39th IAHS Milan Italy 2013

The International Association for Housing Science

POLITECNICO DI MILANO 150°

Changing Needs, Adaptive Buildings, Smart Cities

Volume 2

- Practical Analyses.
- Preliminary Studies.
- Product Reviews.
- Project Presentations.
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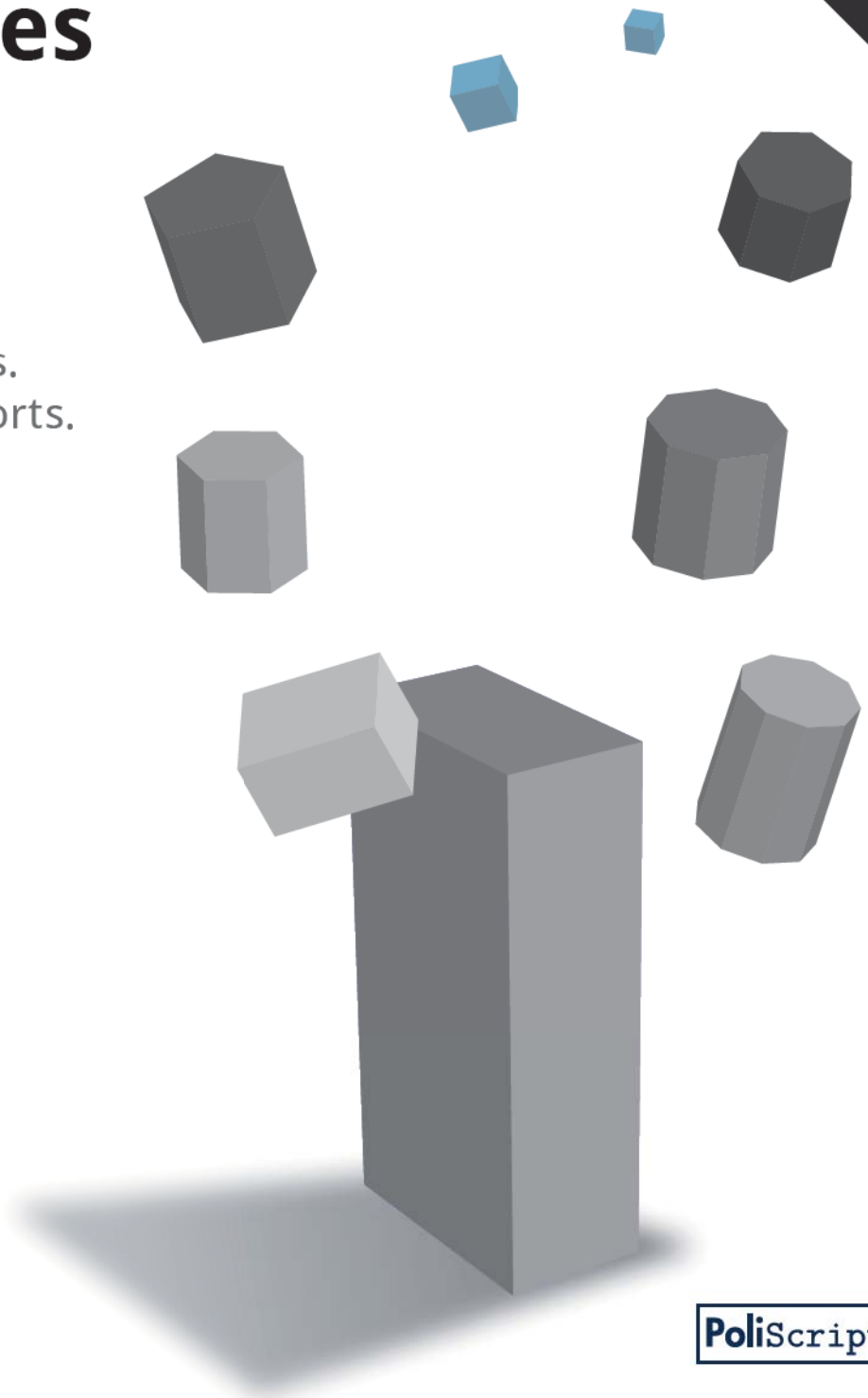

Edited by

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- We warmly thank the Tourist Information Office of Lecco Municipality for having provided the participants with information material regarding the Lecco area, a place which attracted for centuries national and international poets and artists. And
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Changing Needs, Adaptive Buildings, Smart Cities

Proceedings of the thirty-ninth World Congress
on Housing Science, 39 IAHS.

