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2022

RESIDENTIAL BUILDING DESIGN & CONSTRUCTION CONFERENCE PROCEEDINGS

MAY 11–12, 2022

UNIVERSITY PARK, PENNSYLVANIA, USA

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UNIVERSITY PARK, PENNSYLVANIA, USA

Edited by
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PREFACE

While home builders are continuously challenged to consider various criteria such as affordability, energy efficiency, sustainability, serviceability, aesthetic, utility, and resistance to natural hazards among others, there are varying degrees of adherence to such objectives. The more efforts are made for technology transfer and providing the residential construction industry with the latest advancements in construction materials, tools, methods, and code requirements, the more receptive will be the mainstream builders to incorporation of technological advancements. As always, the Pennsylvania Housing Research Center (PHRC) at The Pennsylvania State University considers knowledge sharing and dissemination of the results of recent advancements in the field as one of its primary responsibilities and is pleased to continue organizing the Residential Building Design and Construction Conference series to serve the housing and residential construction industry for this purpose.

It is with great pleasure that we share the proceedings of the 2022 Residential Building Design and Construction Conference, which was held virtually on May 11–12, 2022. As in the past five RBDC Conferences, this sixth conference provided an opportunity for researchers, design professionals, manufacturers, builders, and code officials to exchange the latest advancements in research and practice and to discuss and share their own findings, innovations, and projects related to residential buildings.

The 2022 RBDC Conference hosted 85 attendees and included 61 papers, 60 presentations, and 10 posters on various issues related to residential buildings, which encompass single- and multi-family dwellings, mid-rise and high-rise structures, factory-built housing, dormitories, and hotels/motels. Papers and presentations related to the following areas and topics were invited in the conference call:

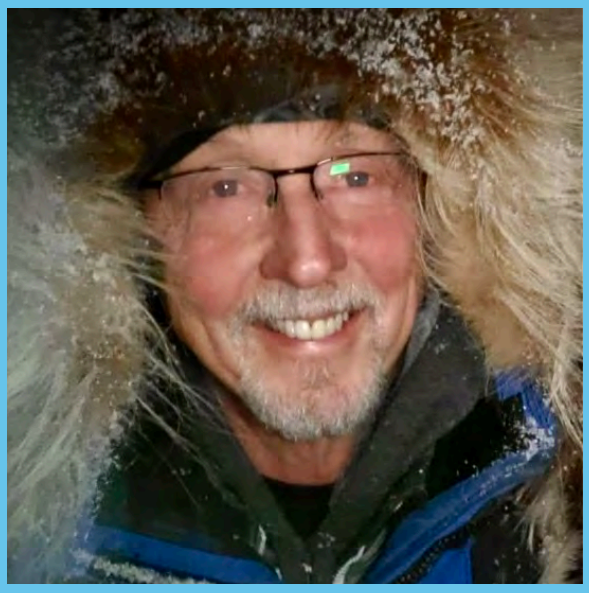
- Aging-in-Place and Senior Living Housing
- Alternative Renewable Energy Generating Systems
- Building Information Modeling (BIM) Application in Residential Construction
- Building Integrated Photovoltaic Systems
- Building Performance Assessment/Metrics/Verification Methods and Occupant Behavior
- Building Science and Building Enclosures
- Education of Residential Design & Construction
- Energy Efficient Building Components
- Fire Damage and Protection
- High-Performance Residential Buildings
- Indoor Air Quality
- Innovations in Green Roofs and Façade/Envelope Systems
- Innovations in Residential Architecture and Design
- Innovations in Modular and Manufactured Housing
- Innovative and Emerging Housing Construction Methods/Systems
- Innovative Wall, Floor, Roof, Window, and Siding Systems
- Learning from the Performance of Residential Buildings under Natural Disasters
- Low-Income and Affordable Housing
- Net Zero Energy Homes
- Panelized Building Components
- Passive House Design Approach
- Resilient New Design and Retrofit of Existing Buildings under Natural Disasters
- Retrofit of Existing Buildings for Energy Efficiency
- Rural Housing Materials and Construction
- Serviceability and Life Safety Damage Aspects
- Smart Home Technologies, Design, and Construction
- Sustainable Housing Construction Materials and Methods
- Temporary Housing for Disaster Situations
- Whole Building Design Approach

As the Table of Contents of these proceedings show, many of the above areas were among the papers and presentations at the conference. There was considerable interest in topics including building envelope, building in Alaska, building science education, disaster resilience, hemp, high-performance housing, innovative and affordable housing, mass timber and CLT, mechanical and lighting systems, occupant behavior, retrofits, and tools for homebuilders.

Two keynote speakers were invited for the conference: Wil V. Srubar III, Ph.D., associate professor at the University of Colorado Boulder and founder and managing director of Aureus Earth, Inc. and Rusty Smith, associate director of the Rural Studio at Auburn University's School of Architecture, Planning, & Landscape Architecture. Srubar discussed his presentation titled "Transforming Buildings into Carbon Sinks." Smith shared his presentation titled "Rural Studio: What Does Affordable, High-Performance Housing Truly Afford?" The conference also hosted a closing plenary session by Jack Hébert, founder of the Cold Climate Housing Research Center and senior research advisor at the National Renewable Energy Laboratory, entitled "Indigenous Wisdom and 21st Century Technologies: An Arctic Approach to Building Science."

We wish to thank the members of the International Scientific Committee of the conference for their contributions in promoting the conference. The support of the PHRC staff for logistics is gratefully acknowledged. Special thanks go to Rachel Fawcett for her contribution as the Conference Coordinator.

