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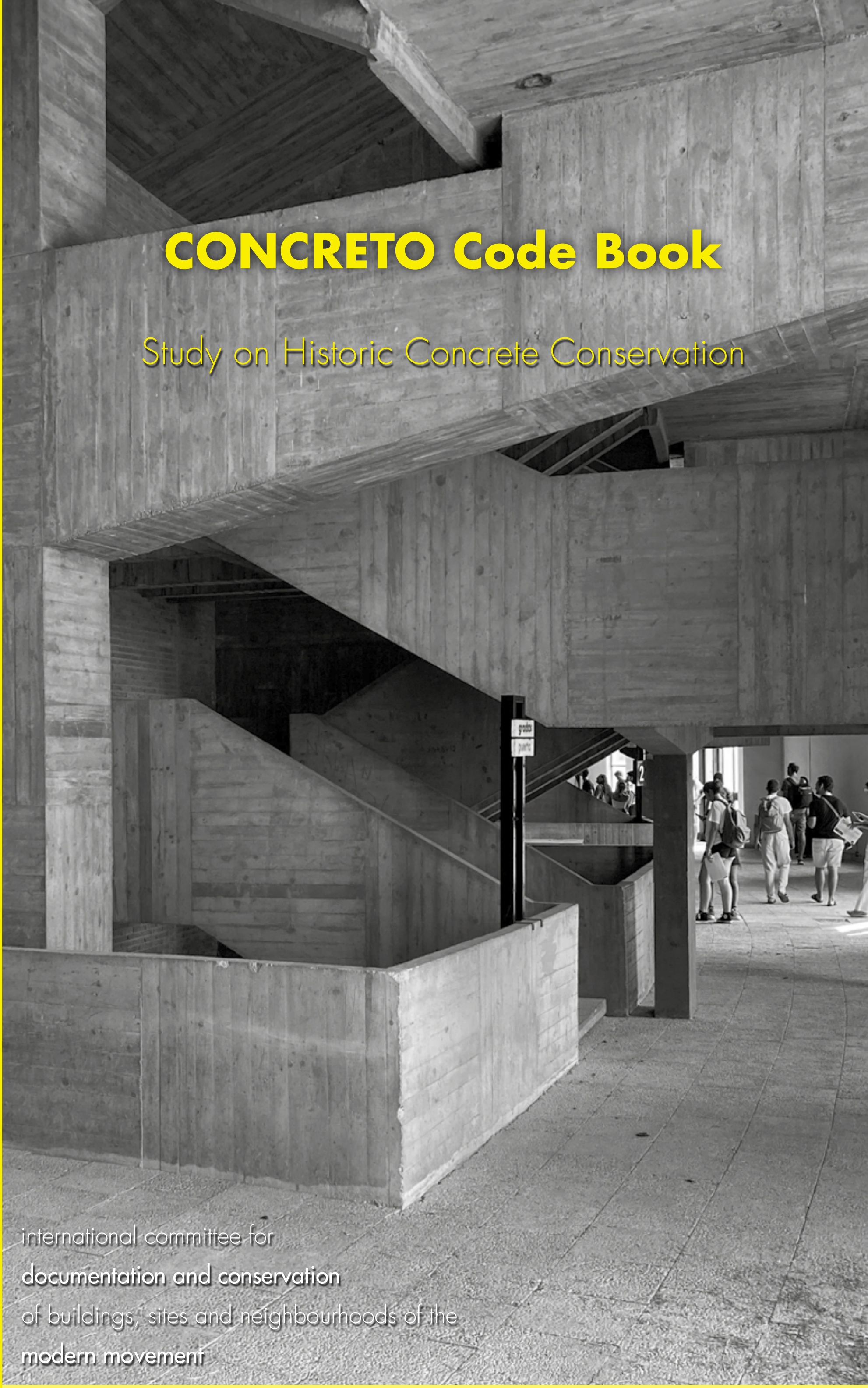

CONCRETO Code Book

Study on Historic Concrete Conservation

international committee for
documentation and conservation
of buildings, sites and neighbourhoods of the
modern movement

CONCRETO CODE BOOK

Study on Historic Concrete Conservation

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2025

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CONCRETO ACADEMY

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FOREWORD

The CONCRETO Code Book represents foundational research conducted within the broader framework of the CONCRETO Academy Project, officially launched in 2024.

The CONCRETO Academy was established to address the increasing demand for specialised skills and craftsmanship in the conservation of concrete historic architecture. Leading this initiative, the Pier Luigi Nervi Project Foundation has played a pivotal role in safeguarding modern heritage, driven by its commitment to preserving the profound legacy of the Italian engineer-architect and builder Pier Luigi Nervi.

Designed as a research hub, the CONCRETO Academy develops training programmes rooted in the principle of Learning by Doing, blending theoretical knowledge with technical expertise and hands-on practice. Participants of the Academy are not students, but fellows engaged in an apprenticeship model that fosters active skill-building and knowledge exchange.

The Code Book serves as the foundation upon which all teaching and learning activities within the Academy are structured. While primarily focused on the European context, its reach extends globally, leveraging insights from the extensive CONCRETO Network of partners and experts. Through rigorous literature review, open questionnaires, and strategic interviews, the Code Book defines the current state of concrete conservation, identifying key challenges and opportunities within the field. This publication is intended for all professionals engaged in the conservation of historic concrete architecture.

As emphasised in this publication, the conservation of concrete architecture demands a diverse and highly specialised team, where experts from different fields collaborate seamlessly. Too often, this work is compartmentalised, restricting the dialogue and the exchange of knowledge between professionals. However, it is never just an *"aesthetic problem" or solely a "structural problem"* – it requires an integrated and holistic approach.

As Pier Luigi Nervi described in his writings from the Charles Eliot Norton Lecture at Harvard first published in 1965, the relationship between aesthetic and technology has acquired *"a new richness" with reinforced concrete. The technological qualities and strength of reinforced concrete are referred to as "the superstone". Thanks to its monolithic nature – "its static unity holds together the various parts of structure"* – there are limitless possibilities of design ideas. A clear understanding of both the technical and of construction methods and problems related to reinforced concrete is particularly important when intervening and working with concrete structures, as often emphasised by Nervi.

A diverse team of professionals and experts are required to collaborate and provide solutions in respect to the original function and fabric of the building, and it is also important to provide solutions to reflect today's standard and code such that these architectures remain alive and relevant for both today and for the future.