Politecnico di Milano, Italy
September 17 - September 20, 2013

Volume 2

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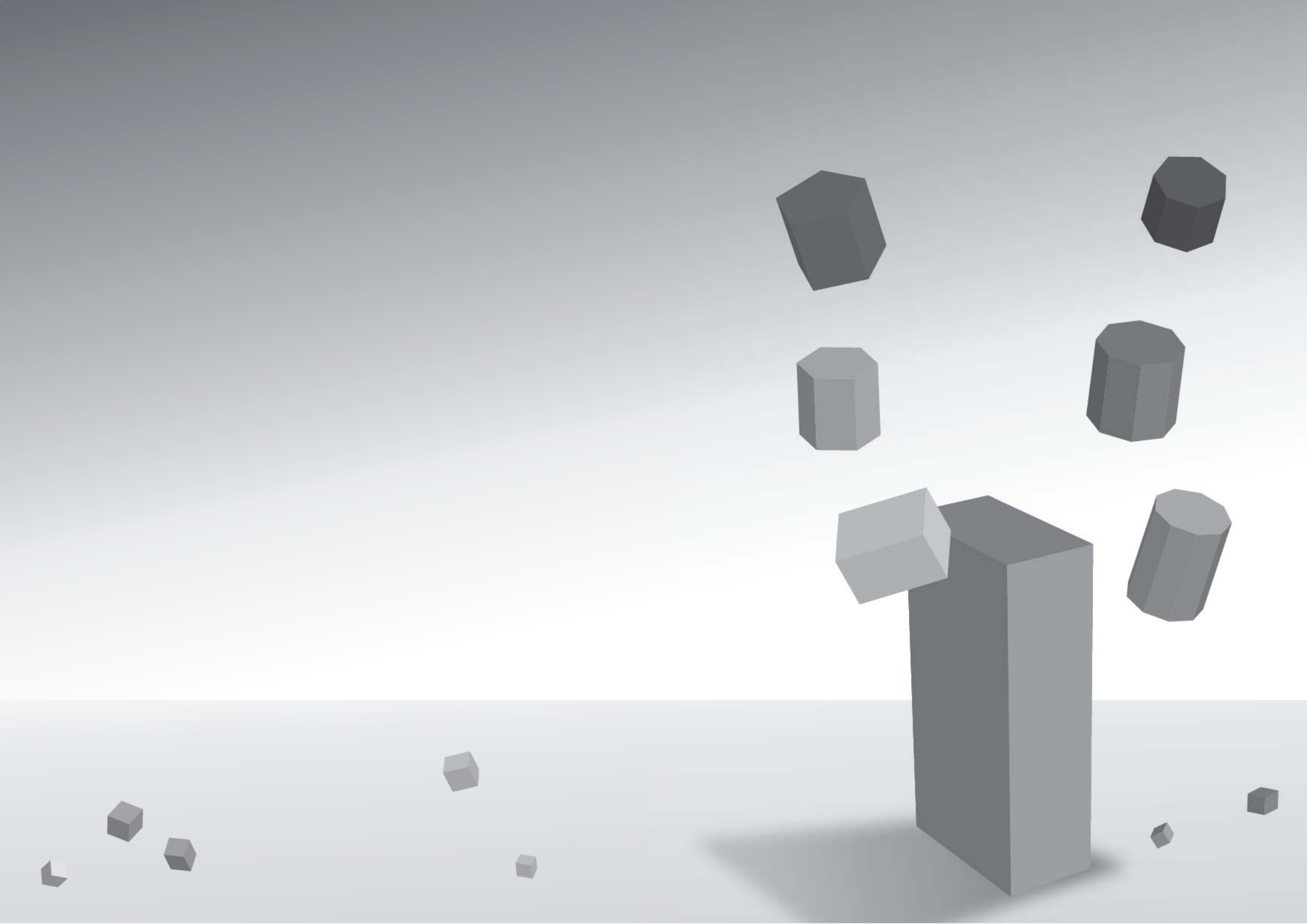