Proceedings Editors:
Ali M. Memari and Sarah Klinetob Lowe
May 2022



CONFERENCE SCHEDULE

WEDNESDAY, MAY 11

8:15am ET - 9:30am ET

Keynote: **Dr. Wil V. Srubar, III | Associate Professor, University of Colorado Boulder**
Title: **Transforming Buildings Into Carbon Sinks**
Opening Remarks by Dr. Ali Memari & Sarah Klinetob Lowe

9:45am ET - 10:15am ET — **Virtual Networking Session**

10:30am ET - 12:00pm ET — **Conference Sessions A**

	Innovative & Affordable Housing	Building Envelope		Building Science Education
10:30-11:00	**High-performing technologies for contemporary residential Rural buildings in the Pianura Padana territory** *Silvia Brunoro (University of Ferrara)*	**Multi-chamber Standardized Testing of Air-permeable Cladding Materials** *Oscar Lafontaine & David O. Prevatt (University of Florida)*		**Introductions, Overview, and Where Are We Now?** *Georg Reichard (Virginia Tech), Pat Huelman (University of Minnesota), & Sam Taylor (Energy & Resource Efficiency)*
11:00-11:30	**Catenary domes for housing: benefits and challenges** *Ryan Bradley (University of Witwatersrand)*	**Performance of OSB and SFS Shear Walls in Residential Building** *Shideh Shadravan (University of Oklahoma), Behnam Shadravan (Florida A&M University), & Chris Ramseyer (University of Oklahoma)*		
11:30-12:00	**THE USE OF ARTIFICIAL INTELLIGENCE TECHNIQUES FOR PREDICTING COMPRESSIVE STRENGTH FOR HIGH PERFORMANCE CONCRETE: A REVIEW** *Refilwe Lediga & Jefferey Mahachi (University of Johannesburg)*	**An Innovative, High-performance Shell Structure for Residential Construction: The SPS System** *Rolf Jacobson; Dan Handeen; Pat Huelman; Garrett Mosiman; Tom Schirber*		**Beyond Boundaries: Education to Advance the Transformation of the Architecture, Engineering, Construction, and Operations Industry** *Jonathan Bean (University of Arizona) & Sarah Truitt (NREL)*

12:00pm ET -12:30pm ET — **LUNCH BREAK**

12:30pm ET - 2:00pm ET — **Conference Sessions B**

	Disaster Resilient Housing	Mechanical & Lighting	Mass Timber & CLT	Building Science Education
12:30-1:00	**Observations and Analysis of wind pressures on roof overhangs and underneath walls of a low-rise building** *Karim Mostafa (Florida International University), Ioannis Zisis (Florida International University), & Ted Stathopoulous (Concordia University)*	**Balance Points are Changing – and That's Just Sensible!** *Pat Huelman (University of Minnesota)*	**Parametric Evaluation of Embodied Carbon within Design for Hybrid Mass Timber Floor Systems** *Samantha Leonard, Ryan Solnosky, Nathan Brown, & Corey Gracie-Griffin (Penn State)*	**Resilience and Social Justice as a Framework for Architectural Education, Research and Practice – The Design+Build Kunga ADU** *Jörg Rügemer (University of Utah)*
1:00-1:30	**Analysis of Complex Flow Characteristics from Field and Simulated Hurricane Measurements** *Jianing Wang & Chelakara Subramanian (Florida Institute of Technology)*	**Development of Smart Watering Algorithm To Improve Biowall Performance** *William Hutzel (Purdue University)*	**Structural Design of a Cross-Laminated Timber (CLT) Single-Family Home** *Anthony Jellen (Jellen Engineering Services) & Ali Memari (Penn State)*	**Facilitating Real-World Project-Based Service-Learning Opportunities by Participating in Department of Energy Race to Zero and Solar Decathlon Competitions** *Jeremy Farner (Weber State University)*
1:30-2:00	**CASE STUDIES OF BUILDING RESILIENCE IN HURRICANES** *Behnam Shadravan (Florida A&M University) & Shideh Shadravan (Oklahoma University)*	**Machine learning based surrogate model for faster daylighting estimation in building design** *Naveen Kumar Muthumanickam (NREL), José Pinto Duarte (Penn State), & Tim Simpson (Penn State)*	**Moisture Vapor Buffering and Latent Heat Effects of CLT Insulated with Wood Fiber Insulation Assembly on Energy Saving** *Ling Li (University of Maine), Jake Snow (University of Maine), Maitham Alabbad (University of Maine), Samuel V. Glass (Forest Service FPL), Benjamin Herzog (University of Maine), & Stephen Shaler (University of Maine)*	**Continued Experiences with the Solar Decathlon Design Challenge** *Tom Collins (Ball State University)*

2:15pm ET - 2:45pm ET — **Poster Session**
See Next Tab

3:00pm ET - 4:30pm ET — **Conference Sessions C**

	Innovative & Affordable Housing	Occupant Behavior	Hemp	Building Science Education
3:00-3:30	**Frame House System: An Open-Source Housing Design and Construction System** *Puja Bhagat, Celina Deng, & Benay Gürsoy (Penn State)*	**Case Study: The Effect of Homeowner Behavior on Energy-Efficiency in a High-Performance Home** *Lindsey Beates (Beates Properties) & Jason Lucas (Clemson University)*	**Use of Industrial Hemp and Bamboo Fiber in Construction** *Dan Hindman, Tom Hammett, & Jonas Hauptman (Virginia Tech)*	**Picking Favorites - A Building Science Education Showcase/Showdown Panel** *Georg Reichard (Virginia Tech), Jonathan Bean (University of Arizona), David Fannon (Northeastern), Walter Grondzik (Ball State University), Bruce Haglund (University of Idaho), Pat Huelman (University of Minnesota), Ulrike Passe (Iowa State University), & Brian Wolfgang (Penn State)*
3:30-4:00	**How to Make Zero Energy Ready Pencil Out at the Production Scale** *Eric Werling (US DOE), Kevin Brozyna (Insight Homes), & Theresa Gilbride (PNNL)*	**Impact of Occupant Characteristics on the Energy Performance of Multifamily Residential Building in the United States** *Debrudra Mitra, Yiyi Chu, & Kristen Cetin (Michigan State University)*	**Critical Review of the Characterization of Environmental and Mechanical Properties of Hemp Hurd and Hempcrete** *Hojae Yi, Corey Gracie-Griffin, & Ali Memari (Penn State)*	
4:00-4:30	**Discussion of Tiny Home Inclusion as a Concentric Diversification Strategy in Production Home Building to Address Housing Crisis** *Molly Smith, Wei Wu, Yupeng (Vivien) Luo, & Michele Randel (California State University, Fresno)*	**Development and validation of a post-occupancy evaluation model for LEED-certified residential projects** *Mohsen Goodarzi (Ball State University) & George H. Berghorn (Michigan State University)*	**Modeling of 3D printing Concrete based on Meshfree Explicit Galerkin Analysis Method** *Aleksandra Radlinska, Hanbin Cheng, Feihong Liu, & Michael Hillman (Penn State)*	