A defining feature of the Academy is its inclusive approach, fostering cooperation among craft workers, contractors, professionals and stakeholders enabling knowledge sharing and interdisciplinary collaboration. This initiative extends beyond heritage-listed structures to embrace what we call mainstream concrete architecture – the everyday buildings that form the backbone of our built environment. Given that officially listed concrete heritage buildings represents only a small fraction of the built landscape, our goal is to equip professionals with the necessary skills and methodologies to work effectively across the full spectrum of concrete architecture.

By integrating theoretical research with practical applications, CONCRETO Academy strives to advance concrete conservation, ensuring that both iconic and everyday concrete structures are recognised, preserved and valued for future generations. Modern architecture represents an essential part of our European heritage, embodying both cultural significance and technological progress, and is worth preserving.

Irene Matteini

Scientific Director, CONCRETO Academy

PREFACE

Our current era is characterised by major liveability challenges associated with social inequality, global warming, and finite resources. As we need to reduce our environmental footprint, this calls upon us and everyone to deal responsibly with the existing built environment.

Reinforced concrete is undoubtedly the most widely used building material of the 20th century. Much of our living environment is dominated by this material. Worldwide, but certainly in Europe, almost no 20th-century building project has been realised without concrete. The Modern Movement contributed to this significantly, but architecture and engineering based on more classical principles did not shy away from the material either. Reinforced concrete is sometimes very eye-catching and significant, sometimes nondescript or insignificant, but whatever the design or its appearance is, the management, maintenance and repair, repurposing or possible (partial) demolition are very much determined by the properties of this composite material.

The non-profit organisation dedicated to documenting and conserving buildings, sites and neighbourhoods of the Modern Movement, DOCOMOMO International, has, from 1988 onwards, tabled the importance of the academic and professional debate on understanding the characteristics and importance of modernity.[1] One of the essential aspects of modernity, addressed by DOCOMOMO International and its international community, is the use and the conservation of new materials and products in 20th-century buildings. With its pioneering symposium and accompanying technology dossier, the International Specialist Committee on Technology (ISC/T) focused on the conservation and repair of exposed concrete as early as 1997.[2] Over the years, numerous research projects, scientific publications, and practical efforts have significantly contributed to the understanding and preservation of reinforced concrete. However, while many technical advances have been achieved, not all challenges have been solved. Substantial gaps remain in the dissemination of knowledge, the development of consistent standards, and the implementation of holistic approaches. This report serves as a key starting point for evaluating the current state of the art in the field.

Addressing these gaps requires sharing experiences across Europe, raising awareness among stakeholders and fostering interdisciplinary collaboration. By doing so, the field can not only advance the preservation of concrete heritage but also integrate it into a more sustainable and inclusive built environment. Therefore, the CONCRETO project is of utmost importance in taking further steps in the rehabilitation of European concrete architecture. European cooperation and learning will make the difference!

Uta Pottgiesser & Wido Quist

Editors DOCOMOMO International book series

1 Henket, H.-J., Jonge, W. de (eds.), 1991. Proceedings of the first International DOCOMOMO Conference, Eindhoven University of Technology, September 12-15 1990, DOCOMOMO International, 329 pp. https://docomomo.com/wp-content/uploads/2023/04/Docomomo_1st-IDC_1990_OCR_reduced.pdf

2 Jonge, W. de, Doolaar, A. (eds.), 1998. The fair face of concrete: conservation and repair of exposed concrete, Preservation Technology Dossier 2, DOCOMOMO International, 151 pp. https://docomomo.com/dossier-2-the-fair-face-of-concrete_ocr/

CONCRETO PROJECT

CONCRETO is an international Erasmus+ training project which aims to promote sustainable practices for the regeneration of reinforced concrete structures through an interdisciplinary and practical approach, in line with the orientation and invitation of European institutions to implement regeneration and recovery strategies for the European built heritage in a sustainable way.

Led by the Pier Luigi Nervi Project Foundation, CONCRETO includes:

- 2 organisations for the conservation of modern heritage: Pier Luigi Nervi Project (PLN), DOCOMOMO International
- 3 higher education institutions: Middle East Technical University (ODTÜ METU), Politecnico di Milano (POLIMI), Universidad Politécnica de Madrid (UPM)
- 5 professional associations: National Council of Architects, Landscape Architects and Conservators (CNAPPC), National Council of Engineers Foundation (FCNI), Consejo Superior de los Colegios de Arquitectos de España (CSCAE), Colegio de Ingenieros de Caminos, Canales y Puertos (CICCP), Association of Turkish Engineers and Architects Consultants (ATCEA).
- 3 vocational training organisations: Fundación Laboral de la Construcción (FLC), Istituto per l'Istruzione Professionale dei Lavoratori Edili della Provincia di Bologna (IIPLE), Turkish Vocational Training Authority (MYK).

Learning by Doing is the principle on which the CONCRETO Academy is based, created as a school of advanced training to promote the knowledge and skills necessary for the rehabilitation of reinforced concrete structures. The CONCRETO Academy brings together university students, students from construction schools, and young professionals, promoting cross-sectoral collaboration between the main players involved in order to create the experts of tomorrow.

CONCRETO has a two-fold approach: on the one hand, it organises training activities and practical workshops on the techniques for the recovery and restoration of reinforced concrete structures; on the other hand, it develops guidelines for professionals on the recovery and conservation of such structures.

The training courses take place over three years, both remotely and in person, and can be considered as multi-level, as are aimed at different types of students. Starting with the three-day online Stepping Stone, each cohort of students learns from professors and experts through case studies on conservation and restoration of concrete heritage. Later, they gather together in person, in Italy, Spain and Türkiye, for Master Your Skills, where they learn from professionals and get their hands dirty. This is complemented by a multiplier event, CONCRETO Day, gathering all stakeholders together, including technical and media sponsors, who ensure that the effects of the project are felt widely.

During the summer, the CONCRETO Academy Masterpiece takes place in Ivrea, with students working directly on selected buildings and in a hands-on laboratory. Through this *"learning by doing"* approach, they put their technical skills into practice, understanding the importance of meticulous craftsmanship in preserving our built environment. The aim is to transform the students into skilled apprentices who are well-versed in the art and science of concrete rehabilitation. Through the

FIVE SKILL PILLARS – Concrete Assessment Investigation, Concrete Repair, Concrete Surface Treatment, Concrete Retrofitting, and Concrete Monitoring and Maintenance – they acquire expertise that is both timeless and highly relevant to today's preservation needs.

To ensure sustainability, all materials produced during the project will be accessible online through an open-source platform in a MOOC being developed by Politecnico di Milano for the CONCRETO Academy. This provides a permanent opportunity for growth and knowledge exchange.

