STAR (Sustainable Thermal and Acoustic self-made solutions for buildings refurbishment in disadvantaged social contexts by Reusing poor materials)

WP2 - Disadvantaged contexts analysis (5 months. Responsible UniBS). This work package concerns the identification and characterization of disadvantaged contexts where the panels made of EoLHM can be installed. The aim of this activity is to identify the typical building technology, dwelling dimensions, wall thermal resistance, wall periodic thermal resistance, and the outdoor climatic condition (indoor and outdoor temperature, humidity and solar radiation) necessary to the definition of numerical models in WP3. Data is collected from the literature, abacus and standards (such as the UNI/TR 11552:2014). The contexts will be characterized also from an acoustics point of view through noise maps (if available from the municipalities), or by making sound pressure level measurements inside and outside the dwellings. On the basis of the information gathered, it will be possible to define classes of buildings and identify how they can be refurbished to meet the thermal and acoustic performance required by national and local regulations. Moreover, it will be identified a test case where the panels can be installed. Also, a real test case is identified in the Brescia province where the in-situ tests described in WP6 will be performed.

WP2 - Disadvantaged context Analysis --- UniBS --- October 2023

UNI/TR 11552:2014 - Abacus of structures constituting the opaque building envelope. Thermophysical parameters.

The technical report UNI/TR 11552:2014 provides reference information for assessing the thermal performance of opaque components of the envelope of existing buildings, which can be used in the lack of more detailed information. In the case of existing buildings, it is indeed very often not possible to obtain certain information on the stratigraphies of the envelope components and the properties of the used materials. The technical report contains the main thermophysical parameters (thermal transmittance U, areic thermal capacity κ_i and periodic thermal transmittance Y_{ie}) of the opaque envelope components most commonly used in existing buildings in Italy. The main typologies for external walls, floors and roofs are considered. The types concerning the external walls are listed below.

1. Solid brick walls
    a. Solid brick masonry (MLP01)
    b. Solid brick masonry – exposed bricks (MLP02)
    c. Semi-solid brick masonry (MLP03)
2. Stone walls
    a. Stone masonry listed with brick (MPI01)
    b. Stone wall (MPI02)
    c. Tuff squared block masonry (MPI03)
    d. Stone cavity masonry (MPI04)
    e. Stone cavity masonry (MPI05)
3. Composite walls
    a. Brick and stone masonry (MCO01)
    b. Masonry with weakly tied filling (MCO02)

   c. Hollow concrete block masonry (MCO03)
   d. Cavity masonry with concrete blocks (MCO04)
   e. Cellular concrete solid block masonry (MCO05)
4. Cavity walls
   a. Hollow brick cavity masonry, example 1 (MCV01)
   b. Hollow brick cavity masonry, example 2 (MCV02)
   c. Solid brick masonry with cavity or light insulation, example 1 (MCV03)
   d. Solid brick masonry with cavity or light insulation, example 2 (MCV04)
   e. Hollow brick cavity masonry and exposed hollow bricks (MCV05)
   f. Hollow brick cavity masonry and exposed solid bricks (MCV06)
5. Prefabricated walls
   a. Concrete wall (MPF01)
   b. Brick wall + prefabricated panel (MPF02)
   c. Precast insulated concrete wall, example 1 (MPF03)
   d. Precast insulated concrete wall, example 2 (MPF04)

The main characteristics and the variability range of the thermophysical properties of the structures are collected in Table 1. In most cases, the change in total element thickness *d* is due to the change in thickness of a single material, so an increase in thickness corresponds to a decrease in transmittance *U* and periodic thermal transmittance Y_{ie}. Variation in air cavity thickness, when present, has no influence on these properties. The unique exception is the MPF02 element, for which there is a variation in the thickness of both the semi-solid brick load-bearing layer and the fiberglass insulation layer: in this case, in fact, it is the variation in the thickness of the insulation that has the greatest influence on transmittance and periodic thermal transmittance. The areic heat capacity κ_i, on the other hand, depends on several factors, and the trend is not observed to have a clear thickness dependence.

The report also gives broad indications of the geographical diffusion of the analyzed structures in eight Italian regions: Abruzzo, Campania, Liguria, Lombardia, Piemonte, Emilia Romagna, Toscana and Veneto. In general, cavity walls have appeared since 1950 (only in Piemonte since 1930) while previously only solid brick walls, stone walls and composite walls without cavity and without insulation were used. Prefabricated walls have been used only in Piemonte, the types with insulation since 1975.