Thursday, May 12

8:15am ET - 9:30am ET

Keynote: **Rusty Smith | Associate Director, Rural Studio at Auburn University**
Title: **Rural Studio: What Does Affordable, High-Performance Housing Truly Afford?**
Opening Remarks by Dr. Ali Memari & Sarah Klinetob Lowe

9:45am ET - 10:15am ET — **Virtual Networking Session**

10:30am - 12:00pm ET — **Conference Sessions D**

	Innovative Housing	Retrofits	Tools for Homebuilders	Disaster Resilience
10:30-11:00	**A Multi-manufacturer Platform Approach to Modular Volumetric Construction – An Experiment in Cross-pollinating Design with Fabrication** *Carlo Carbone (Université du Québec à Montréal)*	**Application of refractive fluid flow imaging techniques for visualizing building exfiltration** *Philip Boudreaux, Emishaw Iffa, & Venkat Singanallur (ORNL)*	**Creating a Virtual Environment Data Collection Tool for Construction Safety** *Daniel Hindman, Leann Rhodes, Rafael Patrick, Alicia Johnson, & Todd Ogle (Virginia Tech)*	**Transdisciplinary Perspectives on Equitable, Sustainable, Resilient Housing: Panel Discussion & Moderated Q&A** *Stacey Connaughton (Purdue University), Mohamed Hilmi (InterAction) , George Foden (Loughborough University), & Esther Obonyo (Penn State)*
11:00-11:30	**Design Grammar of Scaffold-Free 3D Printed Shells** *Mahan Motamedi (ENSAPM, Laboratoire GSA), Shadi Nazarian (Penn State), Romain Mesnil (ENPC, Laboratoire NAVIER), Robin Oval (University of Cambridge), & Olivier Baverel (ENPC, Laboratoire NAVIER)*	**Drone-based scanning technology for characterizing the geometry and thermal conditions of building enclosure system for fast energy audit and design of retrofitting strategies** *Shayan Mirzabeigi (SUNY ESF), Parisa Eteghad (SUNY ESF), Mohamed Razkenari (SUNY ESF), Paul Crovella (SUNY ESF), & Jianshun Zhang (Syracuse University)*	**Likeliness to Recommend: A Mixed Methods Analysis of Consumer Perceptions of Home Builders** *Todd Usher & Jason Lucas (Clemson University)*	
11:30-12:00	**UTILIZING ARTIFICIAL INTELLIGENCE FOR DESIGNING CEMENT-BASED MATERIALS FOR 3D CONCRETE PRINTING APPLICATIONS** *Refilwe Lediga & Jefferey Mahachi (University of Johannesburg)*	**Energy Modeling to Determine Optimum Order of Component Installation in Stepwise Retrofit Towards EnerPHit Standard** *Sophia Welch, Esther Obonyo, & Ali Memari (Penn State)*		

12:00pm ET -12:30pm ET — **LUNCH BREAK**

12:30pm - 2:00pm — **Conference Sessions E**

	High Performance Housing	Retrofits	Building in Alaska	Disaster Resilience
12:30-1:00	**Site Net Zero Target Contemporegional Architecture – The Barn Haus in Utah** *Jörg Rügemer (University of Utah)*	**Comparing Affordable, Durable and Energy Efficient Wall Retrofit Systems** *Chrissi Antonopoulos (PNNL), Patti Gunderson (PNNL), Tyler Pilet (PNNL), Sumitrra Ganguli (PNNL), Jian Zhang (PNNL), Travis Ashley (PNNL), Pat Huelman (University of Minnesota), Antonio Aldykiewicz (ORNL), Garrett Mosiman (University of Minnesota), Harshil Nagda (PNNL), Cheryn Metzger (PNNL), Andre Desjarlais (ORNL), & Rolf Jacobson (University of Minnesota)*	**Design of homes for concrete printing in the permafrost regions of Alaska** *José Duarte, Gonçalo Duarte, Nathan Brown, Shadi Nazarian, & Ali Memari (Penn State)*	**Building for Energy Efficiency and Disaster Resistance: Complementary Goals, Most of the Time** *Edward Louie, Chrissi Antonopoulos, & Theresa Gilbride (PNNL)*
1:00-1:30	**The Intersection of Passive House and Affordability in Cold Climate Residential Construction** *Christopher Wingate (MSR Design) & Sean Sonnabend (AKF Group)*	**Hygrothermal simulation of exterior retrofits in a cold climate** *Antonio Aldykiewicz (ORNL), Andre Desjarlais (ORNL), Pat Huelman (University of Minnesota), & Garrett Mosiman (University of Minnesota)*	**Structural Evaluation of a proposed concrete 3D printed Habitat in remote Alaska** *Gonçalo Duarte, Ali Memari, Nathan Brown, José Duarte, & Zhengyu Wu (Penn State)*	**A parametric investigation of canopy heat islands mitigation strategies: A case study of a new residential development master plan of a U.S. north-eastern city** *Farzad Hashemi, Lisa D. Iulo, & Ute Poerschke (Penn State)*
1:30-2:00	**Reducing Interior Overheating of Residential Buildings by Passive Cooling Measures** *Michal Bartko, Abdelaziz Laouadi, & Michael Lacasse (National Research Council Canada)*	**Insitu Testing for PNNL/ORNL/UMN Deep Wall Insulation Upgrade Project** *Pat Huelman, Garrett Mosiman, Fatih Evren, & Rolf Jacobson (University of Minnesota)*	**A comparison of thermal insulation strategies for 3D printed concrete structures in cold regions** *Nathan Brown, Ali Memari, Ming Xiao, Zhengyu Wu, José Duarte, Shadi Nazarian, & Gonçalo Duarte (Penn State)*	**Small-Scale Testing of Air Barrier Systems Adhered on Sheathing Panels Under In-plane Relative Displacement Simulating Seismic Effect** *Karim Abdelwahab, Corey Gracie-Griffin, Ali Memari, & Lisa D. Iulo (Penn State)*

