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(8th REHABEND Congress)

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Avenue Los Castros s/n 39005 SANTANDER (SPAIN)

Tel: +34 942 201 738 (43)

Fax: +34 942 201 747

E-mail: rehabend@unican.es

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1.- PREVIOUS STUDIES
1.1.- Multidisciplinary studies (historical, archaeological, etc.).

21	METHODOLOGY FOR PREVENTIVE CONSERVATION OF LINEAR LANDSCAPE IN CITIES <i>Ros Torres, Josefa; García-León, Josefina; Vázquez Arenas, Gemma</i>	2
32	THE EVOLUTION OF CONSTRUCTION TECHNIQUE THROUGH THE HISTORY OF ENTERPRISE: THE FEAL <i>Mornati, Stefania</i>	10
34	DOCUMENTING CULTURAL HERITAGE THROUGH INVENTORY <i>Prata, Maria Catharina Reis Queiroz; Carneiro, Silvana Monteiro de Castro</i>	18
52	THE CONSTRUCTION TECHNOLOGY IN SPANISH COLONIES. A CATHEDRAL IN WESTERN COLOMBIA <i>Carvajal, Henry H.; Ochoa, Juan C.</i>	26
78	THE TRANSFORMATION OF MEDIEVAL CHURCHES DURING THE BAROQUE ERA IN SZEKLERLAND <i>Csenge, Gergely</i>	35
97	GOTHIC TRACE OF CARAGOL SOBIRANES OF SANTA CATERINA'S TOWER OF TORTOSA'S CATHEDRAL <i>Lluis i Ginovart, Josep; Lluis i Teruel, Cinta</i>	43
115	THE "PALAZZO DEL GOVERNO" IN TARANTO: AT BEGINNINGS OF A TYPICAL "ITALIAN" STYLE <i>Pagliuca, Antonello; Gallo, Donato; Trausi, Pier Pasquale</i>	51
138	PROPOSAL AND APPLICATION OF MASSH – A HOUSING HEALTH AND SAFETY ASSESSMENT MODEL FOR PORTUGAL <i>Monteiro, Marisa; Silva, Tiago; Pastorinho, M. Ramiro ; Lanzinha, João C.G.</i>	59
159	VISUAL RELATIONSHIP BETWEEN MONUMENTS FROM THE PAST AND CONTEMPORARY ARCHITECTURE. MASTERPIECES BY ANDREA PALLADIO AND NEW SPATIAL CONNECTIONS <i>Pietrogrande, Enrico; Dalla Caneva, Alessandro</i>	67
188	FACTORS THAT PREVENT EFFECTIVE ARTICULATION OF THE PROVINCE OF THE UNION WITH THE PROGRESSIVE DEVELOPMENT OF THE AREQUIPA REGION <i>Cusihuamán Sisa, Gregorio Nicolás</i>	78
197	ANCIENT LIME KILNS: TRADITION, MANUFACTURING AND USE OF LIME IN THE PROVINCE OF GRANADA (ANDALUCIA) <i>Galdó-Ceballos, E.; Arizzi, A.; Sebastián-Pardo, E.</i>	86
200	CHEMICAL, MINERALOGICAL AND PHYSICAL CHARACTERIZATION OF LIGHTWEIGHT BRICKS WITH THE ADDITION OF SAWDUST FOR USE IN CONSTRUCTION AND PRESERVATION OF ARCHITECTURAL HERITAGE <i>Aurrekoexea, Itziar; Cultrone, Giuseppe</i>	94
229	FROM HISTORICAL ANALYSIS TO STRUCTURAL STRENGTHENING. THE CASE OF THE FORMER CONVENT OF SAN ROCCO IN SORAGNA (PR) <i>Otoni, Federica; Celli, Sofia; Mambriani, Carlo</i>	102
259	TRADITIONAL HOUSING IN LAMBAYEQUE - PERU - REMARKABLE AND HERITAGE VALUE ASPECTS THAT CONTRIBUTE TO ITS SUSTAINABILITY <i>Zárate, Eduardo; Chirinos, Haydé; Morales, Nicolás</i>	111
260	VICEREGAL HOUSING FACADES IN LAMBAYEQUE - PERU: STUDIES FOR THEIR ENHANCEMENT <i>Chirinos, Haydé; Zárate, Eduardo; Morales, Nicolás</i>	121
261	THE MODERN MOVEMENT HERITAGE: PROTO-BIOCLIMATIC SOLUTIONS AND BUILDING ELEMENTS <i>Franchini, Caterina; Mele, Caterina</i>	130
268	THE HISTORICAL STUDY IN THE BENIGNO MALO SCHOOL, ITS INCIDENCE IN THE RESTORATION PROJECT AND CONTEMPORARY ARCHITECTURE <i>Cardoso, Fausto; Ullauri, Marlene; Rodas, Tatiana; Jaramillo, Paola</i>	141
285	SPATIAL ANALYSIS OF FINNISH ARCHITECT JUHA LEIVISKÄ'S CHURCHES AND THEIR LINK WITH DE STIJL DUTCH GROUP CONSTRUCTIONS <i>Díez-Blanco, M. Teresa; Millán-Gómez, Antonio</i>	152
287	URBAN-BUILDINGS PERMANENCES IN POST-FRENCH SEVILLE (XIX-XX CENTURY): PLANIMETRIC RECOMPOSITION AND SEQUENTIAL HYPOTHESIS <i>Navarro-de-Pablos, Javier; Navas-Carrillo, Daniel; Rodríguez-Lora, Juan-Andrés; Pérez-Cano, Teresa</i>	162

288	SEGOVIAN SHEEP SHEARING BUILDINGS DURING XVII AND XVIII CENTURIES. REDISCOVERING LOST TRANSHUMANCE HERITAGE, THROUGH GRAPHIC RECONSTRUCTION OF ITS BUILDINGS <i>Gutiérrez, Nicolás</i>	170
291	THE IRONWORK, TOOL FOR THE ANALYSIS OF HISTORIC URBAN LANDSCAPE IN LARBI BEN M'HIDI STREET IN ALGIERS (ALGERIA) <i>Belouchrani, Ouahiba</i>	178
324	PROTOCOLS AND SAMPLING OF ANALYSIS OF MATERIALS FOR THE CHRONOLOGICAL STUDY AND INTERVENTION TECHNIQUES: TOWER PIMENTEL OF TORREMOLINOS, MÁLAGA <i>Pérez-Lomas, Lucía; Ruiz-Jaramillo, Jonathan; García-Pulido, Luis José</i>	187
325	THE ROLE OF ITALIAN IN ARCHITECTURAL CONSERVATION MOVEMENT IN IRAN <i>Shiasi, Nasim; Panahy, Mahmood</i>	195
331	CONSERVATION OF THE FORTIFIED WALLS OF THE ALHAMBRA: PRELIMINARY RESULTS ON THE ORIGINAL AND REPAIR MATERIALS OF THE TOWER OF THE HEADS <i>Crespo-López, Laura; Arizzi, Anna; Sebastián Pardo, Eduardo; Ruíz-Sánchez, Antonio</i>	202
360	THE POWER BEHIND ARCHITECTURE. MODERN BUILDINGS USED AS STRATEGY TO EXPRESS A POLITICAL IDEOLOGY IN THE CARIBBEAN <i>Flores Sasso, Virginia; Fernández Flores, Gabriela; Prieto Vicioso, Esteban</i>	210
366	SHELL CONCRETE STRUCTURES IN VALENCIAN REGION (SPAIN) CATALOGUE <i>Arnau, Fernando; Serrano, Begoña; Fenollosa, Ernesto</i>	222
383	THE TECHNIQUE OF THE ARABAN QANAT IN THE LOW BASIN OF THE HENARES RIVER, AN HIDDEN HERITAGE <i>Fernández Tapia, Enrique José; Ramírez González, Ildefonso</i>	232
410	CHARACTERIZATION OF THE BUILDING STOCK HERITAGE ORIENTED TO STUDIES OF SEISMIC VULNERABILITY AT URBAN SCALE: CASE STUDY HISTORIC CENTRE OF CUENCA, ECUADOR <i>Quezada, Rosa; Jiménez, Juan; García, Hernán; Calderón, José</i>	240
420	RESULTS IN GRANADA OF THE METROLOGICAL INTERPRETATION OF HERITAGE BUILT BY ANTHROPOMETRIC RULES <i>Roldán-Medina, Francisco Javier</i>	252
511	GEOLOGICAL AND GEOMORPHOLOGICAL STUDY OF EL PENDO CAVE (CANTABRIA, NORTHERN SPAIN) <i>Sánchez-Carro, Miguel; Bruschi, Viola</i>	260
526	PROPOSAL OF A SIMPLIFIED APPROACH FOR ASSESSING AND MAPPING FLOOD VULNERABILITY IN HISTORIC SITES: APPLICATION TO THE HISTORIC CITY CENTRE OF GUIMARÃES <i>Ferreira, Tiago Miguel; Miranda, Fabiana Navia</i>	268

1.2.- Heritage and territory.

95	EMPLOYERS AND EMPLOYEES: EACH ONE IN HOME THE TUNA FISHERMEN AND THE COMPANY'S OWNERS <i>Batista, Nuno; Gonçalves, Marta Marçal</i>	274
121	TERRITORY AND DRYSTONE WALLS. COMPARATIVE OF CASE STUDIES IN CENTRAL AND SOUTHERN PORTUGAL <i>Gonçalves, Marta Marçal; Prates, Gonçalo; Pérez-Cano, María Teresa; Rosendahl, Stefan</i>	282
129	CLIMATE CHANGE AND ADAPTATION ON CULTURAL HERITAGE IN THE FACE OF SEA LEVEL RISE. A PERSPECTIVE FROM INSULARITY <i>García Sánchez, Francisco; García Sánchez, Héctor</i>	290
132	NEITHER BOUNDARIES NOR BARRIERS. INTERNATIONAL INTERACTIONS BETWEEN THE CITIES OF SANTANA DO LIVRAMENTO (BRAZIL) AND RIVERA (URUGUAY) <i>Prestes, Laura Roratto; Gonçalves, Marta Marçal</i>	298
139	SALT: THE WHITE GOLD OF ALGARVE <i>Susano, Cátia Loios; Gonçalves, Marta Marçal</i>	306
181	ARCHAEOLOGICAL SITES IN MEXICO AND THEIR RELATION WITH IMMEDIATE HUMAN SETTLEMENTS: DECONSTRUCTIVE IDENTITY <i>Álvarez, María del Pilar; Nava, José María Wildford</i>	314
231	MUELLE DE LEVANTE MASTER PLAN IN HUELVA PORT. PLANNING THE REHABILITATION OF THE PORTUARY INDUSTRIAL HERITAGE TO THE REALITY OF PORT-CITY INTEGRATION <i>Gómez Melgar, Sergio; Carrasco Conejo, María José; Vera González, César; Olmedo Rivas, Javier; Andújar Márquez, José Manuel; Martínez Bohórquez, Miguel Ángel</i>	323

251	THE FARMS IN THE WEST AREA OF PÁRAMOS DEL ESGUEVA. THE CASE STUDY OF THE COUNTRY HOUSE-WINERY OF THE ROYAL MONASTERY OF SAN QUIRCE Y SANTA JULIA <i>Bellido-Blanco, Santiago; Villanueva-Valentín-Gamazo, David; Arcones-Pascual, Gustavo</i>	335
263	PREVIOUS STUDIES FOR INTERVENTIONS IN THE CULTURAL HERITAGE BUILT ON THE COSTA LAMBAYECANA: RAINFALL INTENSITY FOR STORM DRAIN DESIGN <i>Morales, Walter; Chirinos, Haydeé; Zárate, Eduardo</i>	344
350	THE CURRENT STATUS OF LEVANTINE ARCHITECTURAL HERITAGE IN THE CITY OF MERSIN <i>Umar, Nur; Darendeli, Tugce</i>	353
454	BUILD IN TILES WITHOUT WOODEN TILES. A CONTEMPORARY LOOK <i>Vásquez Fierro, Virginia; Huenchullanca Godoy, Fernando; Toneatti Oyaneder, Marco</i>	363
465	VERNACULAR HERITAGE OF NORTHWEST PORTUGAL: THE VALLEY AND THE MOUNTAIN RANGE FARMHOUSE <i>Barroso, Carlos E.; Barros, Fernando C.; Vale, Clara P.; Oliveira, Daniel V.; Ramos, Luís F.</i>	372

1.3.- Urban regeneration.

28	PROTECTION OF POST-WAR HOUSING ESTATES <i>Żychowska, Maria J.</i>	382
38	HOW TO BRING PEOPLE BACK INTO HISTORIC CITY CENTRES: A COMPARISON OF STRATEGIES PROPOSED IN QUITO, ECUADOR TO OTHER INTERNATIONAL CASE STUDIES <i>Córdova, Andrea; Caraguay, Alexandra; Davis, Michael</i>	390
198	MASTER PLAN FOR THE CENTER OF SAN JOSÉ, COSTA RICA: CHALLENGES OF THE INTEGRATED APPROACH AND PLAN IMPLEMENTATION <i>Molina, Patricia; Matesanz, Ángela; Sopelana, Amaia; Von Breyman, Helga; Solano, Erick; Chavarría, Dania; García, Igone; Sasa, Zuhra; Castillo, Liza; Jiménez, Alejandro</i>	399
217	3D-GIS MODELS TO SUPPORT THE CO-CREATION OF ENERGY EFFICIENT STRATEGIES FOR HISTORIC URBAN ENVIRONMENTS <i>Egusquiza, Aitziber; Izkara, Jose Luis; Prieto, Iñaki</i>	409
386	THE REGENERATION OF INDUSTRIAL WATERWAYS AS AN EXTENSION OF THE URBAN OPEN SPACE SYSTEM. LONDON-MILANO-ZARAGOZA <i>Cabau, Beatriz; Hernández-Lamas, Patricia</i>	419
402	TOWARDS EFFICIENT ENERGY RETROFITTING OF RESIDENTIAL BUILDINGS. COMPARING A NEIGHBORHOOD IN PAMPLONA (SPAIN) AND THE NEIGHBORHOOD OF CLINTON HILL, BROOKLYN, NY (USA) <i>Sánchez-Ostiz, Ana; Nenadich, Nadya; San Miguel-Bellod, Jorge; Monge-Barrio, Aurora</i>	430
550	THE REHABILITATION, A FUNDAMENTAL MEASURE FOR THE RECOVERY OF THE HISTORICAL CENTER OF GUADALAJARA <i>Trallero Sanz, Antonio Miguel</i>	440
554	HISTORICAL CENTER OF LIMA. URBAN RENEWAL AND THE IMPLICATION OF URBAN LAW. CASES: CASA DE LAS COLUMNAS, CONJUNTO HABITACIONAL LA MURALLA AND PROYECTO PILOTO MARTINETE <i>Isidro Ferrer, Liz Luisa</i>	449
576	THE PROJECT OF WIDENING FOR THE CITY OF JAÉN IN 1927 <i>Ríos, Miguel Á.; Vigil-Escalera, Manuel; Pérez, Teresa</i>	457

1.4.- Economical and financial policies.

478	COST-BENEFIT ANALYSIS APPLIED TO THE REHABILITATION OF PUBLIC SCHOOL BUILDINGS <i>Salvado, Filipa; Falcão Silva, Maria João; Couto, Paula</i>	464
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1.5.- Social participation processes and socio-cultural aspects in rehabilitation projects.