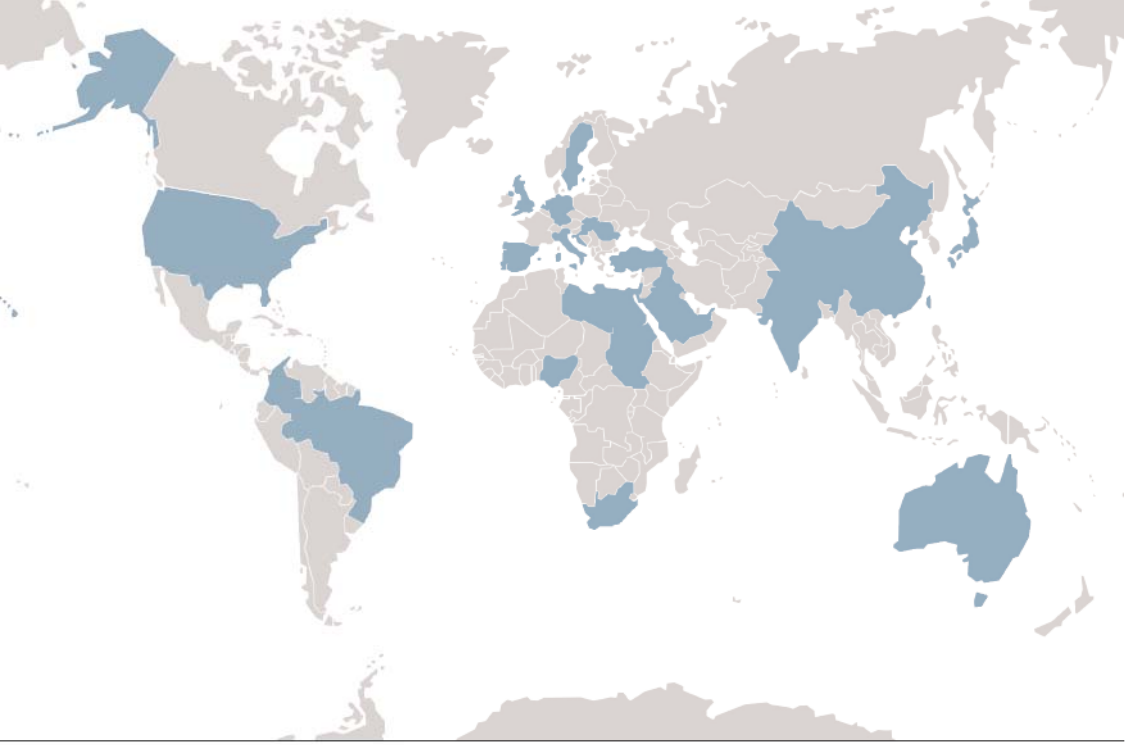

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- UK.
- USA.

FOREWORD

The Proceedings of 'The 39th IAHS World Congress: Changing Needs; Adaptive Buildings; Smart Cities' will introduce abundant innovative ideas with participants from many corners of the world. Against the backdrop of Milan, Italy, this Congress will present a great challenge to all of us: to evaluate our present knowledge and arrive at a new platform where new and innovative concepts are introduced.
Housing Science, inherently has a dynamic nature. Innovative change in housing, against a background of economic and technological changes, is inseparable from its existence and applications. The title of the congress reflects this fact as it emphasizes the multi-disciplinary topics that have an impact on issues of Housing Science. More than two hundred manuscripts will analyse and study special issues with respect to planning, sustainability, technology, refurbishments, durability and policies. Their impact will be present in every technical session of the congress, culminating in integrated recommendations for future adaptive buildings and smart cities.
We must realize that the future of our world will depend on how we can plan and manage the potential of the world's urban centres. We project that the megacities will support over six billion people by the year 2050. This fact will translate into complicated social and economic activities. The societal quality of life will depend on how well we will direct the renewable energy resources for consumption all the while ensuring to protect the environment. The planning and construction of the intelligent buildings will create the smart cities with their complicated infrastructures, the level and success of which will define the boundaries of the quality of life. The success of the smart cities will depend on economics, mobility, environment, culture, and governance to be sustainable.
We are honoured to be the guests of an outstanding European institution of higher learning: Politecnico di Milano – Department of Architecture, Built environment and Construction engineering (ABC).
The City of Milan is one of the most historic and cultural cities of Europe. The congress participants, from numerous countries across the globe, will discover the combined values of history, culture and hospitality of Northern Italy. This will prove to be a memorable experience for each congress participant.
Being in Milan, has another advantage, as the European Union (EU) is involved in multiple studies on strategies for smart cities and innovations to enhance the lives of their citizens. The key to success is to get populations involved in open innovative processes. The EU also initiated a project on energy efficient cities, Planning for Energy Efficient Cities (PLEEC), predicting difficulties in future energy provisions. There are, as cited, major tasks facing our world. We have to rise to the challenge and reach successful results.
International Association for Housing Science, IAHS, is a non-profit scientific world organization. It was founded at the University of Missouri – USA in 1972. It is enjoying forty-one years of global activities. This year, the Milan World Congress is the 39th successful global event. The Proceedings of all previous congresses are available on the webpage: <www.housingscience.org>.
IAHS would like to recognize and express our appreciation to the Politecnico di Milano, and especially to Professor Emilio Pizzi, his colleagues and his extended team who made this a successful global event.
We welcome you, each of you, to the 39th IAHS Congress and to Milan. We wish you an enjoyable stay, hoping you will return to your institutions not only with an abundance of new knowledge but also with an abundance of new friends.

Regards to all.

Oktay URAL
Professor Emeritus, The International Association for Housing Science (IAHS), President, Miami, USA.
39th International Association for Housing Science (IAHS) World Congress Honorary Chairman.

Emilio PIZZI
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39th International Association for Housing Science (IAHS) World Congress Executive Scientific Responsible.

PREFACE

The job of finalising the scientific programme of the Congress, given the number of papers submitted, intensely involved members of the international and local scientific committee who collaborated in the blind review.

It is therefore first of all necessary to express our warm thanks to the Reviewers who played a significant part in the scientific success of the Congress.

