

# UNIVERSITY AND ENTERPRISE: RESEARCH IN DOCTORAL STUDIES WITH INDUSTRIAL CHARACTERIZATION

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## Abstract

Since 2017 the Ministry of Education, University and Research has promoted the high postgraduate training of research doctors in line with the needs expressed by the national production system. Following the guidelines provided by the European Community through the National Strategy of Smart Specialization 2014/2020, "PhD Studies with Industrial characterization" have been financed (PON RI) for that disciplinary areas with a strong scientific-technological vocation.

The financing of the three-year scholarships is granted to research projects which, in line with the development trajectories identified by SNSI, aim to form highly qualified professional figures through a university research trail in partnership with foreign universities and companies that operate on the Italian territory.

The contribution presents an industrial PhD project in progress at the Department of Civil, Construction and Environmental Engineering of the University of Naples "Federico II" aimed at the experimentation of *"Innovative and non-invasive industrialized systems for the characterization of moist content and for the rehabilitation of historical walls with capillary rising damp"* conducted in partnership with the Escuela Técnica Superior de Edificación of Madrid and an Italian company leader in the field of dehumidification of historical masonry.

Through the analysis of the parameters to be respected in the writing of a research project with industrial characterization and in the choice of the partners, it will be possible to highlight the degree of innovation of this research method that approaches the academic world to that of production.

Of particular interest will be the comparison between the classical methodology for the development of a PhD project and that of doctorates financed with PON RI funds, in terms of choice of the research topic, which must be included in the strategic planning of industry 4.0, of articulation of the activities and methodology adopted, of degree of innovation with respect to the sector of intervention, of technical feasibility of the proposed project, of objectives to be pursued and finally of synergy with respect to the insertion of the professional figures formed in the working world.

In second analysis the activities carried out and the work InProgress of the specific project will be described with particular interest to the weaving of networks of relationships that are created in the development of an interdisciplinary project, involving national and foreigners institutions of both public and private competence, highlighting the importance of strengthening these relations in order to promote research at international level.

Keywords: research, industrial PhD, industry 4.0, training, development.

## 1 THE PHD WITH INDUSTRIAL CHARACTERIZATION

### 1.1 The European Community's research and innovation strategies

The development strategies of the European Community have identified some actions aimed at pursuing the social and economic progress of the Member States, through the optimization of research in an innovation key: *"The growth and development of a territory depends mainly on the ability to innovate, to be increasingly intelligent and able to attract and integrate skills, knowledge, needs and technologies to improve the quality of life of citizens and to strengthen the competitiveness of businesses."* [1]

The way that the EU uses to determine the strengths and weaknesses of the innovation systems in each Member State is the Innovation Union Scorebord IUS, an annual evaluation that allows the highlighting of the scenarios to orient public financial resources for smart and inclusive growth. One of the main indicators of the proclivity for innovation of an economic system is the expense invested for research and development in relation to the country's Gross Domestic Product. This parameter

describes the economic impact of research and innovation activities and depends on the degree of cooperation that can be established between the public research system (universities) and the business system.

In order to strengthen the creation of networks between the academic and industrial research worlds, the Ministry of Education University and Research (MIUR) has enabled numerous initiatives for the development of a technology transfer network financed by National Operational Programme Research and Innovation PON RI.

The PON RI Action Line 1 for the five-year period 2014-2020 has allocated funds for investing in the promotion of postgraduate studies through the development of projects of "innovative phd with industrial characterization". The Universities of some Italian regions were therefore invited to submit doctoral projects to be carried out in partnership with a company operating in the national territory and an institution based in another State of the European Community. The periods of study and research that the students are required to perform abroad and at the company aim to "qualify in an industrial sense the formative experiences with forecast of relapse both on the productive field of the territories covered by the program, and employment after obtaining the doctorate." [2]

## 1.2 Eligibility to finance the projects

A fundamental requirement for the admission of projects to financing is the correspondence of the research topic to one of the twelve "areas of regional specialisation" with a strong scientific-technological vocation identified by SNSI for the enhancement of competitive abilities of the national industrial and scientific system: 1. Aerospace; 2. Agrifood; 3. Blue growth; 4. Green chemistry; 5. Design, creativity and made in Italy; 6. Energy; 7. Intelligent Factory; 8. Sustainable mobility; 9. Health; 10. Smart, secure and inclusive communities; 11. Technologies for living environments; 12. Technologies for cultural heritage.