18	THE URBAN TRANSFORMATION AS A COLLECTIVE CREATION: BOTTOM-UP AND PARTICIPATIVE TOOLS TAXONOMY FOR URBANISTS AND ARCHITECTS <i>Sève, Bruno; Redondo, Ernest; Millan, Antonio; Sega, Roberto</i>	470
24	THE OLD BRIDGE OF BROTO: LONGING OF A PEOPLE <i>Febas Borra, José Luís; Díez Hernández, Jesús; Eguiluz, Ziortza</i>	478
84	CULTURAL LANDSCAPE CHARACTERIZATION BASED ON THE PERCEPTION OF ITS INHABITANTS: ALGORTA'S OLD FISHING PORT <i>Usobiaga, Elena; Zubiaga, Mikel; Urra, Silvia; Revilla, Igone</i>	487
213	GROUNDING THEORY AS A RESEARCH BASE FOR INTERVENTION IN MODEST HERITAGE BUILDINGS <i>Villegas, María Claudia</i>	496

226	TOWARDS THE SAFEGUARDING OF CONTEXTUAL DWELLINGS: INDICATORS OF PATRIMONIAL SUSTAINABILITY. MAR DEL PLATA, ARGENTINA <i>Sánchez, Lorena Marina</i>	505
405	A CRITICAL STUDY OF TRANSIT ORIENTED DEVELOPMENT (TOD) IN THE HISTORICAL CENTRE OF QUITO, ECUADOR <i>Davis, M.J.M.; Verlinghieri, E.; Córdova, C.; Orbea, S.</i>	513
452	TRADITIONAL DOVECOTES RESTORATION AND REUSE IN CASTILLA- LEÓN. SPAIN <i>Bellido, Rosa; Villena, Izaskun; Olcese, Juan Jerónimo; Font, Juana</i>	521

1.6.- Construction pathology.

8	LIFTING OF THE MAIN PATHOLOGICAL MANIFESTATIONS IDENTIFIED THROUGH PREDIAL INSPECTIONS IN FORTALEZA-BRAZIL <i>Pinto, Francisco Davi de Lima; Bôes, Jeferson Spiering</i>	530
17	PHYSICO-CHEMICAL ANALYSIS OF HISTORIC CONCRETE STRUCTURES IN THE CARIBBEAN <i>Flores Sasso, Virginia; Prieto Vicioso, Esteban; García de Miguel, José M.</i>	539
56	GLOBAL INSPECTION, DIAGNOSIS AND REPAIR SYSTEM FOR BUILDINGS: HOMOGENISING THE CLASSIFICATION OF DIAGNOSIS METHODS <i>Pereira, Clara; De Brito, Jorge; Silvestre, José D.</i>	554
65	THREE EXAMPLES OF DECISION MAKING IN THE STRUCTURAL INTERVENTION IN HERITAGE <i>Pérez-Valcárcel, Juan</i>	563
76	MICROCEMENT: STANDARDIZATION AND CONSTRUCTIVE PATHOLOGY <i>Oliveira, Miguel José; Gonçalves, Marta Marçal; Renda, Jorge</i>	572
81	ANALYSIS OF FACADES PATHOLOGIES REGISTERED IN A SET OF HERITAGE BUILDINGS IN THE CITY OF UBERLÂNDIA <i>Martins Vale Araújo, Júlia; Cabana Guterres, Paulo Roberto</i>	581
106	DAMAGE CAUSED BY THE COLLAPSE OF GYPSIFEROUS ROCK MASSES. CALLOSA D'EN SARRIÀ (SE SPAIN) CASE STUDY <i>Cano, Miguel; Tomás, Roberto; Pastor, José L.; Riquelme, Adrián; Rabat, Álvaro</i>	590
126	STUDY OF DAMPNES IN LARGE RESIDENTIAL ESTATES IN THE METROPOLITAN AREA OF BARCELONA: THE CASE OF LA VERNEDA, SUD-OEST DEL BESÒS AND CIUTAT MERIDIANA <i>Martín, Estefanía; Cornadó, Còssima; Vima, Sara</i>	599
130	INTERNAL DETERIORATION MECHANISMS OF COLUSA SANDSTONE AND THE DRAWBACKS OF PROTECTIVE COATINGS <i>Carter, Sidney W.; Searls, Carolyn L.; Campbell, Lex F.</i>	609
137	DEVELOPMENT OF A TOOL FOR TECHNICAL DAMAGE AND RISK ASSESSMENT IN CONSTRUCTION <i>Garmendia, Leire; Marcos, Ignacio; Rojí, Eduardo; Gandini, Alessandra; Losada, Ramón; Herrera, Jose; Atares, Fernando</i>	617
157	ALTERNATIVES TO ANALYSE LOW COMPRESSIVE STRENGTH IN PRESTRESSED CONCRETE JOISTS MANUFACTURED WITH HIGH ALUMINA CEMENT <i>Calderón Bello, Enrique; Gómez Barrado, Sergio; Rodríguez Escribano, Raúl Rubén</i>	623
170	MOISTURE DETECTION USING NDE OF DIESTE'S CHURCH OF CHRIST THE WORKER <i>Moltini, Gonzalo; Aulet, Alina; Cetrangolo, Gonzalo</i>	630
177	SULFATE RESISTANCE OF COAL ASH PORTLAND CEMENT MORTARS <i>Menéndez, Esperanza; Argiz, Cristina; Sanjuán, Miguel Ángel</i>	639
190	THE IMPACT OF WATER SUPPLY SYSTEMS TRANSFORMATION ON THE SANITARY STATE AND THE OLD BUILT ENVIRONMENT DETERIORATION OF THE ALGIERS OTTOMAN HOUSES <i>Meriem, Sahraoui; Ali, Belmeziti; Samia, Chergui</i>	647
241	TREE RELATED SUBSIDENCE IN ENGLAND: EFFECTS OF CLIMATE CHANGE ON THE BUILT ENVIRONMENT <i>Bottomley, Rebecca; Kirk, Mark; Pesce Giovanni L.</i>	656
298	ANALYSIS OF PATOLOGICAL INJURIES FROM VISUAL INSPECTION OF THE QUALITY SCHOOLS IN THE CITY OF MEDELLIN (COLOMBIA), BUILT BETWEEN 2004 AND 2007 <i>Cangrejo Bocanegra, Carol; Cañola, Hernán Darío; Pérez, Jhony; Builes-Jaramillo, Alejandro</i>	664
305	HOUSING PATHOLOGY; TOWARDS A HOLISTIC PATHOLOGICAL APPROACH OF RESIDENTIAL BUILDINGS <i>Thomsen, André.</i>	673
328	CERAMIC TILE SYSTEM, PATHOLOGIES AND PERFORMANCE EVALUATION <i>Vilató, Rolando R.</i>	682

361	UNMANNED AERIAL VEHICLES (UAV) AS A TOOL FOR VISUAL INSPECTION OF BUILDINGS FACADES <i>Ballesteros Ruiz, Ramiro; Casado Lordsleem Jr, Alberto</i>	690
387	CONSTRUCTIVE ANALYSIS OF TWENTY RESIDENCIAL BUILDINGS BELONGING TO THE CULTURAL HERITAGE IN HERNANI (BASQUE COUNTRY). PATHOLOGIES AND CAUSES <i>Santolaria, Oihana</i>	699
457	METHODOLOGY OF RISK ANALYSIS IN REPORTS OF BUILT HERITAGE - THE CASE OF THE MUNICIPAL MUSEUM AGOSTINHO MARTHA <i>Betemps Vaz da Silva, Juliana; Uez, Pablo Cesar; Rauber Motter, Cristiane; Santa Catarina, Vinicius; Lorscheiter, Aline</i>	707
474	SALVO PALACE. STATE OF CONSERVATION OF THE SÍMIL PIEDRA FAÇADES RENDERS <i>Mussio, Gianella; Castro, Magdalena</i>	718
533	THE EVOLUTION OF THE 18TH CENTURY SLAVONIAN PALACE OF GENERAL COMMAND OSIJEK, CROATIA – CAN WE RETRIEVE THE AUTHENTIC BUILDING DESIGN? <i>Penava, Davorin; Anić, Filip; Stober, Dina; Kržan, Meta; Radonjić, Antonio; Turkalj – Podmanicki, Margareta; Lozančić, Silva</i>	727
541	PATHOLOGY IN CRUDE EARTH, RESEARCH ON CONSTRUCTIONS IN THE ECUADORIAN ANDEAN AREA <i>Lara, M. Lenin, Galarza-Gallardo, Gabriela</i>	736
580	VIOLIN-JOIST CERAMICS SLABS. EVALUATION AND WORK PROPOSAL WITH DUPLEX-TYPE STAINLESS STEEL <i>Salmerón Martínez, Antonio; Salvador Landmann, Miguel; Ferrando, Elisabeth</i>	744

1.7.- Diagnostic techniques and structural assessment (no destructive testing, monitoring and numerical modeling).

1	INVESTIGATION ON EXPERIMENTAL TECHNIQUES FOR THE MECHANICAL CHARACTERIZATION OF BRICK MASONRY <i>Roca, Pere; Pelà, Luca</i>	752
23	PREVIOUS STUDIES IN A SINGULAR BRIDGE: BRIDGE OF ALMARAIL IN SORIA <i>Díez Hernández, Jesús; Marcos, Ignacio; Piñero, Ignacio; García, Aratz ; Briz, Estibaliz</i>	766
35	NON-DESTRUCTIVE TECHNIQUES APPLIED TO HISTORIC BUILDING FOR MEASURING MOISTURE CONTENT IN BRICK VAULT <i>Flores Sasso, Virginia; Ruiz Valero, Letzai; Prieto Vicioso, Esteban</i>	778
45	VIBRATION ASSESSMENT ON THE HISTORICAL STRUCTURES INDUCED BY TECHNICAL SEISMICITY <i>Urushadze, Shota; Pirner, Miroš; Bayer, Jan</i>	790
48	VIBRATION MONITORING IN HISTORICAL CITY CENTERS: EFFECT OF TRAM SPEED ON THE VIBRATION INTENSITY INDUCED TO THE TEMPLE OF MINERVA MEDICA, ROME <i>Roselli, Ivan; Fioriti, Vincenzo; De Canio, Gerardo; Saitta, Fernando; Colucci, Alessandro; Forliti, Sara</i>	800
63	DAMPING CHARACTERISTICS OF DRY SANDY SOILS UNDER IMPACT <i>Ali, Adnan F.; Ahmed, Balqees A.</i>	810
66	PROTOCOL FOR THE MONITORING OF ENVIRONMENTAL VARIABLES THAT AFFECT THE DEFENSIVE HERITAGE OF TAPIAL: A CASE STUDY OF THE WALL OF THE ALCAZABA CADIMA. GRANADA, SPAIN <i>Arco, Julián; Gutiérrez-Carrillo, M^a Lourdes; Bestué Cardiel, Isabel; Sánchez, José; Pavón, M^a Carmen</i>	818
116	DAMAGE OBSERVED IN ANCIENT CHURCHES DUE TO THE EARTHQUAKES OF SEPTEMBER 7TH AND 19TH, 2017 IN MEXICO <i>Peña, Fernando; Chávez, Marcos M.; García, Natalia</i>	827
131	SEISMIC BEHAVIOUR OF NAVES COVERED WITH POINTED VAULTS <i>Monroy, Gustavo; Peña, Fernando</i>	834
133	SIMPLIFIED SEISMIC VULNERABILITY ASSESSMENT OF WOOD HERITAGE BUILDINGS, IN SOUTH CHILE. NUEVA IMPERIAL <i>Valdebenito, Galo; Vázquez, Virginia; Prieto, Andrés J.</i>	842
140	CONDITION MONITORING OF BUILDING ENVELOPE - TECHNICAL INSPECTION USING DRONE TECHNOLOGY <i>Falorca, Jorge; Lanzinha, João Carlos G.</i>	851
143	SEISMIC PERFORMANCE ASSESSMENT OF HISTORICAL CULTURAL HERITAGE MASONRY BUILDINGS: COCCHI SERRISTORI PALACE IN FLORENCE, ITALY <i>Cardinali, Vieri; Coli, Massimo; Cristofaro, Maria Teresa; De Stefano, Mario; Tanganelli, Marco</i>	859

144	MULTIDISCIPLINARY APPROACH TO THE STUDY OF THE STRUCTURAL EVOLUTION OF PALAZZO VECCHIO FLORENCE (ITALY) <i>Paoletti, Barbara; Coli, Massimo; Ferretti, Emanuela; Tanganelli, Marco</i>	867
155	THE KNOWLEDGE PATH FOR THE DEFINITION OF STRUCTURAL SAFETY: COCCHI SERRISTORI PALACE IN FLORENCE, ITALY <i>Cristofaro, Maria Teresa; Coli, Massimo; Donigaglia, Tessa; Lacanna, Giorgio; De Stefano, Mario; Tanganelli, Marco</i>	875
163	DETECTION OF FILLING DEFECTS IN A SLIDING CONCRETE SILO USING NON-DESTRUCTIVE TECHNIQUES <i>Spalvier, Agustin; Domenech, Leandro; Cetrangolo, Gonzalo</i>	883
168	VISUAL PROGRAMMING FOR THE STRUCTURAL ASSESSMENT OF HISTORIC MASONRY STRUCTURES <i>Funari, Marco Francesco; Spadea, Saverio; Ciantia, Matteo; Lonetti, Paolo; Greco, Fabrizio</i>	891
176	EVALUATION OF VEHICLE TRAFFIC VIBRATION IN ANCIENT BUILDINGS IN SALVADOR HISTORIC CENTER <i>Evaristo, Juliana; Fróis, Leticia; Muñoz, Rosana</i>	899
186	SEISMIC DAMAGES OF THE SEPTEMBER 19, 2017 EARTHQUAKE IN MEXICO AND RETROFIT ALTERNATIVES FOR EXISTING BUILDINGS <i>Jara, José; Olmos, Bertha; Martínez, Guillermo</i>	907
202	STRUCTURAL ANALYSIS MODELS FOR THE ASSESSMENT OF SEISMIC VULNERABILITY OF A MASONRY SCHOOL BUILDING UNDER NEW ITALIAN RULES (NTC 2018 AND CIRCULAR 2019) <i>Custodi, Alberto</i>	915
221	NON-DESTRUCTIVE TESTING OF CONCRETE: ANALYSIS OF EXPERIMENTAL RESULTS <i>Ribeiro, António; Rodrigues, Carlos; Félix, Carlos</i>	925
237	AN INTEGRATED APPROACH OF NON-DESTRUCTIVE METHODS FOR INSPECTION AND CHARACTERIZATION OF CULTURAL HERITAGE: CASE STUDY OF MONASTERY OF BATALHA, PORTUGAL <i>Francisco, Carina; Gonçalves, Luisa M.S.; Gonçalves, Gil; Solla Carracelas, Mercedes; Puente Luna, Ivan; Providência, Paulo; Rodrigues, Hugo; Gaspar, Florindo</i>	936
286	MACRO MODELLING IN THE SEISMIC VULNERABILITY ASSESSMENT OF SCHOOL ARCHITECTURE IN ALGERIA <i>Henni-chebra, Abderrahmen Souleyman; Cheikh-Zouaoui, Mustapha; Abdessemed-Foufa, Amina</i>	944
315	SEISMIC VULNERABILITY ASSESSMENT OF PERUVIAN COLONIAL CHURCHES USING THE COLLAPSE MECHANISMS METHODOLOGY, CASE STUDY: PUNO CATHEDRAL - PERU <i>Apaza, Dennis; Tarque, Nicola</i>	953
317	COMPARATIVE EVALUATION BETWEEN DIFFERENT FORMULATIONS OF PHYSICAL DEGRADATION IN EXISTING STRUCTURES OF RC <i>Pantoja, João da Costa; Moura, Sara Prado Novais; Cated, Samir; Pantoja, Mafalda Fabiene Ferreira</i>	962
338	BRICK MASONRY COMPRESSIVE STRENGTH EVALUATION: COMPARISON BETWEEN PREDICTIVE MODELS <i>Ferretti, Francesca; Mazzotti, Claudio</i>	978
343	ANALYSIS OF THE EFFECTS OF TEMPERATURE ON CONTINUOUS MONITORING OF STRESSES IN MASONRY STRUCTURES <i>Blanco, Haydee; Boffill, Yosbel; Lombillo, Ignacio; Renedo, Carlos; Sosa, Israel; Villegas, Luis</i>	986
347	A DISCUSSION ABOUT THE APPLICATIONS OF INFRARED THERMOGRAPHY FOR BUILDINGS DIAGNOSIS <i>Barreira, Eva; Almeida, Ricardo M.S.F.</i>	996
349	AN AUTOMATIC DISCRETE MACRO-ELEMENT METHOD BASED PROCEDURE FOR THE STRUCTURAL ASSESSMENT OF RAILWAY MASONRY ARCH BRIDGES <i>Caddemi, Salvatore; Caliò, Ivo; Cannizzaro, Francesco; Rapicavoli, Davide; Pantò, Bartolomeo; Occhipinti, Giuseppe; D'Urso, Domenico; Corti, Lorenzo; Spirolazzi, Gabriele; Zurlo, Rocco</i>	1004
369	SEISMIC BEHAVIOR OF A MASONRY BELL-TOWER WITH VERTICALITY DEFECT <i>Micelli, Francesco; Cascardi, Alessio; Aiello, Maria Antonietta</i>	1013
400	THE RESPONSE OF GAZI HASAN PAÇA MOSQUE (KOS ISLAND, GREECE) TO 2017 MW 6,6 EARTHQUAKE <i>Karantoni, Fillitsa; Dimakopoulou, Dionisia</i>	1022
404	REHABILITATING OLD TIMBER IN PORTUGUESE 'POMBALINO' BUILDINGS <i>Henriques, Dulce</i>	1030
415	MULTI-RUN OPERATIONAL MODAL ANALYSIS OF A MASONRY HISTORICAL CHURCH: THE CASE STUDY OF SAN GIOVANNI IN MACERATA <i>Baggio, Carlo; Sabbatini, Valerio; Santini, Silvia; Sebastiani, Claudio</i>	1038