For more information: www.concreto-academy.org

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1 INTRODUCTION

This CONCRETO Code Book presents a comprehensive baseline of the state-of-the-art approaches and practices in the field of historic concrete conservation to identify the knowledge gaps and mismatches existing in current practice. The CONCRETO Code Book aims to serve as a resource for professionals, policymakers and educational institutions, providing a deeper understanding of the current state of the field while offering practical recommendations for future development.

The CONCRETO Academy aims to contribute to closing these knowledge gaps and overcoming the mismatches in knowledge. The overarching aim of the CONCRETO Academy is to contribute to the European Green Deal, which states that 35 million buildings should be renovated by 2030 to reach the goals stated in the Paris Agreement.[1] The focus of the CONCRETO Academy is to speed up the rehabilitation of modern buildings, with a specific focus on the conservation and adaptation of concrete.


Architecten worden de nieuwe activisten: weg met de sloopkogel en bouwen met wat er is

Beeld Joost Stokhof

Er wordt volop gesloopt in Nederland, met de belofte dat nieuwbouw een betere stad oplevert. Ondertussen gaan geschiedenis en sociale structuren verloren, en stijgt de CO2-uitstoot. Een groeiende groep architecten pleit voor een sloopverbod. Maar hoe krijg je dat voor elkaar?

Figure 1.1
"Architects become the new activists: away with the wrecking ball and build with what is there" Volkskrant, 20-02-2025.

1 https://energy.ec.europa.eu/topics/energy-efficiency/energy-efficient-buildings/renovation-wave_en

Figure 1.2
City of London's 'retrofit first' policy to come into force. Architects Journal, 22-02-2025.

City of London's 'retrofit first' policy to come into force

22 JANUARY 2025 • BY WILL HURST

Source: Mistervlad/Shutterstock

A proposal by the City of London to encourage reuse of existing buildings and other circular economy measures will become policy within the coming weeks, the authority has announced

Finally, in early 2025, it seems that both bottom-up and regulatory initiatives are getting into position to speed up the reuse of existing buildings and favour reuse over new construction (see Fig. 1.1 and Fig. 1.2). CONCRETO Academy contributes to these initiatives with a specific focus on concrete.

Concrete is the most used construction material in Europe: rough estimations point at 60% of all materials used in buildings is concrete.[2] When reusing the existing building stock more intensively, architects, engineers and construction workers must inevitably work on maintaining, preserving and adapting this artificial human-made material.

Due to its CO_2-intensive production and the abundant use of raw materials such as sand, limestone (cement production), pebbles and gravel, concrete conservation contributes to many of the Sustainable Development Goals. The conservation of concrete not only concerns the highlights of modern architecture that are inventoried and advocated for by e.g. DOCOMOMO International, Foundation PLN Project, Innovaconcrete, SOSBrutalism, and are in need of preservation, it also concerns a vast number of lesser-known and lesser-appreciated buildings that are facing deep energy renovations.[3]

The CONCRETO Code Book and CONCRETO Academy place significant emphasis on environmental sustainability, particularly in relation to concrete conservation and reuse within the framework of the European Green Deal. However, the cultural and heritage value of reinforced concrete buildings should be equally addressed, as many of these structures are of sig-

2 Aytekin, B., & Mardani-Aghabaglou, A. (2022). Sustainable Materials: A Review of Recycled Concrete Aggregate Utilization as Pavement Material. Transportation Research Record, 2676(3), 468-491. https://doi.org/10.1177/03611981211052026

3 https://energy.ec.europa.eu/topics/energy-efficiency/energy-efficient-buildings/renovation-wave_en

nificant architectural, historical and social importance. Cultural heritage does indeed matter in sustainability. Sustainability is not solely about reducing emissions and reusing materials – it also includes the preservation of cultural significance. International conventions, such as those established by UNESCO and ICOMOS, recognise that cultural heritage is a fundamental element of human well-being. The conservation of historic concrete structures should not only be viewed through the lens of carbon footprint reduction but also as a means of maintaining cultural identity and ensuring continuity between past, present and future generations.

1.1 The magnitude of concrete present in Europe

Looking around in a random European city or village, one cannot avoid concluding that concrete is everywhere: in buildings, public spaces and infrastructure. Much concrete is visible and even more concrete is invisible as it is used for hidden constructions and foundations.

The magnitude of the European building stock seems difficult to agree upon. The Q&A from 2020 regarding the Renovation Wave refers to 220 million building units in Europe, whereas the next paragraph of the same Q&A states that these 220 million only reference the 85% of the building stock built before 2001. This would equal 259 million building units in total.[4]

According to the 2020 survey (based on the EU-27 countries) of the European building stock observatory, the European building stock comprises 112 million buildings (equal to 27 billion m^2), of which 102 million concern residential objects (18 billion m^2) and 10 million objects (9 billion m^2) concern services.[5] RICS Data Services extrapolates these results to a total of approx. 131 million buildings within Europe, with a division of approx. 10:1 residential: non-residential. Looking at square meters, the division is 75% residential and 25% non-residential.[6]

Based on the same European building stock observatory survey, Zandonella Callegher et al. studied the materials used in the inventoried residential buildings.[7] Considering floors, walls and roofs, they come to an overall estimation of 2.6 billion kg of concrete used over the years in all residential buildings of the EU-27 countries inventoried. Combining this with the estimations of RICS Data Services, this adds up to 4.1 billion kg of concrete used in the European building stock. Assuming a density of 2200 kg/m^3 means that 4.1 billion kg of concrete equals 1.9 million m^3 of concrete used in the European building stock, excluding the foundations as they were not included in the Zandonella Callegher et al. study.

There are no historical figures on the use of concrete in infrastructures such as dams, bridges, roads and other pavements, nor is there data on its use in public spaces, but the total use of concrete in the built environment is certainly much higher than the 1.9 million m^3 mentioned above. Especially looking at the historical overview of the annual production of cement. Fig. 1.3 shows how the annual cement production grew from only a few megatonnes just after the Second World War to 4000 megatonnes in 2020. Although only a small part (176 Mt in 2022[8]) is produced in Europe, this equals a large amount of concrete for use in construction.