2:15pm - 2:45pm ET — **Roundtable Networking Session**

3:00pm - 4:30pm ET — **Conference Sessions F**

	Retrofits	Building in Alaska
3:00-3:30	**Siding Retrofits – Never a Better Time to Upgrade Wall Insulation and Windows** *Katherine Cort & Theresa Gilbride (PNNL)*	**Building Durability in Extreme, Changing Climates** *Zoe Kaufman, Robbin Garber-Slaght, Tanushree Charan, & Conor Dennehy (NREL)*
3:30-4:00	**Determining Energy Savings for Various High Performance Ventilated Attic (HPVA) Roof Retrofits** *Sam Meleika & Anthony Fontanini (NREL)*	**Addressing the Housing Infrastructure Challenges of Rural Alaska in a Changing Climate: Physical Characteristics of Residential Infrastructure** *Maria Millan (Michigan State University), Kristen Cetin (Michigan State University), Jessica Taylor (Iowa State University), & Cristina Poleacovschi (Iowa State University)*
4:00-4:30	**A Zero-carbon Bio-based Wall Panel as an Energy Retrofit Solution for Buildings** *Shaghayegh Kurzinski, Paul Crovella, Mohamad Razkenari, & William Smith (SUNY ESF)*	**Design, Construction, and Field Validation of a Blown-in Fiberglass Wall System in a Cold, Wet, and Windy Climate** *Vanessa Stevens, Robbin Garber-Slaght, Haley Nelson, Aaron Cooke, & Chan Charoonsophonsak (CCHRC - NREL)*

4:45pm ET - 6:00pm ET

Closing Plenary: **Jack Hébert| Founder - Cold Climate Housing Research Center (CCHRC)**
Title: **Indigenous Wisdom and 21st Century Technologies: An Arctic Approach to Building Science**
Closing Remarks by Dr. Ali Memari & Sarah Klinetob Lowe

POSTER SESSIONS

Multiple benefits through residential building energy retrofit and thermal resilient design *Shayan Mirzabeigi & Mohamad Razkenari (SUNY ESF)*	**Educating the Youth On Energy Literacy Through Virtual Reality** *Joseph James (Virginia Tech)*	**Practical Construction of 3D Printed Reinforced Concrete Members** *Zhengyu Wu & Ali Memari (Pen State)*	**Review of Mechanical and Structural Testing for 3D Printed Concrete** *Zhengyu Wu & Ali Memari (Penn State)*
Resilience in Modular Construction *Maryam Kouhirostami (University of Florida), Arezou Sadoughi (Appalachian State University), Mahtab Kouhirostami (University of Florida), & Robert Ries (University of Florida)*	**Use of Plastic Waste in Building Construction Industry** *Shahryar Habibi (University of Ferrara) & Ali Memari (Penn State)*	**Small-Scale Testing of Air Barrier Systems Adhered on Sheathing Panels Under In-plane Relative Displacement Simulating Seismic Effect** *Karim Abdelwahab, Corey Gracie-Griffin, Ali Memari and Lisa Iulo (Penn State)*	**Review of Structural Load Resisting Systems for Cross-Laminated Timber Multi-story Residential Buildings** *Nadia M. Mirzai and Ali Memari (Penn State)*
Literature review on triodetic foundation system for permafrost regions *Nima Aminpour and Ali Memari (Penn State)*	**3D Printing of Residential Houses by Adapting the Historical African Sustainable Housings** *Eden Binega and Ali Memari (Penn State)*		

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CONFERENCE SESSIONS B

PROCEEDINGS ONLY

Social Living. An experimental project of tall building in Bolzano (Italy)

Alessandro Gaiani[1]

[1]Assistant Professor, Department of Architecture, University of Ferrara, via Ghiara 36, Ferrara, Italy, 44121, alessandro.gaiani@unife.it

Abstract

Social housing has always been an important topic of research in Italy since the post-war period. Starting from the Fanfani plan to the recent laws on social housing, there has been a constant and uninterrupted research within the architectural project.
Each historical period has produced buildings in line with the thought of their time and has led to a variety of housing types that, however, have not always coincided with a high quality of life within the housing.
The current pandemic crisis has only sharpened the approach that architects have increasingly used since the eighties, aimed at a formal and not structural use of technology, leaving unchanged some typological principles of housing and rewriting only the formal aspect.
This approach implies a very precise thought of the project of social housing in which human activities were decomposed through a function and recomposed in monofunctional spaces, minimum, according to a "mechanistic" logic (spaces servants and served) to create housing.
The recent pandemic has shown how the functionally designed spaces of our homes do not allow a mixed use and a direct relationship between the external and internal environment.
The design of housing, specifically, is called (today more than ever) to translate the needs, an ecosystem of relationships between objects that refers to natural systems characterized by variability, diversity and redundancy, an interconnected structure and a capacity to "self-adapt".
The project of social housing in a tall building, proposed for the company that manages social housing in Bolzano (Italy), suggest a different design system related to the use of a sustainable construction system, (such as load-bearing wooden walls for an earthquake-proof building in height -10 floors-), to the definition of "adaptive" tools for the organization of a space no longer based on the modernist logic of function but on the hybrid use of space, to a different relationship "inside-outside" in the configuration of the spaces of housing, and to the creation of collective spaces dedicated to the inhabitants' community.

BACKGROUND

Modernism has left us a cumbersome inheritance regarding the architectural design of living based on the scientific method.
Developed by Descartes and used throughout the 20th century, the scientific method proposes a coherently logical decomposition, simplification and reduction, from the complex to the simple, – and it has also been used in architecture by some of the Masters of the Modern: Le Corbusier uses the principle of universal determinism with regard to the management that the form establishes with the architectural object in a relationship of continuity with the urban fabric and which allows the predictability of the future based on past events. Mies Van der Rohe employs the principle of disjunction, which disengages the work from the environmental context, so that the work itself it takes on the character of an object structuring the organization of a form, and which isolates and separates objects regardless of their mutual relations, their context, and their relationship with the knowing subject [1] (Guattari, 2013). Aldo Rossi uses the principle of reduction, which suggests interpreting the whole from the basic elements that constitute it, and therefore he builds his popular forms as if they were pieces of the wooden construction boxes used to play with.