Thanks also go to the Authors who were subjected to the 'harassment' of the Reviewers: something not frequent in Congresses but normal practice in the most important international scientific circles.

As it was not possible, given the number of papers, to allow all Authors to make an oral presentation, the selection was based on the assessments of members of the National and International Scientific Committee, giving precedence to conclusive research results.

The other papers accepted by the Scientific Committee, of equal interest, were placed in a special and important review session to give all Authors appropriate and important visibility.

The Proceedings were therefore published in two Volumes.

In the first Volume, which includes papers admitted for oral presentation, are papers pertaining to the results of completed research and the documentation of specific and different issues related to the social and cultural specificities of the many countries present at the congress.

In the second Volume, which includes papers admitted to the review session, are papers concerning practical analyses, preliminary studies, product reviews, project presentations and state-of-the-art reports.

The third Volume, entitled 'Nothing is Permanent', includes, with attractive graphics, iconic reflections of Peter Schmid in partial collaboration with Gabriella Pál-Schmid with reference to each of the numerous IAHS Congresses in which he has participated. This is a kind and precious gift of Professor Schmid to participants of this Congress, to whom we express our sincere gratitude.

In editing the papers and preparing them for inclusion in the Proceedings, every effort was made to produce a faithful reflection of the Authors' contributions based on their revised manuscripts.

In preparing the Volumes, particular attention was also paid to the publishing graphic aspects.

Another activity subject to particular attention, due to the fact that Authors of English mother tongue were by far the minority of those present, concerns the opportunity to request a limited linguistic review and for this we apologise to the Authors.

Publication of the Proceedings was made possible by the much-appreciated contribution of the Authors, but also by the behind-the-scenes effort of the Reviewers whose dedication and knowledge should be recognised and to whom we express our gratitude. The scientific level of this congress was the direct result of their respected opinions.

A salient and positive peculiarity of this Congress was the participation of Authors from as many as forty countries. It was therefore an important opportunity to meet that can only foster and broaden the possibilities of establishing scientific relations between the universities and research centres represented.

Reading the Proceedings, therefore, provides an interesting scenario on the global trends of research in the various scientific fields. And this also due to the fact that there are significant contributions for advancement in the various research fields.

One of the first interesting aspects we come across while reading the manuscripts is the infrequent use of the term 'sustainability' in the titles and throughout the text. This is in itself surprising as it may indicate a paucity of attention being paid to those problems concerning the correct evolution of urban planning, architecture and building design in terms of a more responsible attitude toward environmental issues and the life of future generations. Indeed, if we get to the heart of the matter, we cannot help but notice how raising awareness about sustainability has become a common – albeit unavowed – narrative, which has in turn become part and parcel of those rules governing the art of research in the industry, while tampering with any planning practices in the process.

The season of meaningless self-celebrations of sustainability, which may still be found in glossy architecture magazines, is seemingly over.
A second aspect to highlight is the congress topic dedicated to Urban and City Planning.
The World Health Organization of the UNDP highlights the fact that 40% of the world population currently lives in a city and that this percentage will rise to 60% in 2030.
In particular, the UNDP (United Nations Development Programme) anticipates that in 2015, in the countries with highest HDI (Human Development Index), the urban population will reach 78.5% of the entire population, with an annual increase of 1.7%.
There are many problems related to this global phenomenon. In particular, they require new approaches in growth, policies in order to control so-called Urban Sprawl and Ecological Footprint1.
In this regard, the issues that figure predominantly are those aimed to safeguard the urban heritage and the urban transformation, to rehabilitate and manage informal settlements as well as reclaim degraded and crime-ridden suburbs plagued by severe social hardship. Equally interesting are those projects/essays highlighting the virtuous changes that have been gradually applied to the urban structure in quite diverse environments.
Fewer measures, however, have been taken to curb urban build up in an effort to restrain urban sprawl. Similarly, little has been done to reduce overheating in urban environments as a result of the UHI (Urban Heat Island) phenomenon.
In particular, altering the conditions of thermal comfort in urban environments has significant social and health repercussions, which call for greater attention.
As can be seen, the topic of Building Design, as one would expect, has the highest number of contributions.
Of course many papers were focused on the topic of Nearly Zero Energy Buildings and recourse to renewable energy sources, also in relation to obligations imposed in this regard by the European Community. The topic of forecast modelling of the environmental conditions of buildings for the development of climate sensitive buildings, such as those that characterised the vernacular architecture of the past, appears to have been investigated less. New materials, technologies and the availability of sophisticated simulation models in fact already allow for highly innovative design approaches with respect to the current architectural and technological scenario.
Another aspect investigated in detail, in papers characterised by an in-depth engineering approach, concerns seismic events, the corresponding risk analyses, measures to counter the effects and evacuation and reconstruction interventions.
Much attention was also placed on a topic currently scarcely studied such as that of housing configuration typology, where approaches related to the specific culture and different socio-economic situations are compared in a very different way.
Examining the interventions, also the broad topic of Refurbishment-Rehabilitation-Restoration has a large number of papers that develop historical insights, decision support methodologies and application examples, many of which are again related to energy issues.
Some of these use the analysis of technological and architectural models that characterise certain areas (geo-cluster characterization) for the development of large-scale refurbishment strategies. Others concern analyses oriented towards recognition of the thermal behaviour of buildings, necessary to define the interventions.
Naturally, many papers focus on intervention techniques also via experimental approaches typical of restoration
In third place is the topic of Innovation-Building technology-Construction.
Many are the papers dealing with new materials and systems such as solar screens, vacuum insulation, phase transition materials, photovoltaic panels, glass, textile structure, reflective layers and recycled materials.