4 https://ec.europa.eu/commission/presscorner/detail/en/qanda_20_1836
5 https://building-stock-observatory.energy.ec.europa.eu/factsheets/
6 https://www.rics.org/news-insights/energy-efficiency-of-the-building-stock-in-the-eu
7 Zandonella Callegher, C., Grazieschi, G., Wilczynski , E., Oberegger, U. F., & Pezzutto, S. (2023). Assessment of Building Materials in the European Residential Building Stock: An Analysis at EU27 Level. Sustainability, 15(11), 8840. https://doi.org/10.3390/su15118840
8 David Perilli, Global Cement, 2024: https://www.globalcement.com/news/item/17883-china-starts-to-include-cement-sector-in-emissions-trading-scheme#:~:text=This%20move%20signals%20China's%20intent,Union%20(EU)%20in%202022

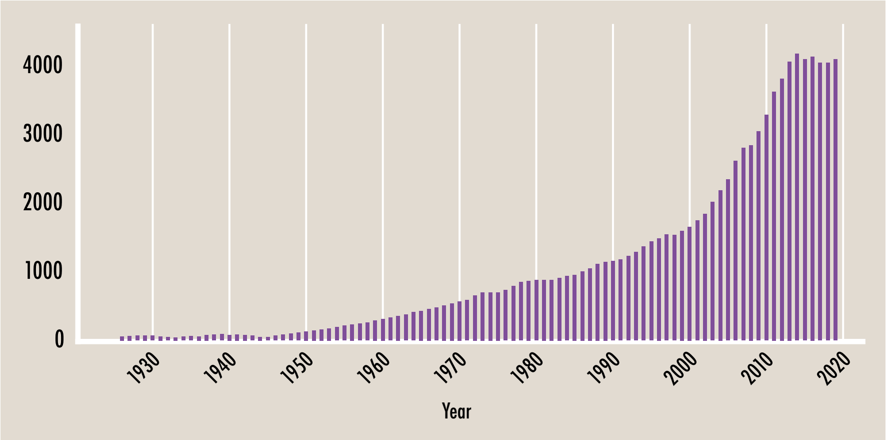


Figure 1.3
Annual production of cement. Graph altered (red line at 1950 removed) from Head et al., p. 364.[9]

Although it is impossible to assess how much concrete is used in European buildings, in light of these data, it is clear that the amount is enormous and that we share a societal responsibility to take good care of it with regard to cultural heritage preservation but also to renovation and adaptation of buildings to our current and future needs.

1.2 European Construction Industry

According to the European Builders Confederation, the construction sector is of vital importance to the European economy. With more than 3 million enterprises and a total direct workforce of 18 million people, the construction sector generates about 9% of the GDP of the EU.[10] Up to 95% of construction, architecture and civil engineering firms are micro-enterprises, and 99.9% of the European construction sector comprises enterprises with fewer than 250 employees. In 2016, construction SMEs (small and medium-sized enterprises) made up 88% of total employment and 80% of the total value added of the construction sector in the EU-28.[11] [12]

From a labour market perspective, it is predicted that the overall number of construction workers in Europe will only increase by 90 thousand until 2035, but it is due to the large number of retirements–4.1 million–that investments in the human capital of the construction market are necessary.[13]

This need for replacement, combined with the ambitions of the Renovation Wave, highlights that education in construction should no longer focus primarily on new buildings but also on the existing stock. Next to knowledge and skills directly related to the application of energy renovation measurements, it also directly calls upon hands-on skills and knowledge about the conservation and adaptation of existing materials in buildings, of which concrete accounts for a large share.

9 Head MJ, Steffen W, Fagerlind D, Waters CN, Poirier C, Syvitski J, Zalasiewicz JA, Barnosky AD, Cearreta A, Jeandel C, Leinfelder R, McNeill J, Rose NL, Summerhayes C, Wagreich M, Zinke J. The Great Acceleration is real and provides a quantitative basis for the proposed Anthropocene Series/Epoch. Episodes 2022;45:359-376. https://doi.org/10.18814/epiiugs/2021/021031

10 https://www.ebc-construction.eu/about-us/facts-figures/

11 https://single-market-economy.ec.europa.eu/sectors/construction_en

12 https://www.ebc-construction.eu/about-us/facts-figures/

13 https://www.cedefop.europa.eu/en/data-insights/construction-workers-skills-opportunities-and-challenges-2023-update

1.3 Education in Europe

Although it is not expected that pure construction work will require more jobs, the expectation is that the green transition could result in the creation of 1 to 2.5 million additional jobs by 2030.[14] To achieve a comprehensive upskilling and reskilling effort for 25% of the construction industry workforce, amounting to 3 million workers (between 2022 and 2027), the need for relevant vocational educational programmes is huge, as stated in the Osnabruck Declaration.[15]

Not only vocational education and training are in need of expansion and redesign, but higher education in architecture and engineering should also adapt to the challenges ahead with a growing emphasis on the conservation and adaptation of twentieth-century architecture. The Getty Conservation Institute and DOCOMOMO International study from 2022 on Education and Training for the Conservation of Twentieth-Century Built Heritage indicates that changes are on their way and new programmes are being established.[16]

Despite this growing interest in 20th-century architecture the need for targeted education is still urgent: interdisciplinary training and stronger collaboration between research and practice to guide conservation efforts are necessary.[17] A holistic approach that integrates both traditional and innovative methods is essential to ensure the long-term durability and preservation of historic concrete buildings across Europe.

1.4 Methodology

The methodology used for the CONCRETO Code Book combines qualitative and quantitative research techniques to ensure a comprehensive analysis of the current state of education, certification and professional practice in the field of historic concrete conservation. Although global developments are touched upon, the focus of the research lies on Europe, more in particular on the countries where the CONCRETO Academy partners are based, i.e. Spain, Italy and Türkiye.

The study has been developed through three main working tools:

- Questionnaire survey: a structured questionnaire was distributed to all project partners, targeting architects, engineers and craftworkers. The aim was to quantitatively assess the tools, resources and methodologies available to these professionals and to identify common needs and gaps in their training and practice (Chapter 2).
- Literature and document analysis: a thorough review of existing reports, academic publications, international charts, organisations and international conferences on the topic of historic concrete conservation was conducted to establish a foundational understanding of best practices and existing knowledge gaps (Chapter 3).
- Stakeholder engagement: experts from different sectors, including architects, restorers, contractors and professors, were interviewed to gather first-hand insights into the skills and challenges faced by the intervention on historical concrete buildings and structures. These qualitative inputs were crucial for contextualising the findings and identifying dis-

14 https://build-up.ec.europa.eu/en/resources-and-tools/articles/skills-development-eu-building-sector

15 European Commission: Directorate-General for Employment, Social Affairs and Inclusion, Osnabrück Declaration on vocational education and training as an enabler of recovery and just transitions to digital and green economies, Publications Office of the European Union, 2021, https://data.europa.eu/doi/10.2767/784423

16 Pedroni, Margherita, Cesar Bargues Ballester, Andrea Canziani, Wessel de Jonge, and Chandler McCoy. 2020. A Global Survey on Education and Training for the Conservation of Twentieth-Century Built Heritage: Research Report. Los Angeles: Getty Conservation Institute; Lisbon: DOCOMOMO International. https://hdl.handle.net/10020/gci_pubs_global_survey_education.