Figure 1. Veduta dell'allestimento della mostra 'Modern Architecture: International Exhibition', MoMA, NY, 10 febbraio-23 Marzo 1932. New York, Museum of Modern Art (MoMA). The Museum of Modern Art Archivies, IN 15.1 © 2017. Immagine digitale, The Museum of Modern art, New York/Scala, Firenze

Such considerations have structured a widespread thought about the dwelling project in which human activities had been decomposed through a function and recomposed in monofunctional spaces, minimal, according to "mechanistic" logics (servant and served spaces) and the relationship with the external environment was less and less present.
However, most of the experiments conducted during the last century on housing (both social and non-social, with different declinations, from the 'minimal house' to the economic one for all social classes, from the experiments with prefabricated systems to the megaforms of living, from mobile homes to the social house or co-housing) have also affected other topics, with particular regard to the adaptations that technoscience has proposed, but they have not challenged the system of organization of space, except in some rare experiments.
Even in Italy, despite some praiseworthy initiatives on social housing that have occurred from the '50s to the '80s, see the Fanfani plan, the INA casa and some social housing districts designed by some great Italian designers (Adalberto Libera with Quartiere Tuscolano in Rome, Giancarlo De Carlo with Villaggio Matteotti in Urbino, Aldo Rossi with the Gallaratese, just to name a few wonderful examples), the housing project referred to the consolidated functional project of separation of spaces.
But we know how, since the beginning of the new century, the design of housing in general, and of the social one even more so, was no longer able to meet the needs of relationships within the complex family units, which, thanks to the rapid spread of digital technology and the massive influx of immigrants, carriers of other cultures, no longer refer to known models and require much more freedom and speed of change.

The most current experiences have "*taken refuge in a formal and non-structural use of technology that keeps unchanged the typological hardware of the house, rewriting only the software in an attractive fashion graphics*"[2].
With the beginning of the new century, we are also witnessing a fundamental shift in knowledge and knowing, no longer based on the scientific system but on the complex system [3] (Morin, 2021).
"*The disjunctive logic proper to Cartesian analytical theory, which separates and decontextualizes, then becomes insufficient; instead, it is necessary to differentiate and connect, to conceive the project as something that is not exhausted in the juxtaposition or sum of the parts, but as an inclusive system, imbued with links, interactions, transversality, mutation and adaptation*" [4] (Ceruti, Bellusci, 2020); composed of elements that in their complexity and constitutive identity constantly contribute to change, nurturing an evolutionary dimension and a co-production of the conditions of reciprocity within the ecosystem, able to "*take into account the contexts, interactions and retroactions, to recognize ambivalences and contradictions, to conceive of emergencies and to take into account the circular relationships from global to local and from local to global*" [5] (Morin, 2021).
For this reason, it is necessary to look for a new method to face the dwelling project, basing on unknown levels of complexity, such as to make "*coarse and prehistoric*" [6] the past approaches to design the domestic space.
Living is not only a spatial composition of elements assigned to an activity, today, it is much more: it is an interweaving/intersection of daily relationships between people who lead different lives, but who find in their domestic space the key and the answer to their relationship and where they seek their "*shared happiness*" [7]. The recent experience of confinement due to Covid has forcefully clarified how our homes are inadequate for contemporary living.
It has also revealed to us how the functionally designed spaces of our homes do not allow any promiscuous use and the direct relationship between the external and internal environment, typical of Mediterranean culture, completely neglecting the threshold spaces that have always defined the porous margin with the environment.
Moreover, we cannot forget that Italy is a country that unfortunately is subject to strong earthquakes. Since the new century, only in the last twenty years, there have been four major earthquakes: in L'Aquila in 2006, in Emilia Romagna in 2012, in Central Italy in 2016 and in Ischia in 2017, with catastrophic consequences.

Figure 2. Residential building crashed in Cavezzo after the 2014 earthquake in Emilia Romagna land.

The succession of these dramatic events has increased the awareness, not only in designers, but also in public administrations and private individuals, that it was necessary to both improve the seismic regulations and apply them to as many buildings as possible, new and existing ones.
In addition, the issue of sustainability of the intervention, included in an ecosystem-based approach, must be the basis of considerations for a social housing project; not only exclusively referred to a social and economic and of the architectural language sustainability, but also to several environmental aspects such as the reduction of land consumption, emissions, and impacts related to the construction and reversibility of the intervention.
The paper will deal with the design of a multi-storey residential building, developed in height, with wooden load-bearing walls construction system in Bolzano, a city located at the base of the Italian Dolomites mountains.
The notifying body of the design competition, the Popular Institute for Social Housing Bolzano, proposed a call based on five points:
- the building was to be developed in height;
- the design system should allow the reversibility and changeability of housing;
- the use of a lightweight and reversible construction system;
- the need for differentiated housing cuts;
- a low cost of construction;
- the use of green.

AIMS and OBJECTIVES

The social living reflects, basically, what is happening both in reality and in the cultural thought of these years.
Social marginality in recent years has expanded considerably, affecting increasingly large segments of the population, located on the "margins" of the social system, and thus denouncing the inability of society to operate with different degrees of integration/interaction. We are witnessing an ever-increasing "social fragility"[8] (Castel, 1997) of individuals who were not initially involved in the phenomenon but who, once any situation of stability has ceased to exist, have become involved in a marginality that has become a daily condition of their existence: separated parents and their children, women and single mothers, elderly people living alone and on low incomes, children removed from their families and, finally, immigrants with no income and of different ethnic groups. These phenomena, more and more extended and complex in their dynamics, induce public institutions to give some answers to the state of discomfort of these families and to provide them with an accommodation that allows both the entry into the Community of these "excluded" and the possibility of living in a low-cost and highly sustainable house.
The concomitance between a possible translation of a complex method for the architectural project and the more focused approach to the solution of social problems, leads us to pursue, for each project of a building dedicated to living, the possibility of creating new relationships for the formulation of the project and between people.
The goal is to create a project - through a polyphonic ecosystemic approach formed by space, landscape and society - that has the attitude of receiving, transmitting and assimilating what comes from the context and from the actors that inhabit it, only after having interpreted and transcribed it within the contemporary world, understanding the latter as a complex reality where both the universalism of contemporary society and the defense of communities and particular identities coexist.

METHODS

The project of living, specifically, is therefore called to translate today more than ever the needs, the instances of a language that goes beyond the sign, or rather, that translates (from *trans-ducere*, “lead

beyond"), through the design sign, a brought relationship between objects which refers to natural systems that have an interconnected structure and an evolutionary ability to 'self-adapt', to introduce by co-option a series of present elements useful for adaptation [9] (Gould, Vrba, 2008), to distribute themselves at different scales. This approach allows to define a new hybrid space between different realities that, as a catalytic agent, can trigger chain reactions within the project of mutation, activating a process of re-signification that favors a *'syntagmatic architectural overwriting'*, in order to shape a new social and architectural identity "*performative and non-representative*" [10] (Irace, 2008), which uses new adaptive tools.