*Table 1. Main characteristics and range of thermal transmittance, areic thermal capacity and periodic thermal transmittance of the structures: ↑means that the values of the property increase when the thickness d increases , ↓means that the values of the property decrease when the thickness d increases, * means that the values of the property have neither an increasing nor a decreasing trend with thickness d, and it is possible that the maximum and/or minimum value is not obtained at the extreme values of the thickness.*

Structure	***d* [cm]**	***U* [W/(m²K)]**	**κ_i [kJ/(m²K)]**	**Y_{ie} [W/(m²K)]**
MLP01	16 – 68↑	0.90 – 2.58↓	61.8 – 68.6*	0.011 – 1.639↓
MLP02	13.5 – 65.5↑	0.93 – 2.79↓	62.2 – 70.0*	0.014 – 2.000↓
MLP03	29 – 34↑	0.90 – 1.18↓	53.7 – 58.5↓	0.197 – 0.423↓
MPI01	16 – 68↑	1.07 – 2.82↓	64.3 – 71.8*	0.016 – 1.757↓
MPI02	44 – 104↑	1.57 – 2.58↓	72.3 – 77.9*	0.010 – 0.385↓
MPI03	34 – 74↑	0.67 – 1.30↓	58.7 – 61.9*	0.004 – 0.229↓
MPI04	42.5 – 90↑	1.67 – 1.94↓	82.8 – 87.9↓	0.065 – 0.229↓
MPI05	44 – 64↑	1.28 – 1.43↓	82.8 – 87.2↓	0.038 – 0.134↓
MCO01	44 – 104↑	0.75 – 1.50↓	62.1 – 65.2*	0.002 – 0.227↓
MCO02	42 – 57↑	0.95 – 1.19↓	48.9 – 50.2↓	0.039 – 0.144↓
MCO03	24 – 34↑	1.22 – 1.61↓	60.2 – 65.1↓	0.239 – 0.656↓
MCO04	17.5 – 60↑	1.02 – 1.47↓	53.3 – 57.6*	0.258 – 1.099↓
MCO05	27 – 43↑	0.35 – 0.55↓	33.3 – 36.7↓	0.039 – 0.229↓
MCV01	26.5 – 71↑	0.62 – 1.10↓	52.4 – 57.9↓	0.089 – 0.594↓
MCV02	39 – 49↑	0.27 – 0.67↓	52.7 – 55.8↑	0.029 – 0.109↓
MCV03	26.5 – 80↑	0.87 – 1.30↓	48.9 – 56.4↓	0.044 – 0.541↓
MCV04	28 – 54↑	0.54 – 0.68↓	53.0 – 56.4↓	0.018 – 0.228↓
MCV05	28.5 – 56↑	1.00	56.7	0.379
MCV06	28.5 – 56↑	1.17	57.0	0.45
MPF01	11 – 31↑	1.43 – 2.80↓	48.7 – 65.4*	0.374 – 2.383↓
MPF02	30 – 37↑	0.46 – 0.71*	12.5 – 18.8*	0.034 – 0.104*
MPF03	12 – 37↑	0.67 – 0.94↓	28.6 – 33.1*	0.082 – 0.818↓
MPF04	15 – 35↑	0.82 – 1.14↓	24.4 – 27.7*	0.113 – 0.766↓

Transmittance limits for walls undergoing energy retrofitting according to DM 162/2015.

The legislative basis for energy requirements for buildings in the European Union is the Directive 2010/31/EU on the energy performance of buildings. At Article 4, "Setting of minimum energy performance requirements", it establishes guidelines for actions to be taken by Member States. Specifically:

- "Member States shall take the necessary measures to ensure that minimum energy performance requirements for buildings or building units are set with a view to achieving cost-optimal levels."
- "Member States shall take the necessary measures to ensure that minimum energy performance requirements are set for building elements that form part of the building envelope and that have a significant impact on the energy performance of the building envelope when they are replaced or retrofitted, with a view to achieving cost-optimal levels."
- "When setting requirements, Member States may differentiate between new and existing buildings and between different categories of buildings."
- "These requirements shall take account of general indoor climate conditions, in order to avoid possible negative effects such as inadequate ventilation, as well as local conditions and the designated function and the age of the building."
- "A Member State shall not be required to set minimum energy performance requirements which are not cost-effective over the estimated economic lifecycle."

Article 7, "Existing buildings", in particular concerns existing buildings:

- "Member States shall take the necessary measures to ensure that when buildings undergo major renovation, the energy performance of the building or the renovated part thereof is upgraded in order to meet minimum energy performance requirements set in accordance with Article 4 in so far as this is technically, functionally and economically feasible."
- "Those requirements shall be applied to the renovated building or building unit as a whole. Additionally or alternatively, requirements may be applied to the renovated building elements."
- "Member States shall in addition take the necessary measures to ensure that when a building element that forms part of the building envelope and has a significant impact on the energy performance of the building envelope, is retrofitted or replaced, the energy performance of the building element meets minimum energy performance requirements in so far as this is technically, functionally and economically feasible."
- "Member States shall determine these minimum energy performance requirements in accordance with Article 4."

