks</td>
<td></td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>reinforced concrete or metal structure and cladding in other materials</td>
<td></td>
<td>6</td>
<td>11</td>
</tr>
</tbody>
</table>

Figure 3. Types of buildings in the industrial district in Maniago (PN): numbers and percentages of buildings, categorised by building systems and types of building envelope, with detail on precast concrete walls.

The energy audits carried out on some sample buildings suggest the possibility of extending this assessment to the whole district, promoting the collection of information on energy and environmental aspects that can complete the typological-constructive knowledge of the industrial buildings. The Green energy audit scheme [26] in the walkthrough audit version (in the form of a checklist), has proved to be a simple and fast assessment tool but also a suitable way for an accurate preliminary estimation of energy and environmental quality of the buildings; furthermore, it provides a summary of the general characteristics of the building (size, dates), information on the building envelope, the systems, and the current management. The standard audit collects thoroughly information on the building features, especially on the building envelope and the systems, from the description of the vertical and horizontal structures and the construction methods and materials, to the details of the thermic-physical parameters of the elements of the “thermal envelope”, and even to the identification of specific problems of some elements, systems
or management aspects. The audit also includes the standard energy analysis (consumption, management and energy performance [20]) and the possible improvement measures including the comparison of solutions in terms of energy performance, CO\textsubscript{2} emissions and economic costs.

So, for instance, the walkthrough audit of a sample building made with precast concrete structures and panels, dated 1961-1971, has shown that, despite the absence of degradation, the presence of thermal insulation in prefabricated elements and some recent upgrading works (such as the installation of double windows), the structure as a whole has still deficits of energy performance. On the contrary, although the renovation of the facade or the replacement of windows are not currently planned, an improvement of the energy performance would be easily achieved through the addition of an external insulation layer or the installation of solar panels on the roof [22].

The comparison within the energy performances of the sample buildings, for which the audit was performed under the EnergyVilLab project [16], is of particular interest in order to synthesise the main problems, highlighted by the percentages of heat loss in opaque and transparent structures, and to define the incidence of possible interventions, related to percentages of energy savings in the same structures (Fig. 4).

<table>
<thead>
<tr>
<th>building elements</th>
<th>description</th>
<th>% heat loss</th>
<th>% energy saving*</th>
</tr>
</thead>
<tbody>
<tr>
<td>opaque vertical structures</td>
<td>walls</td>
<td>31 + 35</td>
<td>16 + 26</td>
</tr>
<tr>
<td>horizontal structures</td>
<td>ground floors</td>
<td>5 + 8</td>
<td>1 + 3</td>
</tr>
<tr>
<td>horizontal structures</td>
<td>roofs</td>
<td>19 + 44</td>
<td>8 + 29</td>
</tr>
<tr>
<td>transparent elements</td>
<td>windows, doors, overhead doors</td>
<td>26 + 39</td>
<td>6 + 24</td>
</tr>
<tr>
<td>transparent elements</td>
<td>building with large windows</td>
<td>26 + 49</td>
<td>25 + 68</td>
</tr>
<tr>
<td>thermal bridges</td>
<td>-</td>
<td>2 + 4</td>
<td>-</td>
</tr>
<tr>
<td>ventilation</td>
<td>mechanical ventilation system</td>
<td>50 + 80</td>
<td>25 + 68</td>
</tr>
<tr>
<td>systems upgrade</td>
<td>heat generator replacement</td>
<td>-</td>
<td>20 + 26</td>
</tr>
</tbody>
</table>

* decrease in consumption related to building envelope

Figure 4. Comparison between heat losses and potential energy savings for each building element, according to energy audits carried out for the sample-buildings in the industrial district; summary of data from [22].

Focusing on the heat loss in the elements of the building envelope, the analysis of each case show that the percentage of heat loss is ascribable for the most part to the opaque and transparent vertical structures (walls and windows), in a significant way even to the horizontal structures (roofs), while only marginally to the floors. Consequently, also the savings percentages, achievable through refurbishment, are more relevant if they involve the vertical structures, consistent for the roofs, and not very significant for the floors (Fig. 4).