The energy sector naturally attracts most interest.
On the construction industry front on which the topic is developed, papers range from the presentation of quality control methodologies, risk analyses, technological optimisation systems and new experimental methods for material behaviour analysis.
Facility management, building condition assessment, construction supply chain, adaptive and predictive analysis, environmental assessment and waste in construction are some of the other topics addressed
Congress topics dedicated to Legal, Economic and Financial Policies and Building Life Cycle on the other hand had fewer interventions than the other topics, but all still very up-to-date and interesting.
Regarding the issue of Building Life cycle papers are concentrated in particular on methodological aspects related to risk assessment, service life prediction and maintenance.
In conclusion, as a whole the papers present a variegated and selected panorama of approaches, methods, techniques, tools, systems and technologies aimed at improving knowledge of the topics investigated. Certainly their reading will allow a better understanding of the problems that characterize the urban and architecture sector in the various countries and of the issues on which to focus the development of positive collaboration and interaction between the members of such a vast, multicultural and interesting scientific forum.

Witness by my hand.

Professor Sergio CROCE
Professor of Constructive Technologies, Faculty of Civil Architecture, Politecnico di Milano, Milan, Italy.
39th International Association for Housing Science (IAHS) World Congress Executive Scientific Responsible.

Endnotes
The Ecological Footprint measures the amount of biologically productive land and sea area an individual, a region, all of humanity, or a human activity requires to produce the resources it consumes and absorb the waste it generates, and compares this measurement to how much land and sea area is available.
More information: <http://www.footprintnetwork.org/en/index.php/GFN/>.

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ENERGY EFFICIENCY IMPROVEMENT AND SUITABILITY INTERVENTIONS ON VERNACULAR GEOCLUSTER (BASILICATA)

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Abstract

In order to reduce the environmental impact of human activities, the refurbishment of built heritage and the reduction of the total energy consumption are the two main ways towards a balanced living between man and nature. The research integrates knowledge of past architectural technologies with new planning methodologies, new calculation instruments and current materials and technologies. In Basilicata (a little area in the southern part of Italy), historical heritage was investigated and catalogued in order to define its peculiarity and to assure the building preservation and functional re-utilizing. The aim of the multidisciplinary research team is to identify the elements that characterize the local 'Geocluster', from the widespread 'minor construction' to urbanized historical ones, by identifying critical issues and/or opportunities to realize an intervention hypothesis of spatial and functional recovery and of energy requalification. The sample areas (Matera, Montescaglioso, Calvello, Missanello) are identified as representative of widespread and homogenous case studies. They are characterized, according to times and social forms, by different building typologies, materials availability (tufa – calcarenite sandstone –, stone and earth), the necessities due to various climates inside the same region and aesthetic-functional solutions according to the local technical-building knowledge. In this way, it is possible to reinterpret traditional Mediterranean architecture creating guidelines for the energy recovery. The aim will be the characterization of the energy efficiency improvement and of the historical-material suitability in the technological recovery processes of built heritage. Basilicata possesses a variety of building typologies which make this study an assessment model which can be reproduced and spread in every area where similar climates and 'Mediterranean' features can be found. For this reason our research aims to promote policies in favour of the efficient use of energy and environmental safeguard, utilizing technological innovations in the building sector that are consistent to the sustainable development.

1. Introduction

The idea of the energy efficiency of buildings has assumed great importance in recent years and has produced, first in Europe, then in Italy, new rules, which are still evolving. The European Directive 2002/91/EC highlights the strategic role of buildings' energy efficiency to achieve the standards to reduce CO_2 emissions, set by the Kyoto Protocol. As is known, in Europe the built heritage is responsible for more than 40% of its final energy consumption, where residential use represents 63% of the construction industry. In Italy, about 65% of the residential built heritage is constituted by buildings built before the Seventies; this heritage was built in the absence of any 'attention' to energy aspects [1] (in fact, the law 30/04/1976 n. 373 was issued in 1976, later replaced by Law 10/1991, which regulated for many years the reduction of energy consumption). It has been shown that each of these buildings consume about five times more than a building built according to current standards and ten times more than a passive house : its energy requirement was estimated on average as 200-250 kWh/m^{2}year. The research aims to investigate the possible solutions that energy recovery can give to the residential built heritage and/or of the widespread 'minor constructions' in masonry, without jeopardising the cultural, architectural, technical and technological values of that built heritage [2].