17 DOCOMOMO International (2022), DOCOMOMO Manifesto on Education Tokyo – Valencia. https://docomomo.com/docomomo-manifesto-on-education/

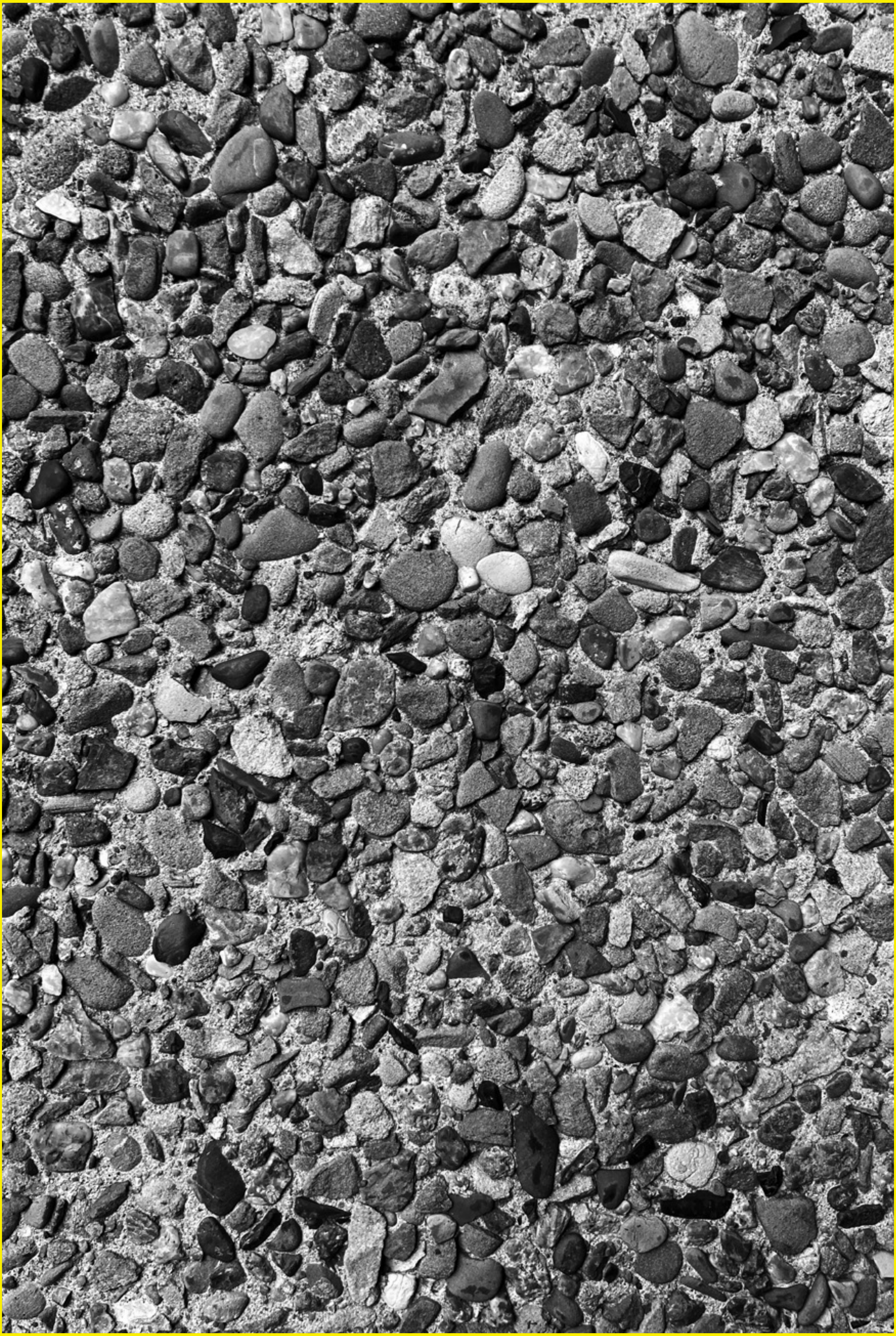
crepancies between educational frameworks and practical requirements (Chapter 4). The combination of these methodologies allows for an evidence-based and practice-oriented approach, ensuring that the CONCRETO Code Book serves as a useful reference for educators, professionals and policymakers in the field of historical concrete conservation.

1.5 Terminology

In this report, when reflecting on data gathered and identifying potential knowledge gaps and mismatches, the definitions of general terms in the conservation of cultural heritage, as stated in EN 15898:2019, will be used as much as possible. Nevertheless, it should be noted that not all respondents to the questionnaires, interviewees, or publications studied use these definitions. Reasons for this are–amongst others–the publication date, the translations to and from Italian, Spanish and Turkish language, and the not (yet) unanimously accepted standard.

According to EN 15898:2019:

- **Cleaning** is defined as the removal of unwanted material from an object.
- **Condition** survey (assessment) is defined as the planned and methodical assessment of the condition of an object or a collection.
- **Conservation** is defined as measures and actions aimed at safeguarding cultural heritage while respecting its significance, including its accessibility to present and future generations.
- **Consolidation** is defined as an improvement of internal cohesion or mechanical stability, usually involving the addition of material.
- **Diagnosis** is defined as the process of identifying the present condition of an object and determining the nature and causes of any change, as well as the likely consequences.
- **Intervention** is defined as any intentional action on an object, ensemble or collection.
- **Maintenance** is defined as periodic conservation actions aimed at sustaining an object in an appropriate condition to retain its significance.
- **Preventive conservation** is defined as measures and actions aimed at avoiding or minimising future damage, deterioration, loss, and, consequently, any invasive intervention.
- **Reconstruction** is defined as the re-establishment of an object to an inferred earlier form using existing and/or replacement material.
- **Rehabilitation** is defined as interventions on an immovable object to recover an inferred earlier functionality, to adapt it to a different function or to standards of comfort, safety and access.
- **Remedial conservation** is defined as actions applied directly to an object to arrest or slow deterioration and/or to limit damage.
- **Renovation** is defined as actions of renewing an object without necessarily respecting its material or significance.
- **Repair** is defined as actions applied to an object or part of it to recover its functionality and/or its appearance.
- **Restoration** is defined as actions applied to a stable or stabilised object aimed at facilitating its appreciation, understanding and/or use while respecting and/or revealing its significance and the materials and techniques used.
- **Treatment** is defined as a direct intervention to achieve stated conservation aims.