The proposed method unites, and connects different fields, looking for a multidisciplinarity enclosed within the presented project, through the difference, variability and redundancy [11] (Moore, 2021), "derived" from what Herbert Simon said: "[…] *Roughly, by a complex system I mean one made up of a large number of parts that interact in a non-simple way*" [12].

In other words, in an attempt to apply this system to the reality, we proceeded with the constitution of "a multidisciplinary community" that, except for the professional figures helpful to the project and involved in the design process since the beginning, was also attended by people outside the technological system of construction, such as a sociologist, a philosopher, an artist and an activist representing the future inhabitants' Community who, through a series of meetings, first of all stated the overall requirements and later took part in some sessions where the designers explained step by step the result of their work, no longer set on the solution of every single need but on their complex relations: "*we have to accept the idea that reality is just interaction*" [13] (Rovelli, 2014).

The selected inputs, outcome of the meetings, are the following:

- the integration of a new building in a territory overlooking a mountain landscape must have the aim of a balanced insertion in the land, to ensure that the landscape and the building create a symbiotic and porous relationship able to totally integrate both elements;
- the reduction of the building footprint in order to keep more permeable ground and therefore to use a building in height;
- the will to provide all the accommodations with outdoor but still covered spaces, so as to increase the internal/external relationship and transform the boundary of the wall into "porous margin";

Figure 3. Building placement strategy in the plot

- the need to answer to seismic activity through a lightweight structure;
- the consequent use of a wood structure that, not only answers the previous paragraph correctly, but that also helps the required energy containment performance and the whole sustainability of the intervention;
- the identification of (structural, technological) invariants within the accommodations;
- the possibility to use dry systems especially for the internal walls, in order to easily reconfigure the apartment;

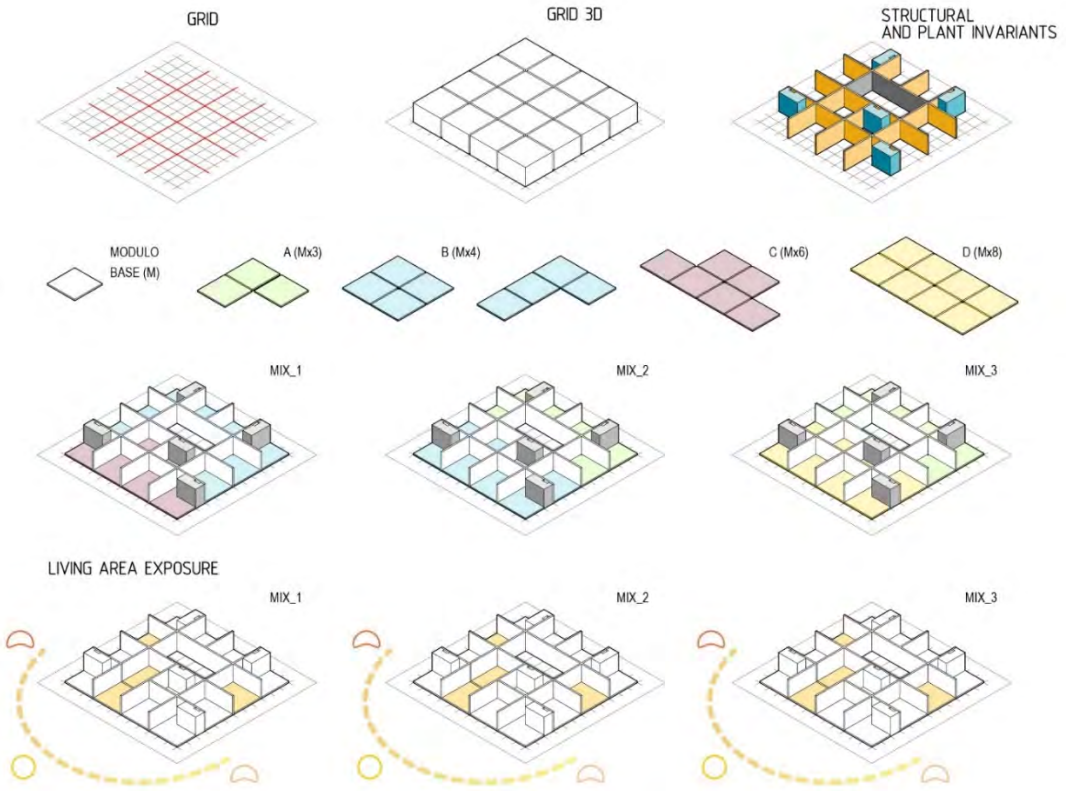

Figure 4. Strategy where it is possible to interlace the structural system, with the invariance of services and the typological mix (same living area exposure but different dimension of flat (See color of module)) . The services are collocated near of the main structure for to facilitate the relationship with technological installations and natural ventilation. Are conceived as transitional spaces between the area of social relations and more intimate ones.

- the use of passive sun protection systems for all seasons;
- the necessity to equip the building with spaces for the use of the inhabitants of the Community and of the quartier, such as shared kitchens, rooms for generational interactions, a small library and an area to let the kids play.

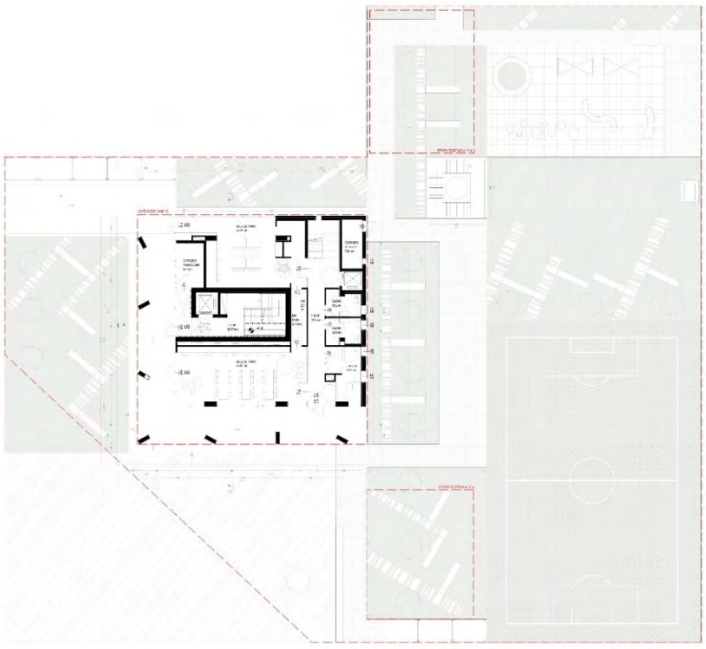

Figure 5. Building plans ground floor.