The DM 162/2015, "Applicazione delle metodologie di calcolo delle prestazioni energetiche e definizione delle prescrizioni e dei requisiti minimi degli edifici" is the transposition in Italy of Directive 2010/31/UE. At Paragraph 1.4 it defines major renovations and retrofitting. Specifically:

- A "major renovation" is defined as an intervention affecting the integrated elements and components constituting the building envelope that enclose a temperature-controlled volume from the external environment and from non-air-conditioned rooms, with an incidence of more than 25% of the total gross dispersion area of the building. "Major renovation" interventions are divided into:
    - (a) first-level major renovations: the intervention, in addition to affecting the building envelope with an incidence of more than 50% of the total gross dispersion area of the building, also includes the renovation of the thermal system for winter and/or summer air conditioning service of the entire building. In such cases, the energy performance requirements apply to the whole building and refer to its energy performance related to the service or services concerned;
    - (b) second-level major renovations: the intervention affects the building envelope with an incidence of more than 25 percent of the total gross dispersion area of the building and may affect the thermal system for winter and/or summer air conditioning service. In such cases,

the energy performance requirements to be verified concern the thermophysical characteristics of the only elements of the building envelope affected by the energy retrofitting and the overall coefficient of heat transfer by transmission (H'T) determined for the entire wall, including all the components on which work has been performed.

- An "energy retrofitting of a building" is defined as all other interventions that have, however, an impact on the energy performance of the building. Such interventions thus involve an area of less than or equal to 25% of the overall gross dispersion area of the building and/or consist of the new installation, renovation of a thermal system serving the building or other partial interventions, including the replacement of the generator. In such cases, the required energy performance requirements apply only to the building components and systems being renovated, and refer to their relative thermophysical or efficiency characteristics.
- In the case of energy retrofitting of the opaque envelope that involves thermal insulation from the inside or thermal insulation in the cavity, regardless of the size of the area involved, The transmittance limits to be met by the elements subject to the intervention are increased by 30% compared to the case where the insulation is applied outside.

Table 2 summarizes the U_{lim} transmittance limit values that a vertical wall undergoing energy retrofitting or second-level major renovation must meet, provided by Appendix B of DM 162/2015. It also shows the values increased by 30 percent that must be met if the insulation is applied from the inside, which is the case covered in this STAR project, or in the cavity.

It should be noted that in the case of first-level or second-level major renovations, additional verifications will also have to be done, such as on the overall exchange coefficient H'_T.

In addition, if it is desired to access potential fiscal incentives, it will be necessary to check the requirements set each time.

Table 2. Transmittance limits for vertical walls undergoing energy retrofitting: U_{lim} is the the limit to be met if the insulation is applied outside since 2021 (from Table 1 of DM 162/2015 – Appendix B); U_{lim} + 30% is the limit to be met if the insulation is applied inside or in the cavity.

Climatic zone	U_{lim} [W/m^{2}K]	U_{lim} + 30 % [W/m^{2}K]
A e B	0.40	0.52
C	0.36	0.47
D	0.32	0.42
E	0.28	0.36
F	0.26	0.34

Thermal resistance of the panel to be installed from inside.

Tables 3 and 4 summarize the minimum thermal resistance values that insulation panels to be installed from the inside must have to meet the minimum requirements given in Table 2 for climate zones A, B and C (Table 3) and climate zones D, E and F (Table 4), respectively. They were calculated from the equation

$$R_{\text{panel}} = (U_{\text{lim}}+30\%)^{-1} - (U)^{-1}$$

Table 3. Thermal resistance values that insulation panels to be installed from the inside must have to meet the minimum requirements of DM 162/2015: climatic zones A, B and C. --- means that the structure already meets the requirements.