421	THE STRUCTURAL CAPACITY EVALUATION: THE IMPORTANCE OF NON-DESTRUCTIVE TESTS <i>Forte, Angelo; Santini, Silvia; Sguerri, Lorena</i>	1047
427	INFLUENCE OF MOISTURE CYCLES AND DIFFERENT IMMERSION MEDIA IN ULTRASONIC VELOCITY IN WOOD <i>Biezma-Moraleda, M^a Victoria; Rodríguez, Cristina; Lombillo, Ignacio; Blanco, Haydee</i>	1055
443	STUDY OF THE MORTAR-SUPPORT INTERFACE BY ADVANCED CHARACTERIZATION TECHNIQUES <i>Travincas, Rafael; Pereira, Manuel; Flores-Colen, Inês; Maurício, António; Torres, Isabel</i>	1064
458	WALL THICKNESS AND WATER CONTENT CONTRIBUTION TO THE OUT-OF-PLANE INSTABILITY OF ADOBE WALLS <i>Al Aqtash, Umaima; Bandini, Paola</i>	1072
462	SEISMIC VULNERABILITY ASSESSMENT OF A MONUMENTAL MASONRY BUILDING <i>De Angelis, Alessandra; Maddaloni, Giuseppe; Pecce, Maria Rosaria</i>	1081
492	SEISMIC VULNERABILITY ASSESSMENT OF THE HISTORICAL CENTRE OF CUSCO, PERU <i>Brando, Giuseppe; Spacone, Enrico; Mazzanti, Claudio; Cocco, Giulia; Sovero, Karim; Alfaro, Crayla; Tarque, Nicola</i>	1089
529	UNCERTAINTIES IN THE EQUIVALENT-FRAME MODELING OF THE SEISMIC BEHAVIOR OF EXISTING MASONRY BUILDINGS <i>Sepe, Vincenzo; Conte, Christian</i>	1097
535	INSPECTION, DIAGNOSTIC ANALYSIS AND SEISMIC IMPROVEMENT OF BUILDINGS DAMAGED BY SEISMIC EVENTS: S. MARIA ASSUNTA CHURCH AT FABBRICO (ITALY) <i>Armanasco, Alessandro; Foppoli, Dario</i>	1106
564	LABORATORY / IN SITU ASSESSMENT OF PREDICTION MODELS FOR MECHANICAL BEHAVIOUR OF ANCIENT BRICKWORK UNDER COMPRESSION <i>Boffill, Yosbel; Blanco, Haydee; Lombillo, Ignacio; Villegas, Luis; Sancibrian, Ramón</i>	1115
568	STRUCTURAL DIAGNOSIS OF THE ARCHITECTURAL HERITAGE: THE KEY ROLE OF HISTORICAL RESEARCH <i>Saisi, Antonella</i>	1124
569	INVESTIGATION STRATEGY FOR THE STRUCTURAL ASSESSMENT OF HISTORIC TOWERS <i>Saisi, Antonella; Gentile, Carmelo</i>	1132
582	AUTOMATIC DETECTION OF DAMPNES PHENOMENA ON ARCHITECTURAL ELEMENTS BY POINT CLOUD SEGMENTATION <i>Galantucci, Rosella Alessia; Musicco, Antonella; Bruno, Silvana; Fatiguso, Fabio</i>	1141
583	INFLUENCE OF THE BACKFILL PARAMETERS IN DISTINCT ELEMENT MODELING (DEM) OF A BACKFILL MASONRY ARCH BRIDGE THROUGH THE PFC2D SOFTWARE <i>García Gómez, Felipe; Martínez Martínez, José Antonio; García Castillo, Luis María; Aragón Torre, Ángel</i>	1149
587	CONTRIBUTION OF CHEMICAL ANALYSIS ON BULDING SURVEYS <i>Tavares Costa, Alice; Costa, Anibal; Magalhães, Clara; Soares, Rosário</i>	1158

1.8.- Guides and regulations.

69	REGULATORY FRAMEWORK ON PRODUCTIVE URBAN LANDSCAPES. WINE URBAN LANDSCAPE OF “EL PUERTO DE SANTA MARIA” CASE STUDY <i>Murillo-Romero, María</i>	1165
272	MANAGEMENT OF THE DIFFERENT PHASES OF AN IRRIGATION DAM CONSTRUCTION PROJECT: CASE STUDY <i>Quiñones Martínez, Rubén; Figueiredo de Oliveira, Rui Alexandre</i>	1174

2.- PROJECT

2.1.- Theoretical criteria of the intervention project.

33	FRONTON CARMELO BALDA OF SAN SEBASTIAN (1969-1973): DECLINE AND INTERVENTION IN BRUTALIST ARCHITECTURE <i>Uranga, Eneko J.; Azcona, Leire; Etxepare, Lauren; Lizundia, Iñigo; Sagarna, Maialen</i>	1183
127	CONTEMPORARY ARCHITECTURE IN PLACES OF MEMORY <i>Pereira, Julia Abreu da Costa</i>	1194
146	MASSERIA CAPPELLI IN THE VALLE DEL CHIARINO, L'AQUILA. REFURBISHMENT STRATEGIES AND REUSE MODELS <i>Bellicoso, Alessandra; Tosone, Alessandra; Sorvillo, Alessandra</i>	1202
175	THEORETICAL APPROACH TO THE RESTORATION AND NEW ARCHITECTURAL DESIGN OF THE BENIGNO MALO HIGH SCHOOL OF CUENCA, ECUADOR <i>Cardoso, Fausto; Rodas, Catalina; Astudillo, Sebastián; Guerra, Jaime</i>	1210
222	ADAPTIVE RE-USE OF THE BUILT HERITAGE: A PROPOSAL FOR THE TOWN OF LEONFORTE (ITALY) <i>Lo Faro, Alessandro; Mondello, Attilio; Moschella, Angela; Salemi, Angelo; Sanfilippo, Giulia</i>	1220
227	THE EXISTING AS STARTING POINT. CONTEMPORARY DESIGN STRATEGIES FOR THE REUSE OF ABANDONED HERITAGE <i>Fernández-Catalina, Manuel; de-los-Ojos-Moral, Jesús</i>	1229
264	STRENGTHENING DEVICES AS ELEMENT OF EXPRESSIVE AND FUNCTIONAL AUTHENTICITY FOR HISTORIC STRUCTURES <i>Ferrari, Lia</i>	1239
265	ROMANIAN CASE STUDY: CHALLENGES IN THE APPLICABILITY OF THE LEEUWARDEN DECLARATION ON LOCAL BUILDINGS HERITAGE <i>Ditoiu, Nina-Cristina; Agachi, Mihaela Ioana Maria</i>	1247
398	ALOIS RIEGL'S AGE VALUE THEORY: SHIFTING IDEOLOGIES AND METHODS IN PRESERVATION PRACTICES <i>Ahmer, Carolyn</i>	1258
407	ENERGY PERFORMANCE AND COMFORT IN SERVICE CONDITIONS OF SOCIAL HOUSING IN HISTORIC CENTERS: TRADITIONAL SOLUTIONS VS PASSIVE HOUSE <i>de Freitas, Vasco Peixoto; de Freitas, Sara Stingl; Feio, Olga; Ferreira, José António</i>	1265
466	APPLICATION OF A MEDITERRANEAN METHODOLOGY IN THE ANALYSIS OF REHABILITATION OF A RESIDENTIAL BUILDING DECLARED HERITAGE MONUMENT OF THE HISTORICAL CENTER OF LIMA - PERU <i>Diaz Santivañez, Mariella; Córdova Camacho, Claudia</i>	1274
479	TECTONICS IN URBAN INTERVENTIONS IN NORMAN FOSTER'S PROJECTS <i>Pantoja, Mafalda; Póvoas, Rui; Pantoja, João</i>	1284
496	WORK PERFORMANCE AS PART OF A DETERMINED SYSTEM OF A CONSTRUCTION PROJECT <i>Dvornik Perhavec, Daniela; Vidaković, Držislav</i>	1292
500	CONSERVATION AND REHABILITATION TO MUSEUM OF LAURINI PALACE IN TITO, POTENZA, ITALY <i>Marino, Francesco Paolo R.; Lembo, Filiberto; Scavone, Paola</i>	1304

2.2.- Traditional materials and construction methods.

43	INFLUENCE OF WATER SATURATION ON MECHANICAL PROPERTIES OF POROUS BUILDING STONES <i>Rabat, Álvaro; Tomás, Roberto; Cano, Miguel</i>	1314
71	THE REINFORCED CONCRETE DOUBLE SLABS FROM THE BEGINNING OF THE 20TH CENTURY. THE FIRST STEPS OF PREFABRICATION IN CONCRETE STRUCTURES <i>Sagarna, Maialen; Uranga, Eneko Jokin; Azcona, Leire; Etxepare, Lauren; Otaduy, Juan Pedro; Lizundia, Iñigo</i>	1324
85	FAILURES OF THE CAST-IRON COLUMNS OF HISTORIC BUILDINGS - CASE STUDIES <i>Goldyn, Michal; Urban, Tadeusz</i>	1333
100	ASSUMPTIONS FOR THE STRUCTURAL AND CONSTRUCTIVE REHABILITATION OF THE TRADITIONAL HOUSING IN THE HISTORICAL CENTER OF GUIMARÃES <i>Silva, Marisa Cardoso; Santiago, Miguel; Lanzinha, João Carlos G.</i>	1341
108	CAPILLARY ABSORPTION COEFFICIENT OF CERAMIC BLOCKS WHEN IN CONTACT WITH MORTAR <i>Azevedo, A.C.; Guimarães, A.S.; Delgado, J.M.P.Q.; Freitas, V.P.</i>	1349
124	MECHANICAL BEHAVIOUR AND RELIABILITY OF ANCIENT CLAY BRICKS FROM ZAMORA (SPAIN) UNDER THREE POINT BENDING TEST <i>Ramos-Gavilán, Ana-Belén; Antón-Iglesias, M^a Natividad; Rodríguez-Esteban, M^a Ascensión; Sáez-Pérez, M^a Paz; Camino-Olea, M^a Soledad; González-Misol, M^a Victoria</i>	1357

161	THE EFFECTS OF TRADITIONAL HOT-LIME TECHNOLOGY ON THE CHARACTERISTICS OF LIME <i>Pesce, Cecilia; Pesce, Giovanni Luca</i>	1366
187	DAMAGES PRODUCED BY THE SEPTEMBER 19, 2017 EARTHQUAKE ON THE TEMPLE OF THE SAINT MATTHEW'S EX CONVENT IN ATLATLAHUCAN, MEXICO <i>Martínez, Guillermo; Jara, José M.; Olmos, Bertha A.</i>	1375
189	MECHANICAL CHARACTERIZATION OF MASONRY SAMPLES EXTRACTED OF MEXICAN CONVENT CHURCHES FROM SIXTEENTH CENTURY <i>Chávez, Marcos M.; Durán, Daniel; Peña, Fernando; García, Natalia</i>	1383
206	ANALYSIS AND CONSERVATION STRATEGIES OF TRADITIONAL TIMBER ROOF STRUCTURES IN NORTHERN MOROCCO <i>Dipasquale, Letizia; Galassi, Stefano; Tempesta, Giacomo; Ruggieri, Nicola</i>	1391
269	MATERIALS AND CONSTRUCTION TECHNIQUES AS A TOOL FOR THE RESTITUTION OF MEDRACENS' BUILDING PROCESS <i>Amokrane, Lamia; Kassab Baba Ahmed, Tsouria; Monjo Carrio, Juan</i>	1399
281	RELATIONSHIP OF THE PRISMA ELASTICITY MODULES OF CERAMIC BLOCKS WITH EMPLOYED MORTARS <i>Fonseca, Platão; Désir, Jean Marie</i>	1407
297	HISTORICAL MORTAR COATING CHARACTERIZATION FOR RECORDING AND RESTORATION PROPOSAL <i>Giordani, Caroline; Guerra, Fernanda L.; Socoloski, Rafaela F.; Zucchetti, Lais; Masuero, Angela B.</i>	1416
370	ACOUSTIC ANALYSIS OF ANCIENT CLAY BRICKS FROM ZAMORA (SPAIN) TO DETERMINE ITS CONTRIBUTION IN REDUCTION OF ENVIRONMENTAL NOISE <i>Antón Iglesias, María Natividad; Rodríguez-Esteban, María Ascensión; Ramos Gavilán, Ana Belén; Sáez-Pérez, María Paz; Camino-Olea, María Soledad; Muñoz-Gamazo, Sebastián Ángel</i>	1425
388	"LOST WOODEN STRUCTURE" THE CHURCH OF SANTIAGO APÓSTOL OF MANJIRÓN (MADRID) <i>Vela Cossío, Antonio; de Mingo García, Javier</i>	1433
422	ALTERNATIVE MATERIALS AND TECHNOLOGICAL SOLUTIONS FOR LOW-INCOME HOUSING IN TROPICAL AFRICA <i>Margani, Giuseppe; Tardo, Carola</i>	1443
447	REINTERPRETATION OF FLAT SCULPTING OF AREQUIPA'S IGNIMBRITE CULTURAL HERITAGE <i>Bustamante, Rosa; Vázquez, Patricia; Llerena, Kelly; Prendes, Nicanor</i>	1451
502	SUSTAINABILITY AND RESOURCE CONSERVATION IN BUILDING INNOVATIONS AND THEIR IMPACT ON SERVICE LIFE EXTENSION OF CONCRETE STRUCTURES <i>Avellan, Kari Christer; Belopotocanova, Erika</i>	1459
531	THE BUILDING OF FALSE VAULTS IN THE MAYA REGION FROM THE EARLY CLASSIC TO THE LATE POSTCLASSIC PERIOD (CENTS. III TO XV D.C.); CONDITIONS OF STRUCTURAL STABILITY, BUILDING FORMS AND REGIONAL VARIATIONS <i>Engelking Keeling, Segismundo</i>	1467
571	ECOLOGICAL RESTORATION MORTARS AND PLASTERS DESIGNED WITH RAW MATERIAL FROM THE ISLAND OF GAVDOS <i>Fotiou, Afroditi; Oiry, Claire; Kapetanaki, Kali; Perdikatsis, Vassilis; Kallithrakas-Kontos, Nikolaos; Maravelaki, Noni-Pagona</i>	1482

2.3.- Novelty products applicable and new technologies.