The proposed assessment method could be extended to the whole industrial
district, making also possible to roughly estimate the major problems and improvement potential through the comparison of these results, from the audits on sample buildings of each type, with the buildings in the area, detected and classified by their constructive features.

5. CONCLUSIONS

The study has confirmed the relevance of some issues involved in the research, and in particular the role of energy and environmental sustainability in relation to the dynamics of transformation of the industrial heritage of the recent past. The importance of the knowledge and the evaluation, above and beyond the proposals and strategies for the renovation and adaptation (functional, structural, environmental) of industrial buildings is confirmed. In fact, despite an ostensible homogeneity of industrial buildings in the context analysed, the process of assessment has pointed out several complications related to the acquisition of data for the classification (about both buildings and systems) and to the use of the tools for energy and environmental sustainability assessment of industrial facilities (due to the complexity of the structures and the heterogeneity of possible interventions). As an additional outcome of the study, on the basis of the process already accomplished, the time and cost for the assessment are estimated; the evaluation of the environmental sustainability of the industrial building stock could therefore be continued, using the methodology proposed, going from the building scale to the district scale, and eventually to the whole Region.

6. CREDITS

The research is carried out during the PhD course in Civil Engineering, Architecture and Territory, XXIX Cycle, at University of Udine, Department of Civil Engineering and Architecture, supervised by prof. Anna Frangipane. The paper summarises the main aspects of the part of the research developed by the author during the training and research period at the Regional Agency for Sustainable Building of Friuli Venezia Giulia (ARES-FVG), regulated by a Convention between the agency and the Department: the activity was related to the energy efficiency of industrial buildings and the European projects in progress, and supervised by the architect Angela Sanchini, who is thanked.

5. REFERENCES


L’analisi delle dispersioni e il confronto delle prestazioni degli edifici campione, per cui è stato eseguito l’audit nell’ambito del progetto EnergyVilLab [16] è di particolare interesse per la sintesi delle principali criticità evidenziate dalle percentuali di consumi rispetto alle strutture orizzonti e trasparenti, e per la definizione dell’incidenza dei possibili interventi, correlata alle percentuali di risparmio (Fig. 4). Per quanto riguarda le strutture disperdenti, dall’analisi dei singoli casi è possibile riuscire come la percentuale di dispersioni sia attribuibile per la maggior parte alle chiusure orizzontali e trasparenti, in modo consistente anche alle chiusure verticali di copertura, mentre solo marginalmente alle chiusure orizzontali di base. Di conseguenza anche le percentuali di risparmio, ottenibili attraverso gli interventi di riqualificazione, sono più rilevanti se riferite alle chiusure verticali, consistenti rispetto alle chiusure orizzontali di copertura, e non molto significative per le chiusure orizzontali di base. Volendo estendere il metodo di valutazione proposto all’interno distretto, è possibile, inoltre, stimare approssimativamente le criticità e le potenzialità di miglioramento attraverso il confronto di questi risultati ottenuti dall’audit sugli edifici “campioni” di ciascuna tipologia, con il patrimonio edilizio rilevato nell’area e classificato in base alle caratteristiche costruttive.

5. CONCLUSIONI

La ricerca ha confermato la centralità di alcuni temi coinvolti nella ricerca, e in particolare il ruolo della sostenibilità energetico-ambientale in relazione alle dinamiche di trasformazione del patrimonio industriale del passato recente. A monte delle proposte e delle strategie di intervento per la riqualificazione del contesto (funzionale, strutturale, energetico) si conferma l’importanza della conoscenza e della valutazione. Infatti, nonostante l’apparente omogeneità dell’edilizia industriale nel contesto analizzato, in questo processo sono emerse diverse criticità legate sia all’acquisizione dei dati per la conoscenza (su aspetti sia edilizi che impiantistici) sia all’applicazione degli strumenti di valutazione della sostenibilità energetico-ambientale (per la complessità delle strutture e per l’eterogeneità degli interventi possibili). Come ulteriore esito del lavoro, facendo seguito alle esperienze già composte, risulta possibile una stima dei tempi e dei costi per la...