2 DAILY PRACTICE

Two questionnaires were used to study the professional field of concrete repair/conservation and how concrete conservation is planned and executed. The questionnaires were developed and sent out to capture the perspectives on the daily practice of professionals, including architects, engineers and craftworkers. The questionnaires also aimed at gaining insights into the participants' professions, training backgrounds, current practices, and interest in further training.

2.1 Methodology

The questionnaires were addressed to architects, engineers and craftworkers in Türkiye, Spain and Italy. They were distributed by Project Partners and Associated Partners of the CONCRETO Consortium, including the following Vocational Training Organisations: Istituto per l'Istruzione Professionale dei Lavoratori Edili della Provincia di Bologna (IIPLE) in Italy; Fundación Laboral de la Construcción, Madrid (FLC) in Spain, and Mesleki Yeterlilik Kurumu (MYK) in Türkiye. The questionnaires were also distributed by the following Trade Associations: Association of Turkish Consulting Engineers and Architects (ATCEA, Türkiye), Colegio de ingenieros de Caminos, Canales y Puertos (CICCP, Spain), Consiglio Nazionale Architetti, Paesaggisti e Conservatori (CNAPPC, Italy), Consiglio Nazionale Ingegneri (FCNI, Italy) and Consejo Superior de los Colegios de Arquitectos de España (CSAE, Spain).

To ensure equal access and applicability in the different geographical and linguistic environments, the questionnaires were translated into the local languages. The template questionnaires, in English, have been added as Appendix A of this document.

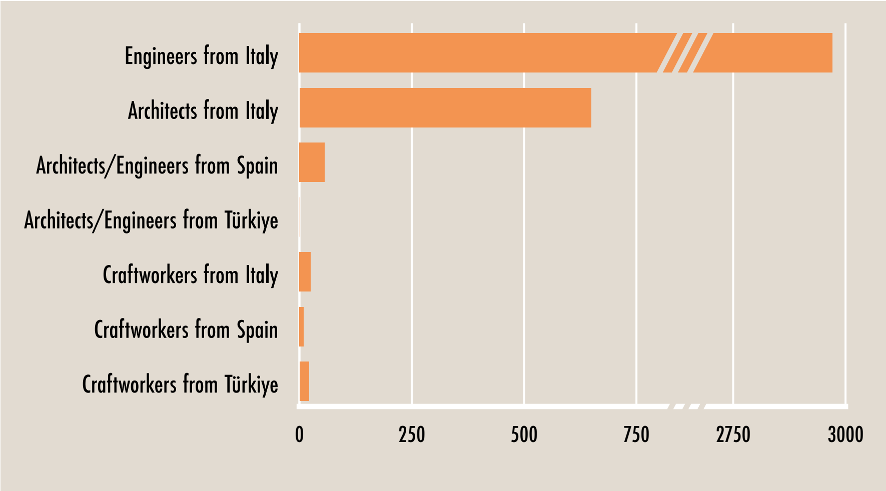
The questionnaires included 15 multiple-choice questions and an opportunity to provide extra comments to an open question at the end. The questionnaires could be answered anonymously, but respondents were able to leave their contact information to stay updated with CONCRETO Academy. The answers were processed anonymously. After finalising the report, personal information will be removed from the data collection.

Amongst architects/engineers, a total of 3600 responses were collected in Italy (3000 engineers, 600 architects), just over 50 in Spain, and no responses were collected in Türkiye (Fig. 2.1). The analysis of the data collected from architects/engineers, therefore, primarily concentrated on the responses received from Italian respondents. Where the Spanish responses strongly diverted from the Italian responses, the Spanish responses were studied and reported.

The questionnaire addressing craftworkers provided a total of 55 responses from Türkiye, Spain and Italy. In terms of data processing, due to the small number of respondents, the total number of responses was processed as one group.

The raw data of the questionnaires is presented in Appendix B.

Figure 2.1
Overview of respondents to the questionnaire.



2.2 Challenges and Limitations

Designing the questionnaire and translating the questions into Spanish, Italian and Turkish was rather challenging. The challenge was related to both content and language. With the joint efforts of the project partners in the different countries, the questionnaires were successfully distributed and the responses collected. Due to privacy regulations (GDPR) it was not possible for the Association of Turkish Consulting Engineers and Architects (ATCEA) to send out the questionnaire within the allocated time slot; therefore, no Turkish responses to the architects/engineers questionnaire were collected.

The unequal number of responses received from the different target groups made it difficult to draw firm conclusions on the outcomes and complicated comparisons. In addition, several incomplete questionnaires made it challenging to correlate the responses internally. Although the overall number of responses was somewhat limited and spread, the sample size was still adequate to identify the most significant trends and patterns.

2.3 Data Analysis: Architects/engineers

The survey of architects and engineers from Italy shows that a significant proportion of participants, almost 90%, has a master's degree or equivalent. Other levels of education are under-represented, underlining the high level of education of the respondents.

In the area of engineering degrees, civil and environmental engineering dominates with 73%, indicating a clear focus on this subject area.

In Italy, most respondents (67% of the architects, 62% of the engineers) work exclusively as consultants. Amongst the Spanish architects, the professional working environment is different, with 77% of the respondents working as employees (Fig. 2.2).

In terms of company size, more than half of the respondents (51%) are self-employed, and another large share (28%) works in small companies with less than 10 employees, correlating with most respondents working as (individual) consultants. The different Spanish responses to the questionnaire seem to be due to the sample taken, as many of the Spanish respondents report working in large companies with over 100 employees. The dominance of small specialist enterprises and self-employed architects and engineers in the study correlates with the general European situation in the construction sector (see paragraph 1.2).