The evaluation of the project proposals presented by each University is carried out by ANVUR, the National Agency for the evaluation of the National University system, through the use of specific criteria indicators, each one with a partial score in percentiles.

Projects receiving an assessment exceeding 65/100 are eligible for funding.

Table 1. Evaluation criteria.

Evaluation criteria	Score
A. Research proposal	max 40
B. Activities at the company	max 20
C. Activities abroad	max 20
D. Educational activities at the university	max 15
E. Contribution to the pursuit of horizontal principles	max 5
	<b>max 100 points</b>

The evaluation of the criterion "A. Proposed research" is carried out in relation to 3 indicators:

- A. 1: The topic of research and its consistency with SNSI. The project must therefore be framed in one of the areas identified by the Ministry as technological lines relevant to the transfer of knowledge and industrial application, to which a score of 20/45 is assigned. The research activities proposed and the methodology with which the project will be developed are therefore subject to evaluation.
- A. 2: the degree of innovation and technical feasibility of the proposed research for the competitiveness of the intervention sector, to which a score of 15/45 is assigned.
- A. 3: The synergy to any subsequent use of the research doctors, to which a score of 5/45 is assigned.

The evaluation indicators for the criterion "B. Activities at the company" shall take into consideration the activities to carry out at the office of the company that is partner of the project, the contribution

provided and a forecast on the use of the research results for the growth of the skills of the doctoral student with reference to the field of intervention.

Similarly for the evaluation of the criterion "C. Activities abroad" the requirement is to indicate the program and the purposes of the activities to carry out at the foreign Institution, as well as the use of the research results for the enhancement of the doctoral skills with reference to the field of intervention.

Partnerships with the company and with the institution where the activities will be carried out are guaranteed by letters of intent drawn up by the host parties, annexed to the application for financing.

As regards the criterion "D. Training activities at the university", the indicators relating to the methods for training activities, the co-design elements and the degree of conformity of the proposal to the high-education demand are subject to evaluation.

Finally, a further score is attributed to the criterion "E. Contribution to the pursuit of horizontal principles", concerning any action taken to ensure anti-discrimination criteria and environmentally friendly solutions in the implementation and management of doctoral pathways.

## **2 ACADEMIC AND INDUSTRIAL RESEARCH**

The analysis of the described parameters highlights some fundamental differences between a PhD project funded with university funds and an industrial PhD project.

Firstly, as indicated by the Guidelines for admission to financing, the scope of research for a PhD in industrial characterization must fall within one of those areas of specialization identified by SNSI. The choice of the theme, therefore, arises from an accurate market demand that, in the specific case, corresponds to a framework of strategic choices in which the country decides to concentrate the investment programs.

Unlike the doctorates with university funds, which are usually inserted in research strands developed by a single group or department, the scope of the intervention of an industrial doctorate must have an inter-disciplinary character in order to promote the development of products and technologies useful to more than one economic sector.

The goals of the project change because, expecting the industrial characterization, are finalized to realize a real and really marketable product. This aspect strongly affects the innovation component required by the project. Research cannot stop at an exploratory study or constitute a single application of a broader project. An industrial characterization must, according to his own nature, be comprehensive, with more or less large dimensions depending on the case but it must be able to determine an impact on the productive and social challenges.

In didactic terms, the development of an industrial doctoral project follows a different methodology, sometimes more rigorous than a doctorate with university funds. In the three-year course, in fact, the students dedicate the first year of research to carry out a wide-ranging study in a disciplinary sector, following which they must be able to define a research theme, the articulation of the project and a projection of the activities they plan to perform over the next two years.

On the contrary, the students who must develop a research with industrial characterization are part of a project that the university has already written, on the basis of which were determined partnership agreements with companies and foreigners Institutions and a grant has been disbursed. The articulation of the research and the activities are already identified. In the first year therefore the PhD student can already immerse themselves in the topic of research with fixed goals following accurate addresses.

This analysis leads to a reflection: the PhD students who develop an industrial project receive on the one hand a definite guide for the development of the research phases, which allows them to focus immediately on the final goal; on the other hand they are lowered in a path with rather definite and accurate outlines that requires a high degree of correspondence of the profile of the student and of his aptitudes to the field of research.