2. Research Aim and Methodology

It has analysed the areas marked by a strong similarity (in terms of climate, geographical context, culture, construction types, economic and energy politics, etc), called 'Geocluster', and it has identified the most common typology of 'energy behaviour' , that includes the analysis of achieved energy consumption.
These processes are possible through monitoring in situ (that depend on the geographical parameters, geometrical and spatial distribution, functional and urban context). So it is possible to determine, within the identified area, the representative case studies.
In a second phase of data collection, two actions, whose results are merged into a database, were carried out site by site. At first, methods and technology solutions for improving the energy performance were selected. These solutions must be suitable to the identified Geocluster and respectful of the requirements of 'environmental sustainability'. Afterwards, it analysed the identified case studies by appropriate simulations, using calculation methods in dynamic conditions.
Finally, it was possible to associate one or more technology solutions and/or equipment to a specific architectural building typology in order to reduce the energy deficit.

3. Characterization of a Geocluster

The Geocluster identification (Figure 1) includes all building aggregates characterized by masonry built in stone, tufa (calcarenite sandstone), raw-clay or excavated into the natural geological formations [3]. Buildings were realized simply by the addition of single living cells or following 'eroded' natural formations. So the envelope is obtained directly from natural reef or from materials available on the site, according to traditional techniques and technologies [4].
This research starts from the knowledge gained, from works previously carried out on the

Figure 1. Geocluster identification.

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built heritage, historical researches regarding materials and typological characteristic of built heritage, interviews with the people who, in many cases, built these buildings and the monitoring of indoor comfort [5].
Moreover, some case studies were implemented in order to define the possible intervention methodologies for the energy improvement of built heritage and to obtain, experimentally, the thermo physical properties (thermal conductivity, capacity and diffusivity) of materials (local calcarenite sandstone) and of masonry [6]. We can also estimate the behaviour of buildings, both in winter and in summer, through the use of software Energy Plus [7] for the simulations in dynamic conditions and Termolog or MC4 for the simulations in stationary conditions.

4. Geoclusters Studied

It has tried to identify different case studies such as excavated buildings and built ones, made from blocks of calcarenite sandstone, stone with different levels of processing, brick, adobe.
In this sense, the sample areas are in Matera, Montescaglioso, Calvello and Missanello and on these it has hypothesized two types of actions to increase energy efficiency:

- 'Passive': by modifying the characteristics of the envelope and then the energy performance with the only additional installation of materials or technologies (for example by increasing the thermal insulation with aerogel panels, windows with wooden frames, double or triple low emissivity glass and gaps filled with noble gas).
- 'Active': by inserting appropriate thermal systems (innovative systems with high efficiency as condensing boilers (only for heating), reversible heat pumps without outdoor unit or of geothermic typology (for heating and cooling), photovoltaic panels - such as tile or of thin film typology, mini wind turbine of the latest generation).

4.1. Matera

The Matera geocluster, a UNESCO world heritage site since 1993, covers an area of approximately 390 km² situated at 45 km from the sea and 401 m above sea level with a population of about 60,000 inhabitants. The territory of the Matera Murgia is characterized by a very flexible rock, the calcarenite sandstone of the Pleistocene, subject to karst phenomena, which rests on a more compact substrate of Pliocene limestone [8].
The strong presence of caves has allowed the development of a rupestrian civilization.
The geocluster corresponding to the ancient Sassi was in turn divided into four types:

- Excavated architectures: cellars, houses and neighborhoods excavated entirely in limestone sandstone.
- Built-architectures: architectural organisms constructed with blocks of calcarenite sandstone.
- Mixed architectures (excavated and built).
- Noble palaces: buildings of historical, artistic and technological quality that have excavated and built parts.

The analysis (20 case studies and 5 illustrative cases) shows that the irregular spaces excavated in the calcarenitic rock, differ greatly from the built architectures with the use, however, of the same material. They are composed of barrel vaulted spaces, called 'lamioni' [9], built on foundations excavated in the rock, and double facing walls with a core often consisting of waste materials.