In a second moment, the selected inputs have been translated in the following design choices:
- a square, the simple form of the building able to generate a relationship of almost empathic belonging to the place, of complementarity, but at the same time declaring its formal autonomy, almost iconic, which is expressed both in the simple and compact form of the building and in the external loggias of the housing units. These large loggias (with a width of 1.80 m) run all around the building and define its perimeter, fragmented by dividing diaphragms, of various sizes, colored in various shades of green, differently inclined on the vertical plane and formally reduced to a single structure that generates discreet and reserved spaces, typical of the local farm buildings. These diaphragms are carefully selected views to ensure privacy between people and different accommodations, but they also offer the discovery and contemplation of the extraordinary natural scenery of the surroundings;
- the building has 10 floors above ground: the ground floor and the first floor (with a site area of 19.90x19.90 m) are dedicated to social activities of the neighborhood (internally served by a dedicated stairwell), while a stairwell, placed at the center to optimize the east-south-west views, serves the remaining 8 floors, with residential use;
- the search to maximize the number of housings in relation to the volume and the program provided, through a mix of 4 main types interchangeable, without changing the "hard" part of the building. The proposed project guarantees the possibility to realize the number of 35 lodgings (maximum foreseen);

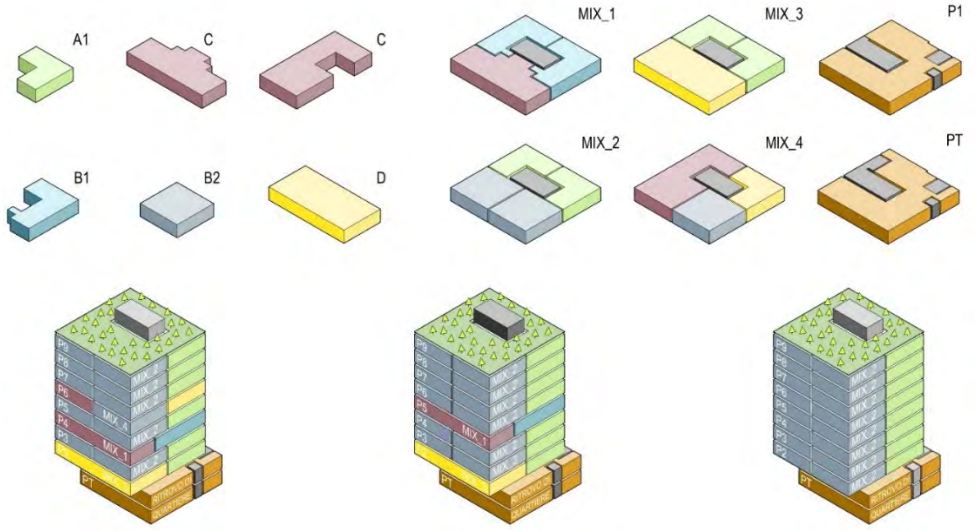

Figure 6. Available mix of apartments

- the respect of the single room sizes for the optimization, together with the envelope, of the management costs of the single families, with particular attention to the openings in order to favor the shading during the hot summer months and the correct irradiation during the winter months;