The importance of the selection phase of the candidates for the award of the Industrial doctoral grants, which, unlike the others, requires specific skills of the students, who must be able to reach goals that have concrete effects in terms of production and innovative development, is highlighted.

To this purpose, the articulation of the research is considerably different, not only conceived as a study or laboratory activity in the disciplinary field of reference but as an intersection of inter-sectoral and inter-cultural exchanges between the university and the company and the foreign Institution, public or private.

Different and more complex is therefore also the role of the academic tutor, who is strongly involved in all the phases of the research. Firstly, the tutor corresponds to the author of the research project that the university sends to the Ministry to ask for the financing, the one who from the initial phase is called to evaluate the feasibility of the research and to make relations with the other partners.

During the development of the project an important action of coordination of all the phases of research and of all the disciplinary sectors involved is required to the tutor, in order to guide the PhD student in the organization and to set up a system of the different competences acquired in the training process and finalize them in an accomplished and organic way in relation to the goals to attain.

The binding periods to carry out in the company or abroad, are therefore moments of strategic relevance for the training, the exchange and the contamination between all the partners involved.

It follows the possibility to guarantee the formation of professional profiles of high level, to disseminate the *know how* of the industrial and academic realities in national and European territory and to expand the network of collaboration between different disciplinary sectors and inter-university research groups, also in order to promote the achievement of a high ranking of the research group in the scientific world.

### **3 THE FUNDED RESEARCH PROJECT**

On the occasion of the first call issued in 2017 for the assignment of additional scholarships for research phd, the Department of Civil Engineering, construction and environmental of the University of Naples "Federico II" presented to MIUR a project for the experimentation of "Innovative and non-invasive industrialized Systems for the characterization of wet content and for the rehabilitation of historical walls with capillary rising damp" [3].

The project, considered worthy of funding, includes the participation of the industrial partner Leonardo Solutions srl and the Escuela Politecnica of Madrid.

#### **3.1 The topic of research and its consistency with SNSI**

The theme is in line with the twelfth area of specialization identified by SNSI on "Technologies for Cultural Heritage" (§ 5.3.13) and specifically concerns the industrial field related to *Management of the historical-artistic-architectural heritage*, intended as the set of "activities dealing with the preservation, fruition and value of cultural heritage, both in its tangible and intangible dimensions". [1]

Recognizing the potential value of Italian cultural heritage and the high competences developed over the years in the field of restoration in our country, the project aims to broaden the scope of research on technologies for the diagnosis and rehabilitation of historical buildings, with particular reference to architectural and monumental heritage.

Deepening a line of research already consolidated within the Department, related to the study of the causes of degradation of historical buildings with a structure in supporting masonry, the project addresses the theme of the rehabilitation of buildings affected by moisture from rising damp. This pathology is one of the most frequent causes of degradation that determines for the masonry a reduction of the mechanical, in terms of lowering the resistance under compression, and thermal performances.

Nevertheless, scientific research and common practice are still linked to the adoption of traditional mechanical, chemical, evaporative and electrical interventions that have demonstrated over time to have great application limits, especially in the area of cultural heritage.

The project therefore, using the partnership with the company Leonardo Solutions srl, Italian company leader in the field of dehumidification of historical masonries, and which is the creator of a modern Charging Neutralization Technology, intends to test the efficacy of CNT devices with real applications in buildings with particular historical and architectural value.

The evolution of the method, compared to the electrical interventions with inversion of polarity, resides in the scientific principle according to which the origin of the capillary ascent is determined by the

forces of electro-static attraction exerted by the walls of the capillary pores of the stone materials on the dipole of the water molecule. The CNT would be able to generate an electromagnetic field capable to cancel the electro-static attraction exerted on the water and to stop the ascent.

In the same way as described for the state of the art relating to the methods of rehabilitation, also for the diagnosis and monitoring field the scientific and industrial research have not produced innovative results in terms of instruments for the measurement of the moist content inside the walls.

Actually, the only valid and scientifically recognized methods for the quantitative diagnosis, both in the initial phase and during the rehabilitation procedure, are those described by the norm UNI 11085 and provide for the execution of ponderal tests by extraction of specimens directly from the wall.