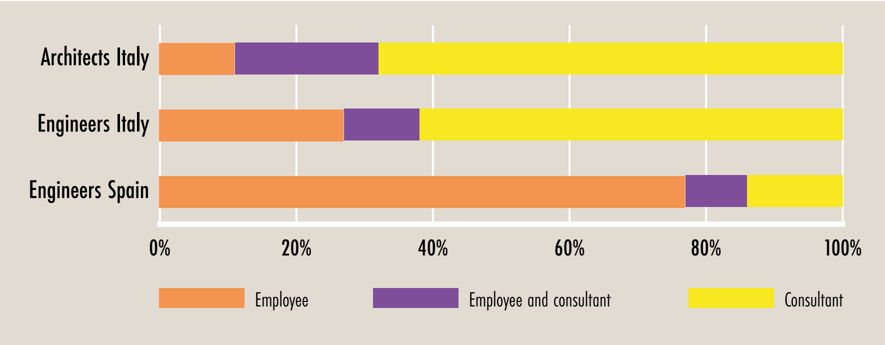


Figure 2.2
Working environment architects/engineers (Italy & Spain).

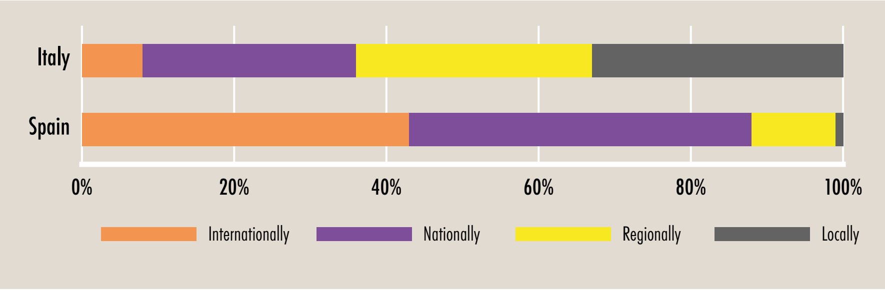


Figure 2.3
Geographical working range architects/engineers.

The Spanish respondents also report a higher level of international activities (43%) compared to their Italian counterparts, where international activities (7%) are less common amongst the respondents (Fig. 2.3). This can be explained through the large company size of the Spanish sample. The activities of architects/engineers in Italy are more or less equally distributed across the scales (local/regional/national) with a slight emphasis on the local scale.

A detailed analysis of the geographical areas of activity of the Italian respondents shows that 39% of the participants working exclusively as consultants carry out their activities locally, whereas this percentage for the employees is only 17%. In the group of employees, most respondents (43%) work nationally, whereas this is only 22% amongst the consultants.

71% of the Italian engineers report regularly working in concrete repair (Fig. 2.4). Amongst the Spanish engineers, this percentage is even higher (89%). Italian architects report only a 46% involvement.

A little less than half of all the engineers who reported working on concrete repair report to have had specific training in this field. The Spanish architects only report a training percentage of 20% amongst the respondents that actually work on concrete repair.

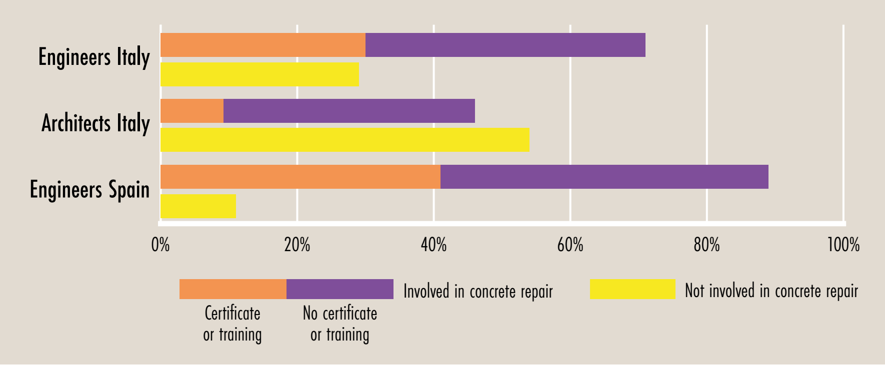


Figure 2.4
Regular involvement in concrete repair, including whether respondents are in possession of any related certificate or not.

Figure 2.5
Amount of work by architects/engineers related to concrete repair (Italy).

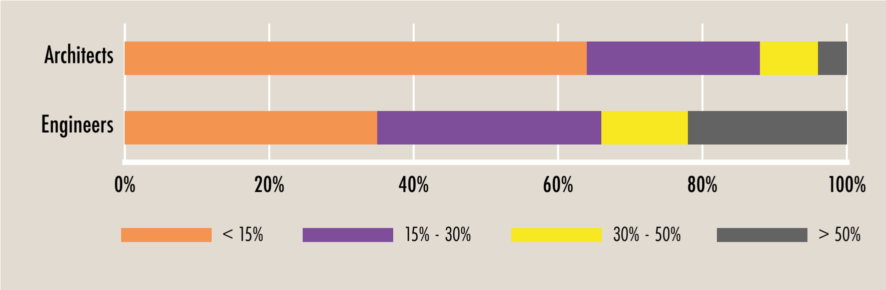
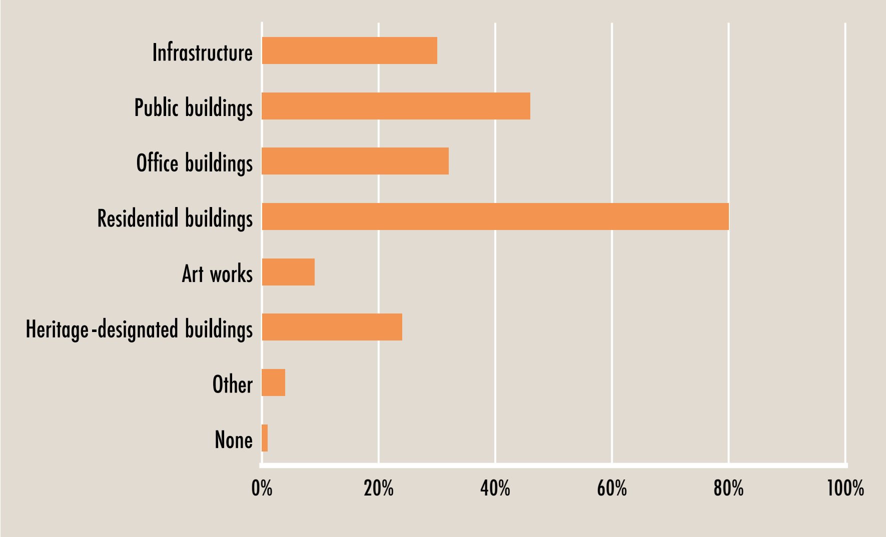


Figure 2.6
Types of concrete structures worked on by architects/engineers (Italy).



Only 22% of the Italian engineers who reported to work on concrete repair said their work is dominated by this field (Fig. 2.5). The largest proportion of this group of respondents (35%) reports that only 15% of their daily work relates to concrete repair. For the architects, the amount of work related to this field is even less; 64% of the respondents reported that less than 15% of their daily work relates to concrete repair.