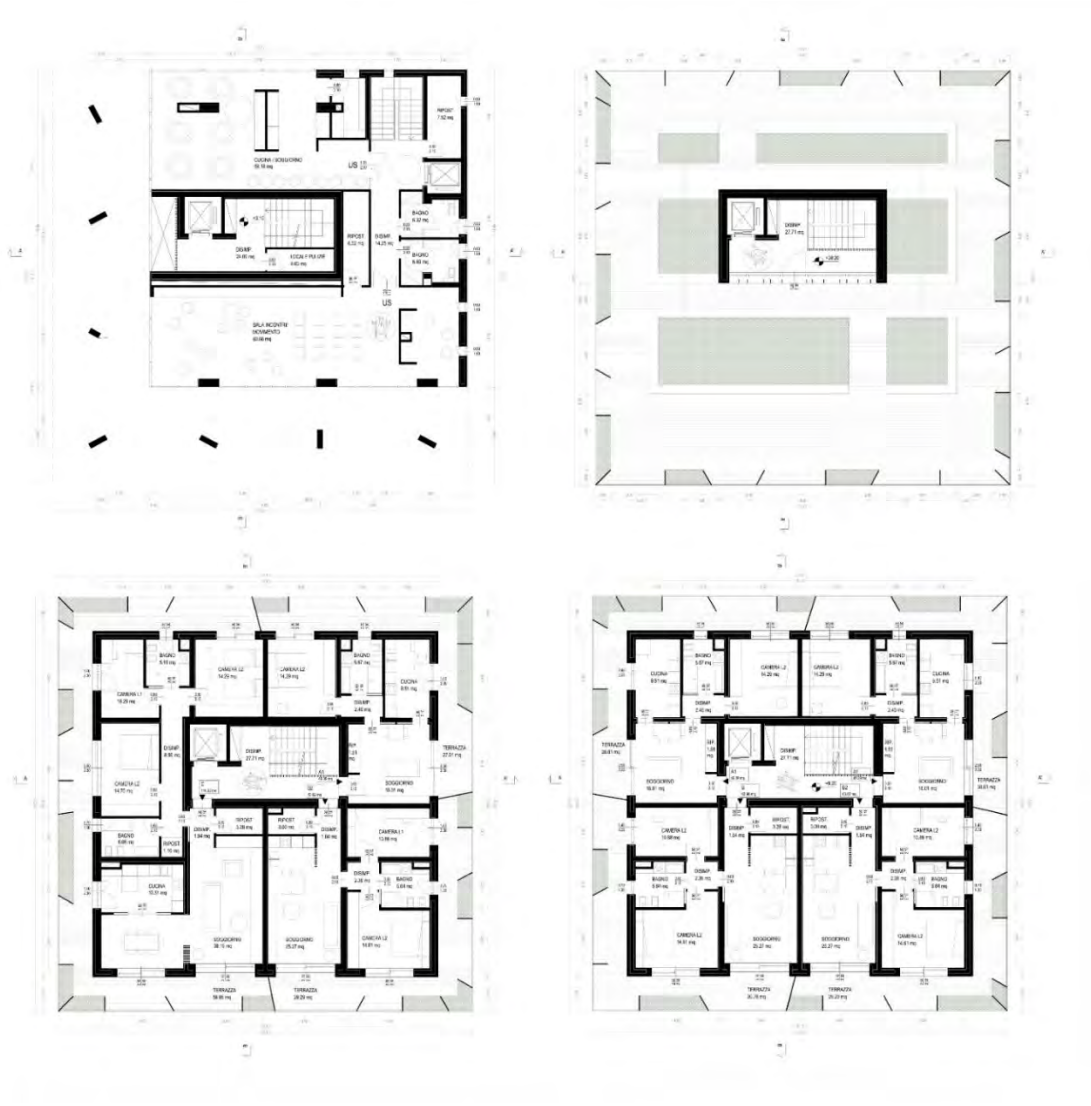

Figure 7. Building plans, first floor, roof and plans type.

- the presence of the porch to the south and west, in addition to protecting the entrance from bad weather and the sun, outlines an unconventional place of transition between the open public space and the more private living or community spaces. We think that the different vertical rotation of the pillars can describe and create new relationships;
- the orientation of the living areas always positioned to the east, the south and the west;
- a use of colors derived from the landscape and the given palette, with panels of different shades of green and an outer brownish wall;
- inside, the lightweight composite walls, dry-built, of different colors, the furniture also used as an acoustic barrier between the lodgings and the floors with earth colors give back the impression of a cozy, enveloping and intimate space;

Figure 8. Outside/Inside view of building/apartment

- the opportunity to use the flat roof as an open-air room for relational sharing among the community;
- the need to integrate the green as a decorative element also with a discreet presence of some small flower beds in the loggias of the housing where *Abelia grandiflora, Pittosporum nana, Juniperus old gold, Lonicera pileate* can grow, while *Ilex crenata, Taxus media hillii, Hydrangea annabell* are placed on the roof.

RESULTS

The multidisciplinary approach, helped by the use of BIM system, has allowed to develop, among the various worlds of the project, in its broadest sense, interesting and unpublished reports that were introduced in the final project responding to answer many initial questions.
We believe that the project, conceived as an open and integrated system, will be able to accommodate new and different needs that will emerge in future years.
The project of living this building is therefore subject to a decisive reversal, where the accommodation has been conceived as a space that will contain within it the permanence without a specific function, such as a school accommodation, a Skype backdrop accommodation, an accommodation for smart working or some spare time. From being a privacy protection space, it becomes a shared space between multiple people, for several activities, basing, then, on the possibility of a continuous remapping of the space/activity ratio to be carried out close to the building and within their own home.
But above all, we tried to provide the building with spaces for the community both specialized (meeting room, newspaper library, children's playroom, neighborhood meeting center) and convivial (the rooftop can be used for events), as well as, for housing, porous spaces between the inside and the outside that allow you to extend the accommodation outside and enjoy and relate to the beautiful mountain scenery surrounding the building.
From the technological point of view, having designed a building in height allows a lower consumption of soil; the use of a lightweight and dry construction typology (Xlam, i.e. Cross Laminated Timber panels for walls and slabs too), perfectly meets both seismic (dissipative structure) and reversibility requirements of the building and, consequently, a greater overall sustainability.

At the same time, also considering the climate of Bolzano city (cold in winter and warm in summer), the building has been designed in compliance with the Technical Directive Casaclima for new buildings and it achieves an energy efficiency of envelope EINres ≤ 30 kWh/m²a and with an EPSRres (Equivalent Primary Energy Requirement Without RESidential Cooling) ≤ 20 kg CO2 eqv /m²a, which corresponds to the definition of "building with nearly zero energy - nZEB", according to the European Directive 31/2010/EU Art.2, paragraph 2. The building has an excellent summer energy performance, due to the fact of using materials for opaque elements with a phase shift > 12 hours and due to the presence of vertical and horizontal projections that allow the shielding of glass surfaces, eliminating, therefore, any active cooling system.

Figure 9. General view of building

REFERENCES

[1] Guattari F., (2013), *Architettura della sparizione*, Mimesis, Milan
[2] Irace F., (2008), edit by, *Casa per tutti. Abitare la città Globale*, Triennale Electa, Milan, p. 17
[3], Morin E., (2021), *La sfida della complessità*, edit by A. Anselmo, G. Gembillo, L Lettere, Florence
[4] Ceruti M., Bellusci F.(2020), *Abitare la complessità*, Mimesis, Milan, p. 58
[5] Morin E., (2021), *op.cit.*, p. 48

[6] Coccia E., (2021), *Filosofia della casa. Lo spazio domestico e la felicità*, Einaudi, Turin, p. 27
[7] Coccia E., (2021), op.cit, p. 22
[8] Castel R., (1997), *Diseguaglianze e vulnerabilità sociale*, in Rassegna Italiana di Sociologia, anno XXXVIII, Il Mulino, Bologna, pp. 41-56
[9] Gould S. J., Vrba E., (2008), *Exaptation. Il bricolage dell'evoluzione*, edit by Telmo Pievani, Bollati Boringhieri, Turin, p. 15
[10] Irace F., op.cit., p.17
[11] Morin E., (2021), *op.cit.*, p. 74
[12] Simon H. A., (1992), *The architecture of complexity, Proceedings of the American Philosophical Socierty, 106 (6),* ., p. 468
[13] Rovelli C. E., (2014), *Sette brevi lezioni di fisica*, Adelphi p. 29

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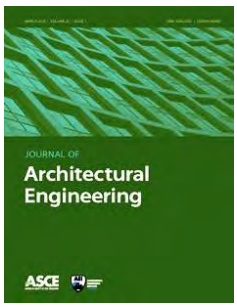

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