41	PROPOSAL OF AN INNOVATIVE SOLUTION FOR VENTILATED FAÇADE: DESIGN CONSIDERATIONS AND RELEVANCE IN BUILDING-REFURBISHMENT <i>Pérez-Fenoy, José; Galán-Marín, Carmen; Rivera-Gómez, Carlos</i>	1490
49	NEW MATERIALS TO INCREASE THE THERMAL MASS OF EXISTING BUILDINGS FOR ITS ENERGY REHABILITATION <i>Bartolomé, César; Alarcón, Arturo; Tenorio, José Antonio; Bermejo, Ester</i>	1498
82	ACOUSTIC STUDIES OF CONCRETES CONTAINING INDUSTRIAL CO-PRODUCTS: NEW EXPERIMENTAL APPROACHES <i>Esteban, Alberto; Losáñez, Milagros; Santamaria, Amaia; Ortega-López, Vanesa; San José, José Tomás</i>	1507
94	DESIGN OF HEMP AGGREGATE CONCRETES FOR REHABILITATION AND RETROFIT WORKS OF VERNACULAR ARCHITECTURE. VALORISATION OF HEMP WASTE <i>Sáez-Pérez, M^a Paz; Brümmer, Monika; Durán Suárez, Jorge A; Carretero Ayuso, M.</i>	1515
109	MECHANICAL PROPERTIES OF SCRAP TYRE DERIVED AGGREGATES: STANDARD AND MODIFIED PROCTOR TESTS <i>Contreras-Marín, Elizabeth; Anguita-García, María; Alonso-Guzmán, Elia Mercedes; Jaramillo-Morilla, Antonio; Mascort-Albea, Emilio; Romero-Hernández, Rocío</i>	1523

110	SUSTAINABLE MASONRY MORTARS BASED ON LADLE FURNACE SLAGS FROM THE STEEL-MAKING INDUSTRY <i>Santamaria, Amaia; Fiol, Francisco; García, Veronica; Setién, Jesús; González, Javier-Jesús</i>	1535
113	DURABILITY OF ETICS INCORPORATING HIGH REFLECTANCE PIGMENTS IN FINISHING COATINGS <i>Ramos, Nuno M. M.; Maia, Joana; Almeida, Ricardo M. S. F.; Souza, Andrea R.</i>	1543
136	SELF-COMPACTING CONCRETE MANUFACTURED WITH RECYCLED CONCRETE AGGREGATE <i>Revilla-Cuesta, Víctor; Fiol, Francisco; Skaf, Marta; Serrano, Roberto; Manso, Juan Manuel; Ortega-López, Vanesa</i>	1551
224	DEVELOPMENT AND CHARACTERIZATION OF EXPANSIVE GROUTS FOR CRACK SEALING <i>García Calvo, José Luis; Pedrosa, Filipe; Carballosa, Pedro; Revuelta, David</i>	1559
242	CONSOLIDATION OF LIME MORTARS WITH Ca(OH) ₂ NANOPARTICLES AND TRADITIONAL COATINGS <i>Martínez-Arredondo, Ana; García-Vera, Victoria E.; Navarro, David; Lanzón, Marcos</i>	1567
300	USE OF BUILDING INFORMATION MODELING IN BUILDING MANAGEMENT RETROFITTING PROJECTS: CASE STUDIES <i>Pinto, Rodrigo; Oliveira, Rui; Lopes, Jorge</i>	1575
336	DESIGN OF NEW MATERIALS FOR THE PROTECTION OF CONSTRUCTION UNITS OF RESIDENTIAL BUILDINGS AGAINST FIRE ACTION <i>Rodríguez Saiz, Angel; Santamaría-Vicario, Isabel; Alonso Díez, Álvaro; Gutiérrez-González, Sara; Calderón Carpintero, Verónica</i>	1583
367	DEVELOPMENT OF SUSTAINABLE MORTARS THROUGH THE VALORIZATION OF CUPOLA SLAG <i>Sosa, Israel; Thomas, Carlos; Polanco, Juan Antonio; Setién, Jesús; Tamayo, Pablo; Gonzalez, Laura</i>	1592
382	TECHNICAL AND ECONOMIC EVALUATION OF A DARK ETICS COATING FORMULATED WITH CONVENTIONAL PIGMENTS VERSUS COOL PIGMENTS <i>Sambento, Filipe; Curado, António</i>	1600
390	AN INNOVATIVE DUCTILE MORTAR TO IMPROVE THE SEISMIC RESPONSE OF MASONRY STRUCTURES <i>Laghi, Vittoria; Palermo, Michele; Incerti, Andrea; Gasparini, Giada; Trombetti, Tomaso</i>	1609
419	PRECAST CONCRETE MODULE FOR STRUCTURAL AND ENERGY REHABILITATION OF REINFORCED CONCRETE BUILDINGS <i>Martiradonna, Silvia; Fatiguso, Fabio; Lombillo, Ignacio</i>	1618
490	BIM METHODOLOGY TO SUPPORT THE FUNCTIONAL REHABILITATION OF A BUILDING <i>Lopes, João; Falcão Silva, Maria João; Couto, Paula; Pinho, Fernando</i>	1627
553	ACCEPTANCE OF BUILDING INTEGRATED PHOTOVOLTAIC (BIPV) IN HERITAGE BUILDINGS AND LANDSCAPES: POTENTIALS, BARRIERS AND ASSESTMENT CRITERIA <i>Polo López, Cristina S.; Lucchi, Elena; Franco, Giovanna</i>	1636

2.4.- Sustainable design and energy efficiency.

36	FACING CLIMATE CHANGE OVERHEATING IN CITIES THROUGH MULTIPLE THERMOREGULATORY COURTYARD POTENTIAL CASE STUDIES APPRAISAL <i>Diz-Mellado, Eduardo M.; Galán-Marín, Carmen; Rivera-Gómez, Carlos; López-Cabeza, Victoria Patricia</i>	1645
74	ACTIVE RENOVATION STRATEGIES WITH BUILDING-INTEGRATED PHOTOVOLTAICS (BIPV). APPLICATION ON AN EARLY 20TH CENTURY MULTI-FAMILY BUILDING <i>Aguacil Moreno, Sergi; Rey, Emmanuel</i>	1653
88	MID-TWENTIETH CENTURY HERITAGE HOUSING'S THERMAL ENVELOPE ASSESSMENT: EL CARMEN NEIGHBOURHOOD CASE STUDY <i>Roa-Fernández, Jorge; Galán-Marín, Carmen; López-Martínez, José A.; Rivera-Gómez, Carlos; Ponce, Mercedes; Romero-Odero, José Antonio</i>	1662
91	SOCIAL HOUSING RETROFIT IN BEIRA INTERIOR FOR PRESENT AND FUTURE CLIMATE SCENARIOS <i>Brandão, Pedro; Lanzinha, João C. G.</i>	1670
103	ENERGY REHABILITATION OF SCHOOLS IN SPAIN. ENERGY STRATEGIES FOR NEARLY ZERO ENERGY BUILDING IN DIFFERENT CLIMATE ZONES <i>Castro Vázquez, José Manuel</i>	1678
141	A MULTI-LEVEL STRATEGY FOR THE SUSTAINABLE RECOVERY OF HISTORIC CENTRES <i>Losco, Giuseppe; Pierleoni, Andrea; Roncaccia, Elisa; Gialluca, Silvia</i>	1686

169	NOVEL METHODOLOGY TOWARDS A DEEP RETROFIT IN MEDITERRANEAN SCHOOL SOF CLIMATIC ZONES: C2, D3, D2, E1 <i>Crespo Sánchez, Eva; Dacosta Díaz, Juan Ramón; Kampouropoulos, Konstantinos</i>	1697
195	NZEB SCHOOLS IN ITALY: DEFINITION AND OPTIMIZATION OF SYSTEM USING PHOTOVOLTAIC TECHNOLOGY <i>Ciacchi, Cecilia; Bazzocchi, Frida; Di Naso, Vincenzo; Rocchetti, Andrea</i>	1705
196	INDOOR ENVIRONMENTAL QUALITY OF DWELLINGS IN THE HISTORICAL CITY CENTER OF VISEU (PORTUGAL) <i>Almeida, Ricardo; Mendes da Silva, José; Lopes, Carla</i>	1714
199	INCOMING STRATEGIES FOR ENERGY PERFORMANCE REQUIREMENTS AT MOST FREQUENTLY ADOPTED GREEN BUILDING RATING SYSTEMS FROM A REFURBISHMENT PERSPECTIVE <i>Sánchez Cordero, Antonio; Gómez Melgar, Sergio; Andújar Márquez, José Manuel</i>	1722
201	EVALUATION OF THERMAL BEHAVIOR IN AN EARLY 20TH CENTURY VALLADOLID BRICK FACADE, ACCORDING TO ITS WATER CONTENT <i>Camino-Olea, María Soledad; Llorente-Álvarez, Alfredo; Cabeza-Prieto, Alejandro; Rodríguez-Esteban, María Ascensión; Sáez-Pérez, María Paz</i>	1735
208	REUSE OF CERAMIC AND PLASTIC WASTE AS AGGREGATE IN MORTARS FOR THE MANUFACTURE OF PREFABRICATED BEAM-FILLING PIECES IN STRUCTURAL FLOORS <i>Pedreño Rojas, Manuel Alejandro; Rubio de Hita, Paloma; Pérez Gálvez, Filomena; Morales Conde, María Jesús; Rodríguez Liñán, Carmen; Romero Gómez, María Isabel</i>	1743
215	AN ARCHITECTURAL APPROACH FOR THE DESIGN, CONSTRUCTION, AND MANAGEMENT OF MINIMUM ENERGY BUILDINGS RETROFITTED IN SUBTROPICAL CLIMATES <i>Gómez Melgar, Sergio; Martínez Bohórquez, Miguel Ángel; Andújar Márquez, José Manuel</i>	1751
220	REGENERATION STRATEGIES ON SOCIAL HOUSING IN CHILE: FROM DEMOLITION TO TRANSFORMATION BETWEEN PAST, PRESENT AND FUTURE <i>Bustamante, Waldo; Bertolini, Enrico; Melano, Mario; Romeo, Emanuele; Schmitt, Cristian; Serra, Valentina</i>	1760
223	TEMPERATURE VALIDATION OF AN ADVANCED HYGROTHERMAL MODEL: STATISTICAL ANALYSIS <i>Barbosa, F.C.; De Freitas, V.P.; Almeida, M.</i>	1771
225	THE INFLUENCE OF INSULATION ON THE PASSIVE DISCOMFORT INDEX OF DWELLINGS LOCATED IN HISTORICAL BUILDINGS WITH INTERMITTENT HEATING PATTERNS <i>Magalhães, Sílvia A.; Freitas, V. P.; Alexandre, J. L.</i>	1778
266	EXPERIMENTS IN HYGROTHERMAL AND FREEZE/THAW EFFECTS OF INSULATING MASS MASONRY WALLS <i>Artigas, David</i>	1788
283	GREEN DESIGN OF ECO-CEM SYSTEMS AS A PROPOSAL FOR SUSTAINABLE REHABILITATION OF HISTORICAL CEMETERIES. CASE STUDY: LA APACHETA GENERAL CEMETERY - AREQUIPA <i>Roque-Rodríguez, Francisco Javier; Hidalgo-Valdivia, Alejandro Víctor; Montesinos-Tubée, Daniel Bernardo; Alvarez-Tejada, Erik Miguel; Medina Ramos, Robert Joaquín</i>	1797
337	DESIGN AND STUDY OF PREFABRICATED MATERIALS FOR USE IN THE INTERIOR CONSTRUCTION AND ENERGY REHABILITATION OF THE BUILT HERITAGE <i>Rodríguez Saiz, Angel; Santamaria-Vicario, Isabel; Alameda Cuenca-Romero, Lourdes; Gutiérrez-González, Sara; Calderón Carpintero, Verónica</i>	1806
372	ENERGY RENOVATION OF THE BUILT HERITAGE HOUSING BASED ON THE LIVING BUILDING CHALLENGE CERTIFICATION. CASE STUDY IN BRESCA (SPAIN) <i>Aguacil, Sergi; Moreno, Victor; Pauwels, Emmanuel</i>	1814
409	HOSPITAL LIGHTING: FROM VISUAL FUNCTION ASSISTANCE TO THE WELCOMING AND HUMANIZATION TOOL <i>Moura, Mariangela; Lopes, Ricardo G.</i>	1823
423	DESIGN OF SUSTAINABLE SOLUTIONS FOR CONCRETE BLOCK WALLS <i>González-Fonteboa, Belén; Seara-Paz, Sindy; Martínez-Abella, Fernando; Pinto-Pérez, Adonay; García-Carrillo, Pablo; Prego-Martínez, Javier; Millán-Pérez, Jose; Díaz-Méndez, Rodrigo</i>	1832
431	A DESIGNING METHODOLOGY FOR OPTIMAL SIZING OF PHOTOVOLTAIC AND ELECTRICAL STORAGE SYSTEMS FOR TERTIARY BUILDINGS <i>Castellà, Marc; Castro, Cristina; Crespo, Eva; Kampouropoulos, Konstantinos</i>	1841
435	A THERMAL COMFORT ASSESSMENT IN A REHABILITATED RESIDENTIAL BUILDING OF THE CITY CENTER OF TEGUCIGALPA, HONDURAS <i>Gamero-Salinas, Juan Carlos; Monge-Barrio, Aurora; Sánchez-Ostiz, Ana</i>	1849
461	ECO-REHABILITATION OF COURTYARD HOUSE <i>Hania, Taib; Aissa, Mahimoud</i>	1857

484	BIM METHODOLOGY IN ENERGETIC REHABILITATION OF BUILDINGS: APPLICATION TO A PUBLIC RESEARCH LABORATORY <i>Silva, Sara; Falcão Silva, Maria João; Couto, Paula; Pinho, Fernando</i>	.....	1865
501	CONSERVATION AND RENOVATION TO NZEB OF SILVIO SPAVENTA FILIPPI ELEMENTARY SCHOOL IN AVIGLIANO, POTENZA, ITALY <i>Lembo, Filiberto; Marino, Francesco Paolo R.; Rinaldi, Carmen</i>	.....	1873
522	NEW FUNCTIONAL ROLES AND ENERGY EFFICIENCY IMPLEMENTATION IN THE RECOVERY OF MINOR HISTORICAL CENTRES <i>Rotilio, Marianna</i>	.....	1882
537	SUSTAINABLE CONSTRUCTION AS A FUTURE HERITAGE: TECHNIQUE, ROOT AND NATURAL CONTRACT <i>Bedoya Montoya, Carlos</i>	.....	1890
543	SUSTAINABILITY THROUGH RECYCLING FOR BUILDING SELF- CONSUMPTION <i>Madrazo, Alfredo; Balbás, Francisco Javier; Aranda, José Ramón; García, Javier; Ceña, Alberto</i>	.....	1897
549	THE THERMAL COMFORT IN BUILDINGS OF VERNACULAR ARCHITECTURE OF THE CITY OF LOJA AND MALACATOS – ECUADOR <i>Tapia, Wilson; Correa, Ramiro</i>	.....	1905
552	DISSEMINATION OF BEST-PRACTICE IN ENERGY RETROFIT OF HISTORIC BUILDINGS. RAINHOF, A CASE STUDY IN THE ITALIAN ALPS <i>Herrera-Avellanosa, Daniel; Exner, Dagmar; Haas, Franziska; Troi, Alexandra</i>	.....	1918
573	IS INFORMATION SYMMETRY SUFFICIENT IN THE PROMOTION OF ENERGY EFFICIENT HOUSING? MAIN RESULTS OF THE ENERVALOR PROJECTS <i>Marmolejo-Duarte, Carlos; Spairani, Silvia; Del Moral, Consuelo; Delgado, Luis; Chen, Ai; Pérez, C.</i>	.....	1927

3.- BUILDING INTERVENTION

3.1.- Intervention plans.