This methodology is rather invasive and absolutely inapplicable in the cultural heritage. Indeed the instruments of not-invasive diagnosis provide only qualitative measurements: the acquisition and the comparison in time of thermographic images, for example, can describe the variation of the damp content of a wall in terms of variation of the temperature on the evaporating surface. This data, in addition to being susceptible to the interference of many parameters (internal temperature, presence of furniture, plants and always different thermo-hygrometric conditions of environments) is limited to the surface of the masonry and is not able to provide a complete diagnosis of the phenomenon in quantitative terms.

The second part of the project, therefore, relates to the experimentation of industrialized and not-invasive probes that are able to determine the quantity of water inside a masonry for simple contact without ponderal tests.

### **3.2 The innovation degree and technical feasibility of the proposed research**

The research project proposes different points of innovation compared to the state of the art in terms of diagnosis and rehabilitation of masonry with the phenomenon of capillary ascent.

First, the experimentation of the CNT devices of Domodry patent allows to test a not-invasive technology able to stop the ascent starting from its origin. The intervention, moreover, combined with the phenomenon of natural evaporation of the residual damp content in the walls following the neutralization, allows to reach the complete drying of the masonry.

Unlike traditional methods, the CNT acts directly on the water, regardless of the nature of the stone materials and the constructive techniques which the buildings are constructed with.

In addition, the CNT is applied by means of modest devices, generators of a spherical electromagnetic field covering a wide range of action up to 15m and requiring only an attack to the domestic electric plant.

These two aspects make the technology extremely innovative, poorly invasive and therefore suitable to be applied in a compatible and reversible way even on historical walls.

Similarly, the experimentation of probes for the characterization of the humid content inside the walls offers many innovations regarding to the state of the art.

In fact, starting from the assumption that there isn't on the market an instrument able to measure instantaneously the quantity of water present inside a masonry, postponing the determination of the moist content to the execution of ponderal tests, the possibility of patenting a probe that works in this direction constitutes a completely new research perspective.

In addition, the project aims to give the probe tested the characteristic of not-invasiveness, in order to obtain an instrument capable of carrying out readings for simple contact with the masonry without the need to make holes or to withdraw material.

### **3.3 Research methodology**

The research is based on an experimental methodology that, in addition to a bibliographical and documentary study on the state of the studies, uses direct tests on the materials and on the devices carried out in the laboratory and partly directly on site.

The project is divided into:

- A phase of documentary investigation on the studies related to the topics: moisture from capillary ascent; construction materials and degradation pathologies produced by the

phenomenon; interventions for rehabilitation; technologies for the diagnosis and measurement of moist content within the historical walls; European and National directives;

- A phase of laboratory experimentation on the performance characteristics of building materials with different degrees of imbibition;
- A phase of experimentation of innovative and not-invasive industrialized systems for the characterization of wet content and the restoration of masonry by means of installation and monitoring of devices in historical buildings in Italy and Spain;
- A phase of study of the theory of capillarity and rehabilitation techniques exploiting the principle of electrocapillarity;
- A phase of analysis of the functioning of innovative and not-invasive industrialized systems subject of experimentation;
- A process of data collection.