The energy study (Figure 2) determined that the calcarenite of Matera has the following characteristics: surface mass of 825 kg/m², conductivity of 0.72 W/mK and specific heat of 1.1 kJ/kgK. Due to the great thickness of the excavated buildings it seems possible to assign an energy class D to them, if we analysed them with the stationary calculation method and an energy class C when they were studied under dynamic calculations. However, these results are indicative because the uncertainty of the calculation in the excavated environments is not negligible, also because of the impossibility to know exactly the thicknesses of the ground surrounding the environments [10].
The built architectures characterized by thicknesses ranging from 30 cm up to 100 cm, are included in the energy class G and they do not show appreciable differences in the two ways of calculation. Therefore, we can deduce that excavated environments can reach a sufficient comfort level with the use of normal heating systems. The greatest problem is the humidity that affects their habitability and, to a lesser extent, interests the built architectures.
In this context, the results are obviously very different depending on excavated or built units: in the MT1 case, 45% excavated, it is not possible to install insulation. So there is a very small improvement in its energy parameters related to the insertion of a better window; in the MT30 case, almost 100% excavated and without insulation, the temperature never reaches a value greater than 23°C with an energy requirement for the cooling of the envelope Qc/Su equal to 0 kWh/m². The value of the useful energy demand for the heating of the envelope Qh/Su is low, equal to 64 kWh/m², although it is important to repeat that these values are rather uncertain because there is not a precise thermal transmittance in similar cases. The use of the heat pump causes a 28 % reduction of primary energy Epi needs in winter. In the built cases in which it is possible to install the insulation the improvement amounts to 30% in winter conditions, while the use of a heat pump allows a 52% reduction of Epi.

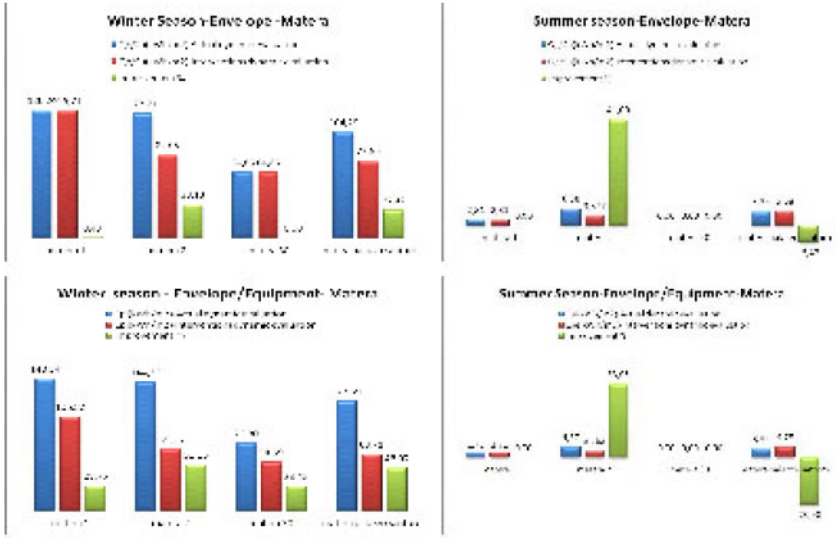

Figure 2. Energy evaluation (Matera).

4.2. Montescaglioso

Montescaglioso is a town in the province of Matera, which is part of the Bradanica Graben.

It is located about 30 km from the sea, at an altitude of about 350 m above sea level, and is part of the climate zone D. It presents a purely clayey and sandy soil with an irregular morphology and marked changes in elevation. The current name, in fact, derives from the substantive 'monte' (mountain) with the adjective 'scaglioso', i.e. 'raw', 'rough', in reference to the morphological characteristics mentioned above.
The historic centre under analysis is built entirely in sandstone calcarenite. It is located in the highest part of the city, has an irregular morphology and includes in it the presence of most of the house types of Basilicata.
We have identified a total of 8 case studied, of which those most representative from the energy point of view were analysed in detail.
Typological studies reveal that the covers are mostly vaulted and completed outside with flat interlocking tiles and are neither isolated nor ventilated. Foundations are continuous masonry. Eventual vertical connections are made with masonry staircases. The structures in elevation, in calcarenite bearing masonry, have very variable thicknesses and can reach up to 70-80 cm. The surfaces are either in plaster or whitewashed with light colours and the windows are made of wood.
From the energy point of view, taking account of the surface mass (825 kg/m^2), conductivity (0.77 W/mK) and the specific heat (0.89 kJ/kgK), all cases studied are in Class G. In this context, the improvement of Qh/Su due to the laying of a good insulation on the external vertical closures is 20%, while the adoption of the heat pump in the summer months results in a 40% improvement of Epi.