22	RETHINKING HOUSES FOR WILDLAND FIRE PROTECTION <i>Tenreiro, Teresa; Branco, Fernando; Arruda, Mario R.T.</i>	1937
70	THE DIRECTOR PLAN FOR THE RECOVERY OF THE LORCA CULTURAL HERITAGE AFTER THE SISM OF 2011. COMPARATIVE ANALYSIS IN THE INTERNATIONAL CONTEXT <i>García Martínez, María del Sagrado Corazón; Martínez Ríos, Carmen</i>	1946
185	MULTI-SCALAR ANALYSIS SYSTEM FOR THE PRIORITIZATION OF INTERVENTIONS IN ARCHITECTURAL HISTORICAL HERITAGE: THE CASE OF SAN AGUSTÍN NEIGHBORHOOD IN PUEBLA CITY, MEXICO <i>Parra, Jaime; Lombillo, Ignacio; Ribalaygua, Cecilia</i>	1955
488	MULTICRITERIA ANALYSIS TO SUPPORT DECISION IN PUBLIC BUILDINGS REHABILITATION INTERVENTIONS <i>Barcelos, João; Falcão Silva, Maria João; Couto, Paula; Pinho, Fernando</i>	1964
489	MULTICRITERIA ANALYSIS APPLIED TO PUBLIC REHABILITATION INVESTMENTS <i>Couto, Paula; Falcão Silva, Maria João; Salvado, Filipa</i>	1972
584	CLASSIFICATION OF ROOF TYPES IN EXISTING RESIDENTIAL BUILDINGS IN MADRID. DATA FOR AN ENERGY REHABILITATION STRATEGY <i>Alonso, Carmen; de Frutos, Fernando; Martín Consuegra, Fernando; Frutos, Borja; Galeano, Javier; Oteiza, Ignacio</i>	1981

3.2.- Rehabilitation and durability.

67	CORROSION PROTECTION FOR STEEL TENDON UNDER THE ANCHORAGE HEAD OF EXISTING GROUND ANCHOR <i>Liao, Hung-Jiun; Chen, Chun-Chung</i>	1989
191	SEISMIC ASSESSMENT AND RETROFITTING OF AN OLD MASONRY BARRACK <i>Zucca, Marco; Crespi, Pietro; Mendoza, Russell; Ruggeri, Luca</i>	1997
204	REHABILITATION OF TWO MASONRY BRIDGES IN CUEVA (BURGOS, SPAIN) <i>Martínez Martínez, José Antonio; Aragón Torre, Angel; García Castillo, Luis María; Aragón Torre, Guillermo</i>	2006
212	CONCRETE SURFACE APPLIED CORROSION INHIBITORS: ON SITE EVALUATION BY NON-DESTRUCTIVE ELECTROCHEMICAL TECHNIQUES <i>Martínez, Isabel; Castillo, Angel</i>	2015
230	NUMERICAL INVESTIGATION OF THE STRUCTURAL PERFORMANCE OF AGED RC BRIDGE COLUMNS SUBJECTED TO CORROSION AND SERVICE LOADS <i>Dabas, Maha; Zaghian, Sepideh; Martín-Perez, Beatriz; Almansour, Husham</i>	2023
232	STRUCTURAL RESTORATION OF THE BUILT HERITAGE: CASE STUDY OF TAZI PALACE HOTEL <i>Kaddouri, Hajar; Cherradi, Toufik; Kourdou, Ibtissam</i>	2032
333	EVOLUTION OF PHYSICAL AND MECHANICAL PROPERTIES OF BRICKS TREATED WITH DIFFERENT CONSERVATION PRODUCTS APPLICABLE IN THE REPLACEMENT OF EXPOSED BRICKS IN HERITAGE BUILDINGS <i>Romay Carola; Charbonier, Andrea; Rodríguez de Sensale, Gemma</i>	2042
429	QUANTIFICATION OF WATER TRANSPORT IN FACADES WITH THE USE OF HYGROTHERMAL SIMULATION <i>Mota, Larissa; Bauer, Elton</i>	2051
532	STUDY OF THE REHABILITATION PRACTICES IN VILA REAL HISTORIC CENTRE: CASE STUDY <i>Mendonça, Alana; Dominguez, Caroline; Mendes da Silva, José; Paiva, Anabela</i>	2060
538	PROMPT QUALITY ASSESSMENT METHODS FOR REHABILITATION PROJECTS: THE METHOD 'MIMAQ' <i>Mouraz, Catarina P.; Silva, J. Mendes</i>	2068
548	EXPERIMENTAL TESTS OF SCHIST MASONRY SINGLE LEAF WALLS STRENGTHENED WITH GROUTS <i>Luso, Eduarda</i>	2078
581	THE RISKS OF THE CURRENT CONCRETE REPAIR SYSTEM. NEW APPROACHES WITH STAINLESS STEEL REINFORCING BAR <i>Salmerón Martínez, Antonio; Salvador Landmann, Miguel; Casero Sogorb, Santiago</i>	2086

3.3.- Reinforcement technologies.

14	ADOBE MASONRY WALLS REINFORCED WITH WEAVING WASTE <i>Buson, Márcio; Varum, Humberto</i>	2094
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54	EVALUATION OF BOND BETWEEN REINFORCEMENT BARS AND REACTIVE POWDER CONCRETE <i>Costa Piccinini, Ángela; Rubem Montedo, Oscar; Pavei Antunes, Elaine</i>	2104
117	REINFORCED INJECTION AS A UNDERPINNING TECHNIQUE CAREFUL WITH ARCHEOLOGY AND ARCHITECTURAL HERITAGE <i>da Casa, Fernando; Echeverría, Ernesto; Celis, Flavio</i>	2112
158	OPEN ISSUE FOR CONFINEMENT OF MASONRY COLUMNS WITH FRCM-SYSTEM: THEORETICAL AND EXPERIMENTAL INVESTIGATION <i>Aiello, Maria Antonietta; Cascardi, Alessio; Ombres, Luciano; Verre, Salvatore</i>	2121
379	EXECUTION AND REPAIR OF MASONRY STRUCTURES USING MORTAR REINFORCED WITH NATURAL FIBERS IN A CEMENTITIOUS MATRIX <i>La Tegola, Antonio; Mera, Walter</i>	2130
385	REPARATION AND STRUCTURAL STRENGTHENING IN MASONRY STRUCTURES WITH INNOVATIVE SYSTEMS OF LOW THICKNESS, SRG AND FRCM <i>Dobón Tamarit José; Sánchez Martínez José L.</i>	2140
439	EXPERIMENTAL STUDY OF IN-PLANE SHEAR BEHAVIOUR OF BRICK MASONRY RETROFITTED WITH BASALT AND STEEL REINFORCED MORTARS <i>García-Ramonda, Larisa; Pelà, Luca; Roca, Pere; Camata, Guido</i>	2149
505	U-SHAPED FRCM FOR STRENGTH AND DEFORMATION ENHANCEMENT OF REINFORCED CONCRETE BEAMS <i>Ebead, Usama; El-Sherif, Hossameldin</i>	2157
512	COMPARATIVE ANALYSIS OF THE EXISTING CALCULATION RECOMMENDATIONS FOR STRENGTHENING WITH COMPOSITE MATERIALS OF RC COLUMNS OF RECTANGULAR SECTION <i>Castro, Viviana J.; De Diego, Ana; Martínez, Sonia; Piñeiro, Rafael; López, Cecilio; Echevarría, Luis; Gutiérrez, José Pedro</i>	2164
513	STRENGTHENING OF LOW-STRENGTH CONCRETE COLUMNS WITH FIBRE REINFORCED POLYMERS. FULL-SCALE TESTS <i>Martínez, Sonia; de Diego, Ana; Castro, Viviana J.; Echevarría, Luis; Barroso, Francisco J.; Rentero, G.; Soldado, R.; Gutiérrez, José Pedro</i>	2172
525	TRANSFORMING THE CONSTRUCTION IN COASTAL ZONES: IMPLEMENTING GFRP REINFORCING BARS IN CONCRETE STRUCTURES <i>Ruiz Empananza, Alvaro; De Caso, Francisco; Nanni, Antonio</i>	2180
527	CASE STUDY OF FRP APPLICATION: THE HALLS RIVER BRIDGE <i>Cadenazzi, Thomas; Ruiz Empananza, Alvaro; Nanni, Antonio</i>	2191
560	NSE/EB-FRCM TECHNIQUE FOR STRENGTHENING OF RC BEAMS IN SHEAR <i>Ebead, Usama; Wakjira, Tadesse</i>	2200
566	EFFICACY OF NSM HYBRID FRP STRIPS FOR SHEAR STRENGTHENING OF RC DEEP BEAMS <i>Ibrahim, Mohamed; Ebead, Usama</i>	2209
578	STRENGTHENING OF A MASONRY WALL IN SEISMIC PRONE AREA WITH THE CAM SYSTEM: EXPERIMENTAL AND NUMERICAL RESULTS <i>Recupero, Antonino; Spinella, Nino</i>	2218
585	SHEAR STRENGTHENING OF RC BEAMS WITH STEEL REINFORCED GROUT (SRG) <i>Wakjira, Tadesse; Ebead, Usama</i>	2229
586	EXTERNALLY BONDED HYBRID CARBON/GLASS FRP STRIPS FOR SHEAR STRENGTHENING OF RC DEEP BEAMS <i>Ibrahim, Mohamed; Ebead, Usama</i>	2237
588	OPTIMISATION OF STAINLESS STEEL REBARS TO REPAIR MASONRY STRUCTURES <i>Rodríguez-Mayorga, Esperanza; Ancio, Fernando; Hortigon, Beatriz</i>	2246
591	EFFECT OF USING MULTIPLE FABRIC PLYS ON THE TENSILE BEHAVIOUR OF CARBON TEXTILE REINFORCED MORTAR <i>Younis, Adel; Ebead, Usama</i>	2255

3.4.- Restoration of artworks.

152	EVALUATION OF THE PHYSICAL AND PATHOLOGICAL STATE USING THE LASER SCANNER TECHNIQUE OF THE MURAL FACES OF THE CITY BY THE ARTIST RAMÓN VÁSQUEZ, AT THE SENA DE PEDREGAL FACILITIES IN THE CITY OF MEDELLÍN - COLOMBIA <i>Pérez-Salazar, Jhony; Cañola, Hernán Darío; Builes-Jaramillo, Alejandro; Cardona-Chavés, Myriam; Múnera-Zapata, Julián</i>	2262
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3.5.- Conservation of industrial heritage.

39	DURABILITY OF THE OLD PREFABRICATED CONCRETE NAVES OF ENSIDESA, AVILÉS (SPAIN) <i>Lozano, Alfonso; Alonso, Mar; Álvarez, Felipe; Del Coz, Juan José</i>	2270
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142	THE SELECTED ISSUES OF ADAPTATION OF 19TH AND 20TH CENTURY POST-INDUSTRIAL BUILDINGS IN ŁÓDŹ <i>Urban, Tadeusz; Goldyn, Michał</i>	2279
180	ANALYSIS OF THE PLANNED WORKER HABITAT IN THE UPPER & MEDIUM BASIN OF SIL RIVER (LEÓN, SPAIN) <i>Magaz Molina, Jorge</i>	2287
192	NORMATIVE, TECHNICAL AND EXECUTION CONDITIONERS FOR THE INTERVENTION IN TWO 19TH CENTURY BRICK CHIMNEYS <i>Gómez Barrado, Sergio; Bustamante Fernández, Víctor; Carricondo Sánchez, Elena; Calderón Bello, Enrique; Rodríguez Escribano, Raúl Rubén</i>	2297
249	CONSTRUCTION OF IRON CARBONATE CALCINATION FURNACES AT THE CATALINA MINE IN SOPUERTA, BISCAY <i>Beldarrain-Calderón, Maider</i>	2306
254	OBSOLESCENCE AND RECONVERSION OF AN HISTORICAL MONUMENT IN SOUTHERN CHILE. THE CASE OF THE RAILWAY BRIDGE OVER THE CHOL CHOL RIVER, LA ARAUCANÍA REGION <i>Horn, Andrés; Vásquez, Virginia; Olivares, Juan Carlos</i>	2317
339	LIFE CYCLE ANALYSES APPLIED TO HISTORIC BUILDINGS: INTRODUCING SOCIO-CULTURAL VALUES IN THE CALCULUS OF SUSTAINABILITY <i>Flyen, Anne-Cathrine; Flyen, Cecilie; Fufa, Selamawit Mamo</i>	2326
374	HYDRAULIC ENGINEERING OF THE XVI CENTURY IN THE HISPANIOLA ISLAND. THE SAN CRISTOBAL SUGAR MILL OF DIEGO CABALLERO <i>Prieto Vicioso, Esteban; Flores Sasso, Virginia</i>	2336
473	APPLICATION OF COST-BENEFIT ANALYSIS TO INDUSTRIAL HERITAGE REHABILITATION INTERVENTIONS <i>Falcão Silva, Maria João; Salvado, Filipa; Couto, Paula; Baião, Manuel</i>	2347
503	CONSTRUCTIVE SOLUTIONS AND REHABILITATION INTERVENTIONS IN LISBON WORKER HOUSING CONSTRUCTION: HISTORICAL OVERVIEW <i>Falcão Silva, Maria João; Baião, Manuel</i>	2356
579	SMART APPROACHES FOR INDUSTRIES CONVERSION THROUGH ADAPTIVE REUSE MODELS: THE INDUSTRIAL AREA OF BARI-MODUGNO <i>Vizzarri, Corrado; Baccaro, Arianna; Fatiguso, Fabio</i>	2363

3.6.- Examples of intervention.