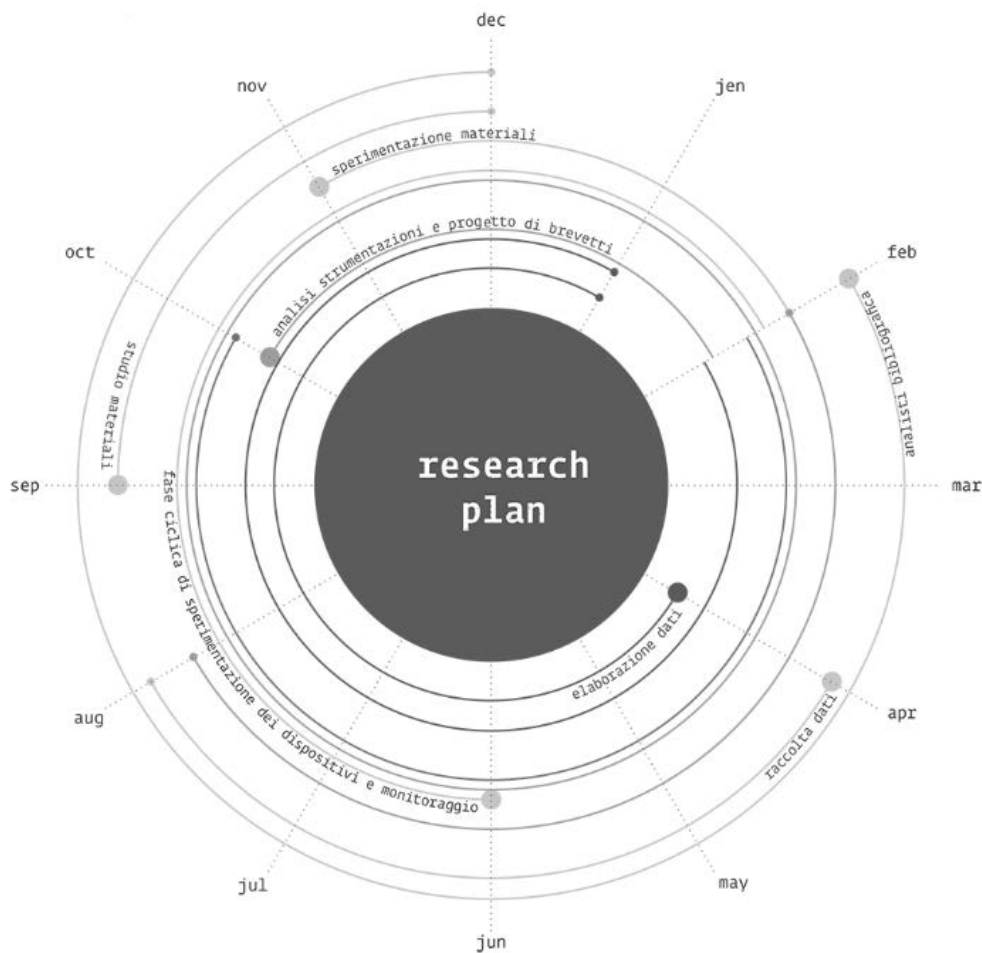


Figure 1. Research plan.

The Phase of experimentation of innovative and non-invasive industrialized systems was developed directly on site by the installation of instruments in historic buildings chosen in the metropolitan city of Naples and in the Spanish capital.

In detail the buildings chosen for the experimentation are:

- the E.T.S. de Ingenieros de Minas y Energía, Calle de Ríos Rosas 21, 28003 Madrid
- the Cuartel de Conde Duque, Calle Conde Duque 9, 28015 Madrid
- the Basilica Pontificia of Pompei, Napoli

The phases of documentary and bibliographical study were carried out mainly at the DICEA of "Federico II" while the phases of experimentation of materials and probes required laboratory activities carried out at the laboratory of "Tecnología Edificatoria y Medio Ambiente" of the ETS of Madrid, the Civil Engineering, Construction and Environmental Department DICEA and the Materials Engineering and Industrial Production Department DICMAPI of "Federico II". Also the phase of investigation of the ongoing experimentation and study of the functioning of the devices carried out at the headquarters of the company partner had a fundamental importance.

The activity of experimentation on the site has required the collaboration with different public Institutions:

- The Departamento de Patrimonio Histórico, Ayuntamiento de Madrid and the Escuela Técnica Superior de Ingenieros de Minas y Energía for the installation of devices and probes in the historic buildings in the Spanish capital;
- The Pontificio Santuario della Beata Maria Vergine del S.Rosario, as regards the same installation at the Basilica of Pompeii in the metropolitan city of Naples.

### 3.4 Project Progress

The activities carried out during the first two years of PhD are:

- Documentary survey on studies related to the topic of rising damp, through a documentary analysis on the state of the art; the collection of the data obtained from the current trials; the study of local materials;
- Experimentation on the performance characteristics of materials turn in part at the Polytechnic of Madrid, in synergy with the laboratory of "Tecnología Edificatoria y Medio Ambiente", partly in the Departments of Civil, construction and environmental engineering and Materials engineering and industrial production of the "Frederico II" of Naples;
- Start of experimentation by the installation of the C.N.T. devices and the probes in the Escuela Técnica de Minas y Energía of UPM, in the Cuartel del Conde Duque, in the historical center of Madrid and in the Pontifical Basilica of Pompeii. The monitoring phases of the intervention are in progress.
- Study of the theory of capillarity
- Analyzing device operation

## 4 CONCLUSIONS

The development of PhD project in progress at the DICEA of the University of Naples "Federico II" has highlighted the complex articulation of a research with industrial characterization, in terms of coordination of the subjects involved and influences from scientific different fields.