4.3. Missanello

The geomorphology of eastern Basilicata has allowed the construction of raw earth buildings, located near the river beds and at altitudes between 200 and 600 meters above sea level in the towns of Accettura, Aliano, Chiaromonte, Ferrandina, Missanello, Roccanova, Sant'Arcangelo and Senise. The segmentation and geoclustering operation made it possible to group the homogeneous entities, that are similar to each other or close to each other, and the town of Missanello was defined as an example.
The small agricultural centre in the province of Potenza is situated in the valley of the Agri River, at an altitude of 650 meters and has a hilly territory. Modest buildings in raw earth are located in very peripheral zones of the town, were completely abandoned in the second half of the last century, or used as shelters and storage areas. The construction technique of the area, which is currently disused, consisted in the construction of brick walls of compressed earth formed by hand into moulds. The raw bricks of a parallelepiped shape and size variables, commonly called 'ciucioli', are staggered and spliced together with a mixture more fluid than that used for the formation of the same brick. They form walls with a maximum thickness of 40 cm approximately. In some cases, moreover, there was an external protection made by blocks of brick put in place with lime and arranged so as to form a thin wall of variable thickness from 6 to 15 cm.
The main building types observed coincide with the isolated single unit, in adobe and stone, which had, over time, an enlargement through a progressive repetition of the minimal cell space (square room of about 4-5 m wide), juxtaposed or superimposed.
From energy simulation we deduce that the useful winter need Qh/Su, with the application of insulation along the walls, is reduced by 35% and that the Epi is reduced by 52%.

4.4. Calvello

The Town of Calvello, located in the province of Potenza, was chosen as a representative

example of historical centres made of masonry (local limestone) and arranged in radial directions during the early Middle Ages.
After having analysed and reported in detail seven case studies from different historical periods, we proceeded to estimate the building performance, through dynamic simulation software, useful for the energy qualification and certification, of four cases:

- Aligned multi-level house with basement.
- Isolated house on three levels (business, post office).
- Isolated house on two levels with basement.
- Aligned house on two floors with two basement levels.

In winter conditions, the application of appropriate thermal insulation and the replacement of shutters and windows allows the reduction of energy requirements of about 40%, with variations in the order of 1% depending on whether the insulation is applied inside or outside. In the latter case, however, thermal bridges and therefore problems of condensation and moisture are more easily avoided. In summer conditions it is necessary, however, to resort to plant solutions strongly integrated into the shape of the building to increase the energy efficiency. For example, the adoption of a heat pump, also with a nominal COP of only 2.64, reduces the primary energy requirement Epi by approximately 60% compared to the case without insulation and with traditional boiler.

5. Conclusion

The results in the summer time are obtainable only through an analysis carried out in dynamic conditions, because of the high thermal mass of the building envelope. They show that the internal temperature of this Geocluster very rarely exceeds the value of the set-point of 26°C in summer, making the cooling unnecessary or minimal in the energy management of these buildings.
While, in the winter, it is to be noted that the deviation between the results obtained in stationary and dynamic conditions, in the assessment of energy demand, is often greatly reduced; this reduction, in fact, allows the use of the stationary methods in some situations.
In quantitative terms, using the above passive interventions, the reduction of envelope energy demand (kWh/m^2) ranges between 20% and 40%. The use of heat pump, instead, implies a reduction of energy requirements in terms of primary energy from 40% to 60%. In excavated dwellings, where it is not possible to install the insulation due to the high surface irregularities, the only way to reduce consumption is to intervene using active solutions, but it the problem of managing the moisture content of the air remains.
Other data which must be taken into account in the simulation with Energy Plus (hypothesis of one-dimensional flow) is the evaluation of thermal bridges characterized by a bidimensional or tridimensional flow. In cases where the walls have planar surfaces, it has been possible to consider opportune fictitious surfaces and to verify that, in winter, the envelope energy requirements of buildings in Calvello and Missanello increase on average by 2.7%, while in summer they increase on average by 4.1%. Obviously, the comparative analysis between the obtained results were carried out in the absence of thermal bridges, because it is not possible to take them into account in excavated cases and given its small incidence.
In conclusion, the evaluated intervention strategies are extended to all the circumstances possible, but limited to only those elements considered in the analysed cases: building envelope, windows, heating systems (combined or not with natural ventilation) and integrated systems between them. Following the study of the different solutions, related to the specific characteristics of each case study, finally it was possible to:

- Define a handbook of 'best practices' for each technical and technological ty-

pology found in a Geocluster that are repeatable in similar situations with similar climate and 'Mediterranean' constructional characteristics. It was able to suggest, for each case, a possible solution, while ensuring the preservation of the intrinsic characteristics of historic built heritage and allowing an energy improvement. This makes it competitive and allows a substantial reduction of CO_2 emissions in the life cycle of the product.

- Assess the environmental impact of the proposed works through the analysis of the life cycle assessment (LCA) of the elements.
- Consider a practical experimentation applied to buildings in raw clay (but expendable for all interventions) to verify the technical and regulations' feasibility of a thermal insulation panel, realized in an 'ancient' material but used in a 'modern' way. In the future, it will be possible, using a 'Hot box', that we are currently developing, to measure the thermo physical characteristics of the opaque and transparent walls.

The results are finalized to verify energy performance in order to support the technician in the adaptation or improvement of built heritage, where often the values imposed by the rules are not always obtainable.

Endnotes

[1] The term 'Geocluster' indicates an area marked by a strong architectural and/or typological similarity

[2] In Italy, the residential built heritage is composed of about 26,5 million dwellings, where 9 million consist of one/two houses. About 17,5 million of these dwellings were built before the Seventies.

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