29	HIGHER EDUCATION INSTITUTIONS IN HISTORIC BUILDINGS <i>Bialkiewicz, Andrzej</i>	2372
47	EXAMINING THE RELATIONSHIP BETWEEN NEW FUNCTION AND BUILDING SUB-SYSTEM INTERVENTIONS OF REUSED INDUSTRIAL BUILDINGS-CASE OF TURKEY <i>Çakur, Hatice Yasemin; Edis, Ecem</i>	2379
77	MODERN FAÇADE CLADDINGS REFURBISHMENT: METHODOLOGY AND APPLICATION TO A SIGNIFICANT CASE STUDY <i>Mazzucchelli, Enrico Sergio; Stefanazzi, Alberto</i>	2389
99	TRACES OF TIME: SECOND STAGE OF THE RESTORATION PROJECT ON QUINTA TORRE ARIAS'S CLOSURE WALL, MADRID <i>Sánchez Arroyo, Jesús; Bustamante Fernández, Víctor; Gómez Barrado, Sergio; Calderón Bello, Enrique; López Sánchez, Pedro; Blanco Zorroza, Alberto</i>	2399
123	ASSESSMENT OF BUILDINGS OF HISTORICAL PATRIMONIAL VALUE. STUDY CASE: MANOR "EL LEONCITO", SAN JUAN, ARGENTINA <i>Saldívar, Mary; Merlo, Alberto; Videla, Federico; Herrera, Fernanda; Garino, Lucas; Flores, Mario</i>	2410
145	CRACKING OF A EXTERIOR DOUBLE WALL OF A HIGHER EDUCATION SCHOOL <i>Pinto, M., Padrão, J., Oliveira, A.</i>	2418
214	EXTENSION OF THE 19TH CENTURY ROAD BRIDGE PLATFORM <i>Collazos-Arias, Felipe; Garcia-Sánchez, David; Ruiz-Bedia Maria L.</i>	2427
243	PRESERVING THE DESIGN INTENT WITH MODERN TECHNOLOGY <i>Sacks, David</i>	2435
294	THE INTERVENTION PROJECT OF THE "BANCO PELOTENSE DO VALE DO CAÍ" <i>Betemps Vaz da Silva, Juliana; Uez, Pablo Cesar; Rauber Motter, Cristiane; Deitos Dalmas, Mirela; Langaro, Carmen Silvia</i>	2443
302	SAN FRANCISCO RAMADA: RELIGIOUS VICE REGAL ARCHITECTURE IN LAMBAYEQUE - PERU <i>Chirinos, Haydeé; Zárate, Eduardo; Beltrán, Freddy</i>	2451
310	FEASIBILITY STUDY AND CONTROL OF THE CONSTRUCTION IN THE REHABILITATION OF TRADITIONAL DWELLINGS: REHABILITATION OF MANOR HOUSE IN ARDANAZ DE EGÜÉS (NAVARRA) <i>Torres-Ramo, Joaquín; Quintanilla-Crespo, Verónica</i>	2460

313	METHODOLOGICAL PROCESS FOR THE INTERVENTION IN THE PATRIMONIAL BUILDINGS OF THE NEIGHBORHOOD EL VERGEL, "LAS HERRERÍAS" STREET, CUENCA - ECUADOR <i>Rodas, Catalina; Auquilla, Silvia; Rodas, Tatiana; Barsallo, Gabriela</i>	2468
408	COMMISSIONING OF AIR-CONDITIONING AND VENTILATION SYSTEMS IN A PUBLIC MUSEUM STORING HISTORICAL CULTURAL PROPERTIES <i>Ishikawa, Kazuki; Iba, Chiemi; Ogura, Daisuke; Hokoi, Shuichi; Yokoyama Misao</i>	2477
414	ANOMALIES IN THE PARTITION WALLS OF A PUBLIC BUILDING: ANALYSIS OF POSSIBLE CAUSES AND REPAIRING STRATEGY <i>Sousa, Rui; Sousa, Hipolito; Vila Pouca, Nelson</i>	2486
417	EVALUATION OF CONSERVATION STATE AND STRUCTURAL SAFETY OF A WOOD STRUCTURE AND PROPOSAL OF INTERVENTION MEASURES <i>Sousa, Rui; Faria, Amorim</i>	2497
430	XIX CENTURY BRIDGE REPAIR, IN DEBA, NORTH OF SPAIN DUE TO THE VERTICAL SUBSIDENCE OF ONE OF ITS PIERS <i>Cosano López-Fando, Luis; Collazos-Arias, Felipe; Echeveste, Txomin ; Garcia-Sánchez, David</i>	2506
433	TECHNOLOGICAL ANALYSIS, TYPOLOGICAL FEATURES AND SEISMIC VULNERABILITIES OF POST-WORLD WAR II ITALIAN SCHOOL BUILDINGS <i>Monni, Francesco; Maracchini, Gianluca; Quagliarini, Enrico; Lenci, Stefano</i>	2514
436	OPTIMIZATION OF AN ACTIVE DEPRESSURIZATION SYSTEM, FOR RADON MITIGATION IN AN EXISTING BUILDING IN MADRID <i>Frutos, Borja; Alonso, Carmen; Muñoz, Eduardo; Martín-Consuegra, Fernando; Sainz, Carlos; Oteiza, Ignacio</i>	2522
441	RIONE FOSSI AND THE DUCAL PALACE OF ACCADIA: RECOVERY CRITERIA, SEISMIC RETROFITTING AND REHABILITATION <i>Viskovic, Alberto; Radogna, Donatella; Casamassima, Giorgia Noemi</i>	2531
455	LOCAL HERITAGE ENFORCEMENT METHODOLOGY: A GLOBAL PROCESS OF IDENTITY REVIVAL. STUDY CASE OF THE TOWER OF THE CHURCH OF THE ASSUMPTION (GUADALCANAL, SEVILLA) <i>Rincón-Calderón, José María; Galán-Marín, Carmen; Rivera-Gómez, Carlos</i>	2539
485	COSTS AND TECHNOLOGIES IN SCHOOL BUILDINGS REHABILITATION WORKS <i>Neto, Tiago; Couto, Paula; Falcão Silva, Maria João; Baião, Manuel; Pinho, Fernando</i>	2548
499	REHABILITATION OF THE ROOF STRUCTURE OF THE MULTIUSE ROOM OF THE "ALVES MARTINS" SECONDARY SCHOOL, VISEU, PORTUGAL <i>Negrão, João</i>	2557
555	PATRIMONIAL STUDY OF THE REAL FELIPE FORTRESS OF CALLAO-PERU <i>Celis Estrada, Diego Javier</i>	2567
570	ALMALLUTX: A RENOVATION PROPOSAL IN A VERNACULAR ARCHITECTURE EXAMPLE IN SIERRA DE TRAMUNTANA (MALLORCA) <i>Martínez Cuart, Irene; González Yunta, Francisco; Moreno Fernández, Esther; Sepulcre Aguilar, Alberto</i>	2575

4.- MAINTENANCE

4.1.- Construction maintenance.

50	DIRECTIVES FOR THE EVALUATION OF THE CONDITIONS OF THE ENVELOPE OF CURRENT BUILDINGS IN CONDOMINIUM REGIME <i>Neves, Vitorino; Lanzinha, João</i>	2585
83	GENIA: INSPECTION, EVALUATION AND BRIDGE MANAGEMENT TOOL <i>Piñero Santiago, Ignacio; Díez Hernández, Jesús; Salgado Marina, David; Cuadrado Rojo, Jesús; Orbe Mateo, Aimar</i>	2593
203	METHODOLOGY FOR THE STUDY OF PATHOLOGIES IN POST-TENSIONED SLAB BRIDGES. AN APPROACH TO MONITORING AND CONTROL <i>López Rodríguez, Eduardo; Carpintero García, Ismael</i>	2604
468	THE COMMON MISTAKES DURING THE INTERVENTION IN EARTHEN VERNACULAR ARCHITECTURE <i>García, Gabriela; Caldas, Victor; Vázquez, Marcelo</i>	2613
518	AIR POLLUTION IMPACTS ON TRADITIONAL BUILDING MATERIALS: FROM SAMPLE EXPOSURE TESTING TO AN URBAN SCALE ASSESSMENT <i>Vidal, Fábio; Vicente, Romeu; Mendes Silva, J.; Dias, Daniela; Pina, Noela; Tchepel, Oxana</i>	2622

4.2.- Preventive conservation of built heritage.

55	RISK ANALYSIS METHODOLOGY APPLIED TO EARTHEN FORTIFICATIONS. THE TORRE DE RIJANA: A CASE STUDY <i>Gutiérrez-Carrillo, M^a Lourdes; Bestué Cardiel, Isabel; Molina Gaitán, Juan C.; Molero Melgarejo, Emilio</i>	2631
96	MICROCLIMATIC ANALYSIS IN THE LIBRARY OF THE FACULTY OF HUMANITIES AND EDUCATION SCIENCES, UNIVERSITY OF LA PLATA, ARGENTINA: A CASE-STUDY <i>Gómez, Analía Fernanda; Diulio, María de la Paz</i>	2640
178	VULNERABILITY AND IDENTIFICATION OF EVACUATION ROUTES FOR HAZARDS IN THE HISTORIC ENVIRONMENT OF THE LOWER ALBAYCÍN <i>Martínez Ramos e Iruela, Roser; Martín Martín, Adelaida; García Nofuentes, Juan Francisco</i>	2648
234	CULTURAL HERITAGE MAINTENANCE CAMPAIGNS AS TRIGGERS OF PARTICIPATORY PROCESSES IN THE CITY OF CUENCA (ECUADOR) <i>Tenze, Alicia; García, Gabriela; Jara, David; Cardoso, Fausto; Amaya, Jorge</i>	2659
236	WHOLE HISTORICAL STUDIES OF FIFTY BRIDGES OF THE SPANISH ROAD AND RAIL NETWORKS <i>Carpintero García, Ismael; Rueda Puerta, Jorge</i>	2668
248	A CASE STUDY ON SEISMIC VULNERABILITY ASSESSMENT OF MASONRY BUILDINGS BY USING CARTIS DATABASE <i>Olivito, Renato S.; Porzio, Saverio; Codispoti, Rosamaria; Scuro, Carmelo</i>	2677
278	MAINTENANCE BOOKLETS FOR BUILT HERITAGE, APPLIED IN THE HISTORICAL CENTER OF CUENCA - ECUADOR <i>Barsallo, Gabriela; Cardoso, Fausto; Astudillo, Sebastián; Achig-Balarezo, María Cecilia</i>	2685
396	METHODOLOGIES FOR EVALUATING THE IMPACT OF CLIMATE ASPECTS ON HERITAGE CONSTRUCTIONS: A DELPHI METHOD APPLICATION <i>Carpio, Manuel; Prieto, Andrés J.</i>	2694
460	RISK ASSESSMENT AND ACTIONS FOR MAINTENANCE OF PUBLIC BUILDINGS - CASE OF THE MUSEU NACIONAL/RJ <i>Chaves Gonçalves Tavares, Danielle; Qualharini Linhares, Eduardo; da Silva Ramos, Maiane</i>	2703

5.- DIFFUSION AND PROMOTION

5.1.- Heritage and cultural tourism.

42	NUBIAN AUTHENTIC CULTURE NOW, BETWEEN COMMODIFICATION AND ENDURANCE <i>Sherif, Nagwa</i>	2715
211	CULTURAL TOURISM AROUND NON-MONUMENTAL HERITAGE: THE CASE OF THE PUREPECHA EMPIRE <i>Núñez-Camarena, Gina; Loren-Méndez, Mar</i>	2723
253	CULTURAL TOURISM IN EUROPE. DISCOVERING HERITAGE CREATED BY WOMEN ARCHITECTS AND DESIGNERS <i>Di Mari, Giuliana; Franchini, Caterina; Garda, Emilia; Renzulli, Alessandra</i>	2732
276	CANNING PORTIMÃO. PROPOSAL OF A PEDESTRIAN ROUTE IN PORTIMÃO, PORTUGAL <i>Grade, António; Gonçalves, Marta Marçal; Penetra, Andreia</i>	2741
335	BUCHAREST IN BETWEEN RECOGNIZING AND MANAGING HERITAGE BUILDINGS <i>Prisecaru, Delia Alexandra</i>	2749
376	THE EXPERIENCE OF ITÁLICA GREENWAY. CULTURAL AND ETHNOLOGICAL HERITAGE IN AN AGRICULTURAL ENVIRONMENT IN THE ALJARAFE, SEVILLE, SPAIN <i>Barrios-Padura, Angela; Mayoral Campa, Esther; Molina-Huelva, Marta</i>	2756
572	ADAPTING HERITAGE SITES COMPRISING AN ARCHITECTURAL HERITAGE TRAIL FOR THE PURPOSES OF TOURISM. PROTECTING THE VALUES OF THE CULTURAL LANDSCAPE <i>Sroczyńska, Jolanta</i>	2764

5.2.- Teaching and training.

238	LUDIC LEARNING AS A TOOL TO VALUE THE IDENTITY AND CULTURAL HERITAGE IN EL SALVADOR WITH UNIVERSITY STUDENTS <i>Avendaño, Ayansi; Zarceño, Ada</i>	2772
271	THE CITY AS A LABORATORY: TEACHING PRACTICE IN THE FIELD OF HERITAGE CONSERVATION. THE CASE OF CUENCA-ECUADOR <i>Tenze, Alicia; Cardoso, Fausto; Achig, María Cecilia</i>	2780
565	USE THE FLIP TEACHING METHODOLOGY TO ENHANCE THE TEACHING-LEARNING PROCESS IN UNIVERSITY EDUCATION <i>Tuesta Durango, Nelson; Villanueva Valentín-Gamazo, David; Palacios Burgos, Francisco; Alvarado Lorenzo, Mario; Aldavero Peña, Cristina; Cantalapiedra Cantalapiedra, Ángel</i>	2789

5.3.- New technologies applied to the heritage diffusion.

11	VIRTUAL REBUILDING OF THE OLD DEMOLISHED DRAWBRIDGE OF PIRAN <i>Kuhta, Milan; Humar, Gorazd; Rebolj, Danijel</i>	2798
58	3D RECONSTRUCTION OF THE MARINIDS SITE LOCATED AT THE CHELLAH ARCHAEOLOGICAL AREA <i>Simou, Sana; Baba, Khadija; Tajayouti, Mohammed; Jemmal, Mohammed; Nounah, Abderrahman; Aarab, Abdelatif</i>	2807
60	SEQUENTIAL VISUALIZATION OF THE INFORMATION GENERATED IN A REFURBISHMENT PROJECT THROUGH HBIM 7D <i>Carrasco, César A.; Lombillo, Ignacio; Peña, E. Raquel; Sánchez, Javier M.</i>	2815
122	SILVES BRIDGE GEOMETRIC MODEL VIA STRUCTURE-FROM-MOTION: TOOL FOR HERITAGE DIGITAL CATALOGS <i>Prates, Gonçalo; Gonçalves, Marta Marçal; Lopes, Ana Clara; Laranja, Roberto</i>	2825
151	AUGMENTED REALITY SYSTEM FOR TOURISM AND CULTURAL HERITAGE MANAGEMENT <i>Cosido, Oscar; Campi, Massimiliano; Pulcrano, Margherita; Ruiz, Oscar; Cera, Valeria; di Luggo, Antonella</i>	2831
252	CONCEPTUAL DEVELOPMENT OF AN INFORMATION SYSTEM FOR THE MANAGEMENT OF THE DOCUMENTATION GENERATED IN THE PREVENTIVE CONSERVATION PROCESS. CASE STUDY: CUENCA-ECUADOR <i>Sinchi, Edison; Jara, Andrea; Caldas, Victor; Zalamea, Olga</i>	2839
255	MULTI-TEMPORAL ANALYSIS OF VERNACULAR FARM BUILDINGS AND RURAL LANDSCAPE THROUGH HISTORICAL CARTOGRAPHY AND 3-D GIS <i>Statuto, Dina; Cillis, Giuseppe; Picuno, Pietro</i>	2847

5.4.- Accessibility to cultural heritage.