The need to achieve real results with effective impact on the social and economic development of the country requires to widen each time the boundaries of research and experimentation, in relation also to the levels of study required by each disciplinary field involved in the project.

This approach, albeit demanding, determines the greater weight of an industrial research compared to a research with university funds, in line with the interest of the public Institutions to finance these training courses included in the strategic planning lines of Industry 4.0.

## REFERENCES

- [1] Ministry of Development Economic and Ministry of Education, University and research, *Strategia nazionale di specializzazione intelligente*, 2014.
- [2] Ministry of Education, University and research, Department for Higher Education and research, *Decreto per la presentazione di domande di finanziamento di borse di dottorato aggiuntive rispetto a quelle già finanziate dalle Università per l'a.a. 2016/2017 – ciclo XXXII*, 2016.

- [3] The PhD project described in this article was written by Roberto Castelluccio, currently researcher at the DICEA of the University of Naples "Federico II". The grant financed by the MIUR was assigned to Veronica Vitiello, currently enrolled in the third year of doctorate in civil systems engineering.
- [4] R. Ceroni, M. Pece, G. Manfredi, G. Marcari, S. Voto. "Analisi e caratterizzazione meccanica di murature di tufo". *15° Congresso C.T.E.*, Bari 2004
- [5] E. Franzoni, C. Gentilini, G. Graziani, S. Bandini, "Compressive behaviour of brick masonry triplets in wet and dry conditions". *Construction and Building Materials*, 2015
- [6] A. Marshall, R. Fittonb, W. Swanb, D. Farmerc, D. Johnstonc, M. Benjaberb, Y. Ji, "Domestic building fabric performance: Closing the gap between their situ measured and modelled performance", *Energy and Buildings*, 2017
- [7] R. Castelluccio, V. Vitiello. "Deleting of rising damp in the archaeological site of Piazza Armerina through the application of the technology by neutralizing electrical charge T.N.C.", *Le Vie dei Mercanti - XIV Forum Internazionale di Studi*, Capri 2016
- [8] R. Castelluccio, V. Vitiello, M. Infante. "The charge neutralization technology: diagnosis and performance efficacy", *Colloqui.A.T.e*, Cagliari 2018
- [9] Torres, V. Peixoto de Freitas, "The influence of the thickness of the walls and their properties on the treatment of rising damp in historic buildings". *Construction and Building Materials*, 2010
- [10] R. Castelluccio, V. Vitiello. "Performance analysis of method T.N.C. on masonries in tuff affected by capillary rising damp", *Colloqui.A.T.e*, Matera 2016.
- [11] R. Castelluccio, M. Rossetto. "Rising Dump in Historical Buildings: Restoration using the Charge Neutralization Technology CNT Domodry®". *SMC–Water and Construction*, vol. 2, 2015
- [12] R. Castelluccio, *Interventi con intonaci da risanamento su murature in tufo giallo napoletano affette da umidità da risalita capillare. La sperimentazione in laboratorio*. Luciano Editore, Napoli, 2013
- [13] R. Castelluccio, *I fenomeni di umidità sulle murature in tufo giallo napoletano – La risalita capillare, gli interventi con intonaci da risanamento*. Luciano Editore, Napoli 2013
- [14] M. Rossetto, *Il sistema elettrofisico a neutralizzazione di carica Domodry® per la deumidificazione e il controllo dell'umidità nelle murature. Principio di funzionamento e casi applicativi*. Servizio Opere Inedite, Roma, 2012
- [15] G. Roche, *La Termografia per l'edilizia e l'industria. Manuale operativo per le verifiche termografiche*. Maggioli Editore, Santarcangelo di Romagna (RN), 2012
- [16] R. Walker, S. Pavía, M. Dalton, "Measurement of moisture content in solid brick walls using timber dowel". *Materials and structures*, July 2015.
- [17] F.D.I. Gordejuela, "Expansión por la humedad de los productos cerámicos españoles: revision de la normativa". *Congreso Nacional de Tecnología en la Arquitectura*, 1994
- [18] UNI EN 11085, *Materiali lapidei naturali ed artificiali. Determinazione del contenuto d'acqua: metodo ponderale*, 2003