Structure			Panel to be installed inside or in the cavity					
			Zone A		Zone B		Zone C	
UNI/TR 11552:2014	Umax [W/(m2K)]	Umin [W/(m2K)]	Rmax [(m2K)/W]	Rmin [(m2K)/W]	Rmax [(m2K)/W]	Rmin [(m2K)/W]	Rmax [(m2K)/W]	Rmin [(m2K)/W]
MLP01	2.58	0.90	1.54	0.81	1.54	0.81	1.75	1.03
MLP02	2.79	0.93	1.56	0.85	1.56	0.85	1.78	1.06
MLP03	1.18	0.90	1.08	0.81	1.08	0.81	1.29	1.03
MPI01	2.82	1.07	1.57	0.99	1.57	0.99	1.78	1.20
MPI02	2.58	1.57	1.54	1.29	1.54	1.29	1.75	1.50
MPI03	1.30	0.67	1.15	0.43	1.15	0.43	1.37	0.64
MPI04	1.94	1.67	1.41	1.32	1.41	1.32	1.62	1.54
MPI05	1.43	1.28	1.22	1.14	1.22	1.14	1.44	1.36
MCO01	1.50	0.75	1.26	0.59	1.26	0.59	1.47	0.80
MCO02	1.19	0.95	1.08	0.87	1.08	0.87	1.30	1.08
MCO03	1.61	1.22	1.30	1.10	1.30	1.10	1.52	1.32
MCO04	1.47	1.02	1.24	0.94	1.24	0.94	1.46	1.16
MCO05	0.55	0.35	0.10	---	0.10	---	0.32	---
MCV01	1.10	0.62	1.01	0.31	1.01	0.31	1.23	0.52
MCV02	0.67	0.27	0.43	---	0.43	---	0.64	---
MCV03	1.30	0.87	1.15	0.77	1.15	0.77	1.37	0.99
MCV04	0.68	0.54	0.45	---	0.45	0.07	0.67	0.28
MCV05	1.00	1.00	0.92	0.92	0.92	0.92	1.14	1.14
MCV06	1.17	1.17	1.07	1.07	1.07	1.07	1.28	1.28
MPF01	2.80	1.43	1.57	1.22	1.57	1.22	1.78	1.44
MPF02	0.71	0.46	0.51	---	0.51	---	0.73	---
MPF03	0.94	0.67	0.86	0.43	0.86	0.43	1.07	0.64
MPF04	1.14	0.82	1.05	0.70	1.05	0.70	1.26	0.92

Table 4. Thermal resistance values that insulation panels to be installed from the inside must have to meet the minimum requirements of DM 162/2015: climatic zones D, E and F. --- means that the structure already meets the requirements.

Structure			Panel to be installed inside or in the cavity					
			Zone D		Zone E		Zone F	
UNI/TR 11552:2014	Umax [W/(m2K)]	Umin [W/(m2K)]	Rmax [(m2K)/W]	Rmin [(m2K)/W]	Rmax [(m2K)/W]	Rmin [(m2K)/W]	Rmax [(m2K)/W]	Rmin [(m2K)/W]
MLP01	2.58	0.9	2.02	1.29	2.36	1.64	2.57	1.85
MLP02	2.79	0.93	2.05	1.33	2.39	1.67	2.60	1.88
MLP03	1.18	0.9	1.56	1.29	1.90	1.64	2.11	1.85
MPI01	2.82	1.07	2.05	1.47	2.39	1.81	2.60	2.02
MPI02	2.58	1.57	2.02	1.77	2.36	2.11	2.57	2.32
MPI03	1.3	0.67	1.63	0.91	1.98	1.25	2.19	1.47
MPI04	1.94	1.67	1.89	1.81	2.23	2.15	2.44	2.36
MPI05	1.43	1.28	1.70	1.62	2.05	1.97	2.26	2.18
MCO01	1.5	0.75	1.74	1.07	2.08	1.41	2.29	1.63
MCO02	1.19	0.95	1.56	1.35	1.91	1.69	2.12	1.91
MCO03	1.61	1.22	1.78	1.58	2.13	1.93	2.34	2.14
MCO04	1.47	1.02	1.72	1.42	2.07	1.77	2.28	1.98
MCO05	0.55	0.35	0.59	---	0.93	---	1.14	0.10
MCV01	1.1	0.62	1.49	0.79	1.84	1.13	2.05	1.35
MCV02	0.67	0.27	0.91	---	1.25	---	1.47	---
MCV03	1.3	0.87	1.63	1.25	1.98	1.60	2.19	1.81
MCV04	0.68	0.54	0.93	0.55	1.28	0.90	1.49	1.11
MCV05	1	1	1.40	1.40	1.75	1.75	1.96	1.96
MCV06	1.17	1.17	1.55	1.55	1.89	1.89	2.10	2.10
MPF01	2.80	1.43	2.05	1.70	2.39	2.05	2.60	2.26
MPF02	0.71	0.46	1.00	0.23	1.34	0.57	1.55	0.78
MPF03	0.94	0.67	1.34	0.91	1.68	1.25	1.89	1.47
MPF04	1.14	0.82	1.53	1.18	1.87	1.53	2.08	1.74