46	THE ADDITION OF NEW ELEVATORS IN BUILDINGS OF MODERN HOUSING ESTATES OF THE METROPOLITAN AREA OF BARCELONA <i>Díaz Cèsar; Cornadó, Còssima; Vima, Sara</i>	.....	2855
153	MOBILITY INFRASTRUCTURE PROPOSALS FOR PROTECTION PURPOSES OF THE HISTORICAL CENTER OF MANIZALES (COLOMBIA) FROM AN URBAN TERRITORIAL ACCESSIBILITY ANALYSIS <i>Escobar, Diego; Montoya, Jorge; Moncada, Carlos</i>	.....	2863
182	THE CONVENT OF SAN FRANCISCO IN OLINDA: THE AUTHENTICITY AS A GUIDE FOR THE ADAPTATION OF BRAZILIAN CULTURAL HERITAGE SITES TO UNIVERSAL ACCESSIBILITY <i>Máximo, Marco Aurélio da Silva; Ferreira, Oscar Luís</i>	.....	2872
318	THE MATTER OF THE SMALL HISTORIC VILLAGES IN ABRUZZO. ACCESSIBILITY AND ENHANCEMENT AS STRATEGIES FOR CONSERVATION <i>Bitondi, Mariangela</i>	.....	2881
456	HABITABLE. ACCESSIBILITY TO HERITAGE BY APPLYING A FUZZY MULTI-CRITERIA ANALYSIS <i>Del Moral Ávila, Consuelo; Delgado Méndez, Luis</i>	.....	2890

5.5.- Working networks in the cultural heritage.

120	NEED FOR INTEGRAL MANAGEMENT STRATEGIES IN THE ARCHITECTURAL CULTURAL HERITAGE <i>da Casa, Fernando; Vega, Juan Manuel</i>	.....	2901
371	HERITAGE AS A RESOURCE OF DEVELOPMENT: PROPOSAL FOR INTERVENTION FOR THE “ANTIGUA HACIENDA DE LLAVIUCU” CAJAS NATIONAL PARK - ECUADOR <i>Rodas, Tatiana</i>	.....	2909

CODE 261

THE MODERN MOVEMENT HERITAGE: PROTO-BIOCLIMATIC SOLUTIONS AND BUILDING ELEMENTS

Franchini, Caterina¹; Mele, Caterina²

1: Responsible Risk Resilience Centre; Dep. of Structural, Geotechnical and Building Engineering
Politecnico di Torino

e-mail: caterina.franchini@polito.it , web: <http://www.r3c.polito.it> ; <http://www.diseg.polito.it/en/>

2: Responsible Risk Resilience Centre; Dep. of Structural, Geotechnical and Building Engineering
Politecnico di Torino

e-mail: caterina.mele@polito.it , web: <http://www.r3c.polito.it> ; <http://www.diseg.polito.it/en/>

ABSTRACT

Before the publication of the book *Design with climate: a bioclimatic approach to architectural regionalism* (1963), which established its author, V. Olgyay, as an international figure in the bioclimatic design, several works of the Modern Movement (hereafter MoMo) had already revealed a variety of passive thermal solutions/elements.

Le Corbusier's *brise-soleil* has spread throughout the world the concern of merging *arté* and *teknê* in the design of shading elements increasingly adaptable to control changes in light radiation, since the 1920s. Natural ventilation building solutions are integral parts of the iconic architectures designed by F.L. Wright masterfully revealing some paradigms of climatic sustainability into the material heritage of the MoMo. Forward-thinking Italian architects have started testing an impressive combination of new thermo-insulation autarkic materials (e.g. Eraclit, Populit, Faesite) to design performative climate-responsive building envelopes also suitable for colonial buildings.

By considering the 'anatomy' of the building, our study focuses on the identification, analysis, and categorisation of proto-bioclimatic building solutions conceived by the architects of the MoMo to achieve both the climate adaptability of building elements and adaptation of the International Style to diverse climatic conditions.

Our critical survey goes beyond a single discipline as it is the result of an integrated process of interpretation of the history of architecture, building design and construction history. This process has assumed a reductionist paradigm to highlight those systems seeking to reduce the negative impact of the building through its passive thermal efficiency.

Looking under the lens of thermal sustainability the building solutions of the MoMo legacy, our study aims to foster further progress in improving the resilience to climate change in design practices devoted to both: the conservation of the MoMo architecture and renovation of the 20th-century building stock.

KEYWORDS: Modern movement heritage; proto-bioclimatic; solar shading solutions; sustainable heritage; passive thermal control.

1. INTRODUCTION: WHY THE MODERN MOVEMENT AND THE BIOCLIMATIC ?²

It may seem odd to associate the heritage of the Modern Movement (hereafter MoMo) with the bioclimatic, when its most famous strand, the International Style still is synonymous with a lack of concern for the energy performance of buildings. The ideal of the International Style was perceived as the possibility of ‘creating every building in every place’ regardless of the climatic conditions of the site. This ideal has been applied on a large scale since the second half of the 20th century when it was possible to heat and cool buildings with mechanical systems thanks to the low-cost fossil fuels energy.

Concerning building techniques, the poetics of the MoMo had led to the construction of architectures that had progressively disrupted the traditional building organised on a massive shell that, thanks to its thermal inertia, could behave as a conservative structure of its environmental conditions. The response to the environmental factors of discomfort in new buildings was found mainly through the use of mechanised systems, increasingly energy-intensive based on fossil fuels. However, since the first MoMo, there were trends and studies – even by the best-known authors, including Le Corbusier – which showed interest in climatic and site factors in architectural design.

Among the projects characterised by ‘architectural regionalism’ – defined in 1958 by Sigfried Giedion as designing with religious respect for the habits of life and climate [1] – there are several works of the protagonists of the MoMo who conceived what in this essay we call proto-bioclimatic solutions. By this term we mean those technological solutions that through passive devices, such as solar shadings, integrated into the structure or applied, contribute to increasing the thermal-hygrometric comfort of the building acting together with the openings of the façades. Le Corbusier was the creator of the “*mur neutralisant*” (based on a double glass with hot or cold air circulating between the two shells) which he applied in the Cité de Refuge (Paris, 1933). However, the wrong orientation of the glassed façade to the Southwest created severe problems of overheating in summer, which the Master solved by adding a *brise-soleil*. This example shows that the correct understanding of bioclimatic principles in architectural design demanded further insights at those time.

The Hungarian twin brothers Olgyay – who emigrated to America after the Second World War – laid the scientific foundations of bioclimatic in their 1957 *Solar Control and Shading Devices* [2], and subsequently in 1963, in the more comprehensive manual *Design with Climate: A Bioclimatic Approach to Architectural Regionalism* [3]. However, in the golden age of the uncontrolled economic growth of the 1960s, the studies of the Olgyays remained little known. Though, at the same time in the 1960s and 1970s, several events changed the knowledge of the environment and human society.

Ludwig von Bertalanffy general systems theory (1956) of and later research works by philosophers and scientists, such as Edgard Morin or Edward Lorenz, have laid the foundations for studying and understanding complex systems that questioned the worldview based on the laws of Newtonian linearity. The space race and the conquest of the Moon and the first vision of the Earth from space favoured the birth of global ecological consciousness. The publication in 1971 of the MIT study, funded by Aurelio Peccei and the Club of Rome *Limits to Growth*, and the 1973 oil crisis showed the physical limits to the exploitation of environmental resources for the first time. These events triggered a decisive interest in controlling energy in buildings and gave relevance to the studies of the Olgyays for the first time. As a demonstration of the fact that at the beginning of the 1960s the time was ripe to start a design experiment consistent with the bioclimatic principles of passive energy, in England Emslie Morgan – an almost unknown architect – built the new secondary provincial school of St. George in Wallasey (1961). As mentioned by R. Banham in *Architecture of the Well-Tempered Environment* (1st ed. 1969) [4], Morgan built a massive structure coupled with a solar wall adaptable to the seasons and completed the system with adjustable windows for natural ventilation. Just like the studies of the Olgyays, it took several years for this project to be appreciated and at least two decades for the application of bioclimatic principles with passive energy to be understood by design culture.

Our research addresses the issue of energy sustainability through the lens of architecture and construction history, focusing on the MoMo heritage and legacy. We propose a classification of external solar shading devices as a result of an integrated process of interpretation of the history of architecture, building design and construction history. The aim is revaluing passive thermal solutions of the MoMo to foster further progress in sustainable-design practices devoted to both: the conservation of the MoMo architecture and renovation of the 20th-century existing building stock facing to the hazards of climate change.

2. DESIGN AND CLIMATE BEFORE “DESIGN WITH CLIMATE”¹

Bioclimatic architecture reached its first systematic scientific formulation in 1963 with the book by Victor Olgyay *Design with Climate* [3]. This foundational text is the result of a series of scientific studies on climate and architecture that, according to Barber [5], Aladar and Victor Olgyay – who were also modernist architects – have possibly started at the end of 1934 in the United States of America. By the definition of an integrated system of architectural principles based on calculation and application methods, the Olgyays pushed forward the modernist vision of architecture as a science. Though many issues addressed in the book – such as the solar-air orientation, wind and architecture, thermal effects of materials – had previously been explored in a disjointed way within several contexts of the early MoMo in the Old continent.

2.1. Acting with the forces of nature: earth, water, air and sun

Earth, water and air were among the pedagogical concerns of the legendary Bauhaus school as shows, for example, the graphic scheme of P. Klee published in his *Bauhausbücher Pädagogisches Skizzenbuch* (1925, vol. 2, fig. 53). (Figure: 1) The Sun and its radiation appear recurrently in Le Corbusier’s published sketches to exemplify his architectural and urban theories and projects [6]. Environmental concerns took part in formulating the Master’s thought about the conception of Modern, and they become explicit in the texts of the 1942 book *La Maison de l’Homme* by F. de Pierrefeu and le Corbusier. (Figure: 2) It is also noteworthy that, already in 1934, Le Corbusier built for the Mason de weekend (La Celle-St-Cloud, Paris) one of the first green roof solutions on a reinforced concrete structure. In this work, he also exposed a variety of natural-traditional local materials to minimise the environmental visual impact of the building deliberately. (Figure: 3)

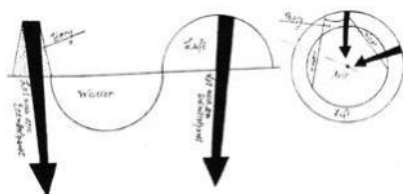


Figure 1: Paul Klee’s sketch “Erde, Wasser und Luft” (1925)

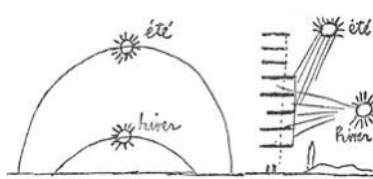


Figure 2: Le Corbusier’s sketch. (*La Maison de L’Homme*, 1942)



Figure 3: Le Corbusier, Maison de weekend, 1934. Fond. Le Corbusier.

In the 1920s and 1930s, an astonishing number of new bio-based building materials entered the market, including thermal-acoustic insulation materials made out, for example, of the processing of the wood industry waste – such as Eraclit, Populit, Faesite or Masonite, and Frigorite (from the cork industry). Trade journals, architecture magazines and technical manuals – in Italy those by Griffini (*Dizionario dei nuovi materiali per l’edilizia*, 1934; *Elementi costruttivi nell’edilizia*, 1943) – widely advertised and described the performances and suitable applications of these materials, thus favouring their use in line with the functionalist paradigm of the MoMo. The autarky policies of Italy’s fascist government fostered the experimentation of the new thermal-insulation materials that spread in Italian rationalist architecture as well as in projects for the African colonies. As noticed by Ascione [7], these materials are hidden into the building envelope, sometimes multi-layered, offering different performances

according to the heliothermic orientation of each building front. The heliothermic orientation of buildings gained ground in many architectural manuals, and calculation methods found applications in the “global Modernities” soon. For example, the use of the solar diagram by Mattioni’s method is well illustrated in the plates published by Diotallevi and Marescotti [12]. Together with the solar orientation of buildings, the concern about solar thermal control is the one that most features the face of the material heritage of the MoMo through the external solar shading solutions and devices designed according to different climatic regions.

3. PASSIVE THERMAL CONTROL: CLASSIFICATION OF EXTERNAL SOLAR SHADING SOLUTIONS¹

We have identified and analysed a vast repertoire of external solar shading systems and devices, gathered by over 250 works designed by the architects of the MoMo between the 1920s and 1950s, to provide a classification. We based our sorting on the relationship between the building ‘anatomy’ and the shading solutions, and we defined the followings three macro-typologies:

1. **Self-bearing:** with detached structure from the building envelope, thus enabling ventilation too;
2. **Structural:** resulting from external extensions of the horizontal/vertical structural elements of the building, including those of the roofing;
3. **Supported:** variously fixed to the structure or envelope of the building.

These macro-typologies do can also coexist in the same building and often act combined with several solutions for natural ventilation.

For each macro-typology, while taking in consideration the Olgyays brothers’ taxonomy based on the shading masks – horizontal, vertical, “egg crate”, and fixed/mobile – published in their pioneering 1957 book [2], we set a different classification as shown in the graphic scheme below. (Figure: 4)

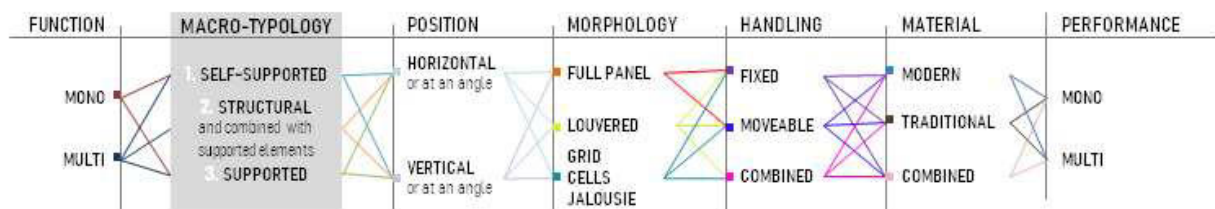


Figure 4: Classification scheme of external solar shading systems (by. C. Franchini).

Primarily motivated to address the issues of healthy living, hygiene and well-being, the international Masters of the MoMo conceived proto-bioclimate solutions for passive thermal control. They succeeded in offering both the climate adaptability of building elements and the adaptation of the International Style to diverse climatic regions, including the tropical and subtropical zones, by combining *arté* and *teknê*.

In the next two paragraphs, according to our classification, we will initially provide a summary of some examples that show the functional combination of different solutions and their synergy with natural ventilation considering the meeting of various needs and the "paradigms" that have guided the MoMo. To follow, we will present the case study of E.1027 as an epitome of the adaptation of the Riviera traditional louvred shutters (vertical solar shading) to modernism.

3.1. Proto-bioclimate heritage: from hygienism to humanism

When in the first decades of the 20th century Europe was ravaged by tuberculosis and other diseases, Functionalism and Rationalism embraced the hygienist cause. Sunlight, ventilation, “fresh air”, and exposure to the outdoors became the significant factors of a healthier life in the *existence-minimum* houses as well as in schools and buildings for care.

Driven by hygienism, the team of architects BBPR designed an ingenious **self-bearing vertical solar** shading to shade the glassed Southern façade of the Health Centre of the Summer Day Camp for Children (Legnano, Milan, 1937-38). The Milanese team built a vertical self-bearing wooden structure that is multi-functional, as it serves as porch-solarium, and multi-performance, as it provides for shading and allows ventilation of the double-height interior space of the dining hall behind it. (Figure: 5) This “double façade” for passive thermal control makes it possible the heating in winter and cooling in summer required in the temperate climate zone. The Olgays presented it in 1957, but it was already identified in 1943 as an excellent solution by Ireneo Dotallevi and Franco Marescotti, who published the technical drawings in *Particolari costruttivi di architettura in Casabella-Costruzioni* n. 186, pl. XLIX [8]. Ingenious and inexpensive, it still a unique case of its kind and need to be preserved and restored together with the entire building that is in state of decay.

Outstanding examples of **self-bearing horizontal** shadings systems originated from the Argentinean Structuralism by the late 1940s. The paradigm of ‘scientific aesthetic’ drove the researches of Amancio Williams and Horacio Caminos on thin concrete-shells for spectacular umbrellas protecting infrastructural buildings underneath. Even though astonishing projects such as the three Hospitals in Corrientes Province (Williams and Giulio Pizzetti, 1948-52. Figure: 6) or the Community Center of the University City of Tucúman (Caminos, 1953) remained on paper their use as multi-functional and multi-performance shading structures inspired many other modernist architects active in Humid Subtropical climate zones, thus becoming representatives of a climatic-regional MoMo. This “Regionalism” assumes the proper meaning given by V. Olgay in his 1963 book, while different is the sense within other modernist strands such as those of the Sarasota School in Florida.

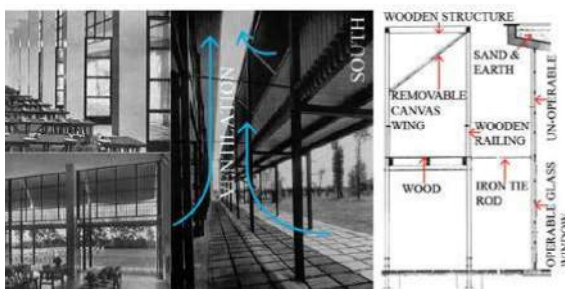


Figure 5: BBPR, Porch-solarium, Health Centre of the Summer Day Camp for Children, Legnano, 1937-38.



Figure 6: A. Williams, Hospital in Corrientes Province, 1943-52 (Archive Amancio William).

By the early 1950s, architects of the Sarasota School, such as Paul Rudolph, changed the traditional front porch of Florida’s home into large self-bearing ventilated structures. These structures, acting with several solutions for interior cross-ventilation, provided a passive cooling of the houses making saving energy possible. Hence, by associating the architectural language of the International Style with the traditional dwelling design of the region, they gave rise to a Modern proto-bioclimate “regionalism” typical of the tropical modernism. The Hiss Residence or “Umbrella House” (Lido Shores, Sarasota, 1953-54) is an epitome of this strand of modernism. (Figure: 7)



Figure 7: P. Rudolph, Hiss Residence or “Umbrella House”, Lido Shores, 1953-54. (Paul Rudolph Foundation and *House & Home*, p.103 [13])

In the early 1950s, mechanical conditioning systems were spreading in homes in the U.S. In July 1954, the article *Hot-wether houses* in the magazine *House & Home* celebrated the Hixon house for its design solutions of natural ventilation cooling, thus limiting the use of air conditioning.

As regards the second macro-type, the **structural solar shading** notable examples are many and various, including those designed by the Masters.

By the first decade of the 20th century, Frank Lloyd Wright had already started to define an architectural concept for the humid continental Midwest climate based on the “cantilever principle”, the second principle of his legendary “organic architecture”. In the Prairie Houses at first – whose the Frederick C. Robie Residence (Chicago, 1906) is an archetype – and later in the Usonian houses, the cantilevered roofing acts as horizontal solar shading. In the Affleck Residence (Bloomfield Hills, 1940), Wright demonstrates total control and appreciation of microclimatic effects. For this Usonian House, he designed an original solution for evaporative cooling that acts with the solar shading of the upper porch allowing for up-draft air movement and cross-ventilation. (Figure: 8) Wright turned the Affleck Residence into a prototype for low-cost single-family homes accessible for everybody, thus making American “Dream Home” come thermally sustainable.

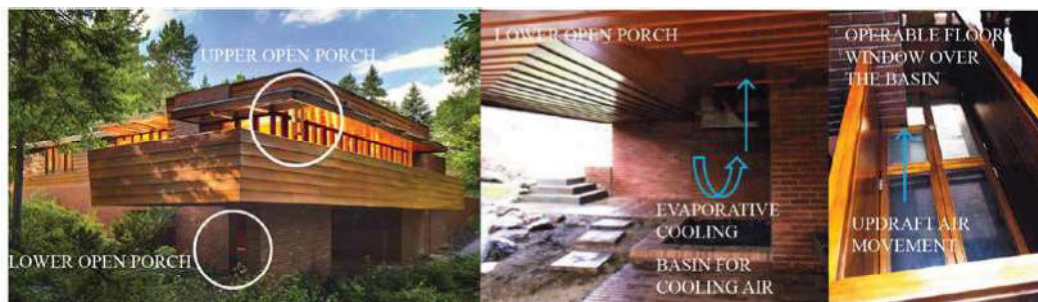


Figure 8: F.L. Wright, Affleck Residence, Bloomfield Hills, 1940.

Wright’s cantilever principle inspired others leading modern American architects, including Richard J. Neutra, whose cantilevered reinforced concrete flat roofs shading the glazed walls underneath mark his humanist poetic. In his Californian works, the structural solar shading defines patios, verandas and arcades playing a multi-functional role. It is in extreme climatic conditions, with the famous Kaufmann Desert House (1946, Palm Spring) that Neutra fully reached the expressive and bioclimatic performance potentials of the solar shading, alternating and associating roof overhangs with innovative mobile vertical aluminium sun louvers [9].

In the book *Architecture of Social Concern for Regions of Mild Climate* (1948, São Paulo, Brazil: Gerth Todtmann), Neutra suggests using passive climate design to improve social conditions with minimal financial and infrastructural expenditure. The book is the result of the prototypes and methods developed for the construction of schools and hospitals in Puerto Rico (1943) mainly based on induced ventilation, to better adapt to the regional climate.

The most popular structural solar shading is the *brise-soleil* developed by Le Corbusier to export his lesson in hot climates, from the French colonies in Africa to India passing from Argentina. In the first project for Villa Baizeau a Carthage (Tunisia, 1928. Figure: 9) and, twentieth years later, for Villa Shodhan at Ahmedabad (India, 1951), the Swiss-French master used the *Dom-ino* structure as solar shading. And for his projects in Algiers such as Maison locative Ponsik (1933. Figure: 10) and the skyscraper Cité des Affaires (1938) he designed his famous grid of rectangular cells *brise-soleil*, that later appeared in many works including, in Argentina the Maison Curutchet (project 1948-49) built at La Plata by A. Williams (1949-55. Figure: 11), in the Indian Palais des Filateurs (Ahmedabad, 1951) and the Haute Cour of Chandigarh, 1952 (Figure: 12). In the latter, Le Corbusier combined the *brise-soleil* of the façade with the colossal concrete shell of the covering that acts as self-bearing solar-shading and the water mirror in front of this masterpiece acts as a gigantic evaporative cooling basin.



Figure: 9

Figure: 10

Figure: 11

Figure: 12

Le Corbusier (Le Corbusier Foundation)

Supported solar shading offers an impressive variety of solutions from the fixed balustrade/railing-sun shadings, that spread globally in the modern terraces, to the operable louvres covering entire façades of Oscar Niemeyer's architectural legacy. The concept of adaptability pervades the Modern kinetic façades since Oscar Niemeyer's first significant project; the Day nursery Obra do Berço (Rio de Janeiro, 1937-40. Figure: 13). Through the combination of adjustable oversized louvres, smaller-scaled louvres, and voids, the Brazilian master offered a low-cost thermal comfort and richly layered external solutions for highly functional and dynamic façades. He oriented and shaped the louvres always according to the sun orientation of each façade and the ventilation flows. In several works such as the Ministry of Education and Health in (Rio de Janeiro, 1937-40. Figure: 14) – designed with Lucio Costa and Le Corbusier – or in the Boavista Bank (Rio de Janeiro, 1937-46. Figure: 15), the Brazilian Master painted the adjustable louvres in different hues of white and blue so as to reflect or absorb light and thermal radiation. He also took into account the need for privacy to place and design the louvres as it is evident in the case of the Boavista Bank. He used for the same building the *combogós* – like other protagonists of the Brazilian MoMo did [10] – in combination with adjustable louvres façades as occurred the Building for the Empresas Gráficas o Cruzeiro (Rio de Janeiro, 1949. Figure: 17). Concerning the possibilities offered by the solar shading devices, in 1939 Niemeyer published an article in the *Revista Municipal de Engenharia* [11] where he wrote:

O sistema proposto nos garante ainda as seguintes possibilidades:

- a) - o desvio será feito conforme a época do ano, para um lado ou para outro o que permitirá sempre mínimo de inclinação.*
- b) - durante as horas não insoladas (6 horas da manhã às 2 da tarde) ou nos dias sombrios teremos a vista inteiramente livre, bastando para isto conservar as placas normais à fachada;*
- c) - nos dias frios ou chuvosos poderemos evitar as rajadas de SO com uma pequena retificação;*
- d) - a luz interior poderá ser graduada a vontade em função do dia e das exigências do trabalho.*



Figure: 13

Figure: 14

Figure: 16

Figure: 17

Oscar Niemeyer, Rio do Janeiro (Oscar Niemeyer Foundation)

The designers of the MoMo were able to upgrade of traditional local shutters or ventilated screens to create Modern and more performing solutions for supported solar shading devices in the humid

subtropical as well as in warm temperate climates. In several cases, these solutions originated from a humanist approach to modernism, as epitomised by the E.1027.

3.2. Traditional elements for Modern solutions: the sensitive prosthetic approach of the E.1027

Already in the 1920s a pioneering masterful interpretation of the traditional louvred shutters of the Italian-French Riviera was designed for the E.1027 *Maison en bord de mer* (Roquebrune-Cap-Martin, 1926-29). A masterpiece of the MoMo, the E.1027 is the first architectural work by Eileen Gray: an exceptional designer, eclipsed by history for decades, and later internationally recognised as a pioneer of “non-heroic” modernism [12]. (Figure: 18). She chose a parcel of land on the Cap-Martin that had no car access to building a vacation home with minimal luxuries, but maximal comfort. The relationship of the building to its site anthologises the principles of Modern architecture. Its rotation in the direction of the terraces of the ground allows for a more favourable solar orientation, meanwhile preserving the terraced skyline typical of this coastal landscape. Taking advantages from the slope of the hill, the most significant space – the open-space living room – is raised on *pilotis* to create both a covered area for the outdoor kitchen and the ventilation below the floor.

In collaboration with the young client and co-designer, architect Jean Badovici, Gray designed the “*fenêtre-paravent*” (screen-window). This shading and ventilation device alternates fixed louvres shutters with a horizontally pivoting part operable to the outside and simple fixed louvres shutters, both sliding on multiple rails, moved away from the building envelope by a frame, closed or open on the sides as needed. This dynamic shading device, which was patented, is both original in shape and performing as, like the window, it can be operable in several different ways to better adapt to the climatic conditions. As stated by the architects, they considered the problem of shutters as crucial and often neglected. In the special issue devoted to the E-1027 of the avant-garde magazine *L'Architecture Vivante* (1929), directed by Badovici, they wrote: “A window without shutters is an eye without bows. Moreover, all the combinations commonly in use obtain the same result: insufficient aeration when the shutters are closed. Our solution is large and open to the outdoor air while blocking excess of light” [13].

The design of each shielding element is integrated with that of the opening system of its window (three different types) and takes into account the orientation and the handling combination of both. For example, the north-northeast oriented living room window has a thin metal hinged window frame completely foldable as a room divider, so that the view of the landscape can be left completely clear and the flow of light and air can be controlled at will. The shutters frame protrude from the edge of the façade not only to accommodate the folded window protecting it but also to offer the maximal ventilation. The “screen-windows” belong to the same design research of Gray’s furnishing like the “*coiffeuse-paravent*” (vanity table-screen), “*bar-dégagement*” (bar-alcove). They result from the same design process that has driven Gray’s legendary pieces of furniture of the house that are ingeniously shiftable, slidable, foldable, adaptable, transformable. Gray pursued the conviction that “An object must be given the form best suited to the spontaneous gesture or the instinctive reflex that accompanies its use” [13].

To shield the main terrace (south) from the sun, horizontal and vertical white canvases – as easily removable as a bimini-top – give to the façade a nautical appearance. The system is multi-functional as the terrace of the large room can extend outside when the glazed is folded back against the pillars. And it is also multi-performance: “A removable canvas serves as the balustrade; in the winter months it may be removed to warm the legs in the heat of the sun. The canvas awning is made in four independent pieces and can resist even the Mistral wind” [13].

The upgrade of the shutters of the Riviera is not a solitary element of the local tradition. As the preliminary study for restoration works revealed [13], the original plastering was made out of lime mortar and the finishing coats tinted with lime wash, whether chosen by the architects or imposed by the local contractors, this finishing materials offered a practical solution for both thermal insulation and protection to humidity. In *L'Architecture Vivante*, the accurate caption of the technical detail of the terrace-roof demonstrates, once more, the concern of achieving effective insulation, waterproof and weather resistant. The published

dual “scheme of circulation and sunlight” shows independent paths through living spaces based on the rhythm of the sun. Natural ventilation, particularly cross-ventilation, and solar control feature the entire building design and leads its spatial, morphological and aesthetic characteristics. Giedion in his article “*L’architecture contemporaine dans les pays méridionaux: Midi de la France, Tunisie, Amérique du Sud*” (*Cahier d’Art*, 1931) infers that E. Gray established a new response tailored to the Mediterranean climate.



Figure 18: Eileen Gray, Jean Badovici, E.1027, Roquebrune-Cap-Martin, 1926-29.

In this seaside house on Cap Martin, both the principles of Le Corbusier and those of the De Stijl coexist in a personal humanist view of the Modern. While remaining functional, this masterpiece of Modern architecture transcends the “*machine à habiter*” formula to embody a sort of “prosthetic” view of the dwelling space: an “organic unity” that can change as both an adaptive reaction to external conditions and intimate emotions of an individual human being. Gray states “Formulas are worth nothing; life is everything. And life is the mind and the heart simultaneously. [...] One must build for human beings, so that man may rediscover in architectural construction the joy of feeling himself, of being in a whole that extends and completes him” [13].

4. CONCLUSIONS²

From our research, it seems clear that the interest in climatic and environmental factors has characterised studies and projects of significant strands of the MoMo since its inception. The reasons come only in part from the reforming hygienism of which the architecture of the MoMo was the ‘spokesman’ - as it is in common opinion - and they are ascribable to several others causes explained in this essay through some selected cases among the many we classified in our repertoire.

The need for well-lit, ventilated, and healthy interiors led the designers to consider natural factors such as solar radiation, wind and humidity carefully in the joint conceptual and technical design process. Notably, in the architectural production closest to the local building practices, some technological and formal solutions were adopted to improve the comfort, such as solar shading systems, anticipating what now we call bioclimatic design. On the other hand, it is clear that the conceptual principles at the base of the new architecture, which involved the rejection of the massive shell, the emptying and transparency of the structure of the building, caused problems of a thermal, lighting and acoustic nature that had to be solved. From these needs, today called performances, originated the search for technological solutions formally consistent to be applied to buildings, despite the lack of awareness of the need to reduce the energy consumption of buildings, which would arise only after the 1970s.

It is unfortunate that in the same years in which the Olgays laid the foundations for bioclimatic architecture, thermal and environmental control in the building started to be entrusted to energy-intensive systems based on the consumption of fossil fuel, then spreading globally. The availability of low-cost energy, the diffusion of plant systems suitable for any building and residential context, together with the affirmation of cost-effective industrialised construction systems based on reinforced concrete, have probably obscured the alternatives and experiments started decades earlier within the

Modern Movement itself. If these alternatives had gained ground, they would have led to more sustainable building and urban models. Today the building sector is still responsible for about a third of climate-changing emissions and global energy consumption. As part of the challenge for energy sustainability, the need to know and investigate the solutions and elements adopted in the built heritage of the recent past seems more relevant than ever. It is essential not only for the proper maintenance and restoration of the MoMo heritage but also for the possible replication of the best performing solutions to huge 20th-century building stock of our cities.

NOTE

Sections 1 and 4 by C. Mele (scientific research responsible); sections 2 and 3 by C. Franchini.

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