The type of concrete structures that respondents report to have worked on are residential buildings (80%), followed by public buildings (46%), and infrastructure (30%) (Fig. 2.6). Many Italian architects/engineers report to have worked on patching work (81%), reinforcement repair (59%), and crack repair (49%). CFRP-strengthening (46%), cleaning (33%) and coating (29%) were reported to also belong to the regular work (Fig. 2.7).

Knowledge of concrete assessment techniques amongst architects/engineers varies: 51% of respondents have basic knowledge, and 31% have advanced knowledge. The majority (72%) always carries out an initial assessment during concrete repair works, whereas 23% does this only occasionally. Visual inspections combined with non-destructive testing (37%) and a combination of all assessment methods (35%) are most commonly used.

The question regarding the integration of maintenance plans into repair strategies is almost evenly answered: 21% of the respondents always integrate a maintenance plan, 23% do so frequently, 27% occasionally, and 29% rarely or never. Field inspections during a project seem to be common practice, as 97% of the respondents carry them out.

The vast majority (98%) of respondents said yes to the need for additional training in con-

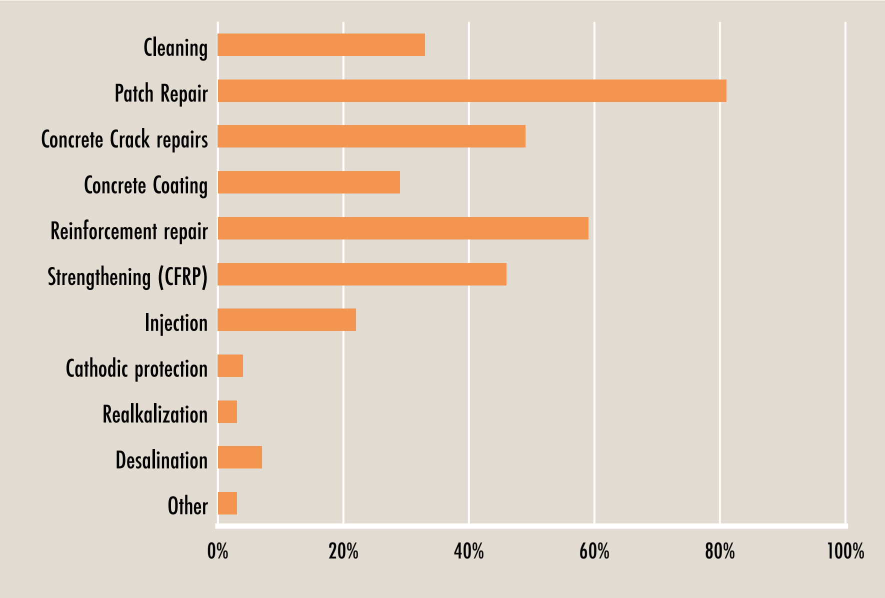


Figure 2.7
Type of repair regularly performed by architects/engineers (Italy).

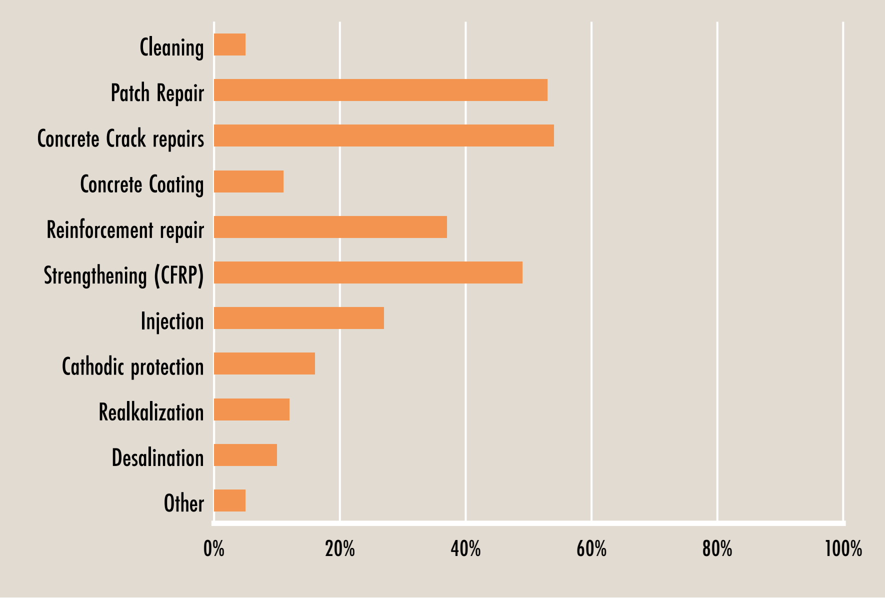


Figure 2.8
Topics for further training mentioned by architects/engineers (Italy).

crete repair and maintenance. Training in concrete crack repair (54%), patch repair (53%), and CFRP-strengthening (49%) are particularly in demand (Fig. 2.8). Also, reinforcement repairs is mentioned by more than a third (47%) of the respondents as an important topic for training.

2.4 Data Analysis: Craftworkers

The analysis of the data collected from craftworkers concentrates on all the responses received together. Where relevant, the Turkish, Spanish and Italian responses are analysed and reported individually.

The survey reveals that most respondents report to work nationally (36%). A big difference can be observed between the respondents from the three countries: in Spain, the regional level is overrepresented (44%), whereas in Türkiye, most respondents report working either internationally (43%) or nationally (43%) and the Italian respondents report to be working almost equally spread across the national, regional and local levels (Fig. 2.9).

Considering employment, 75% of respondents work for a company, while 25% are self-employed. Regarding company size, one third (33%) work in small businesses with less than 10 employees, but 20% of the respondents report working for a large company (>100 employees).

Most respondents (89%) have over 5 years of professional experience, and a large majority (78%) does not possess specific training or certification in concrete repair. Only a small number of the respondents (8%) identify themselves as craftworker, 22% as restorer/conservator, and the majority (70%) as neither. This "other" 70% includes architects, engineers, planners and technicians.

Only a few respondents (5%) report that their main work (>50%) is related to concrete repair, whereas the larger part of the respondents (60%) indicate that less than 15% of their work is related to concrete repair (Fig. 2.10). The Italian respondents divert from the overall picture as the majority of the respondents (52%) claim that 15%-30% of their work is related to concrete repair.

Figure 2.9
Geographical working range craftworkers.

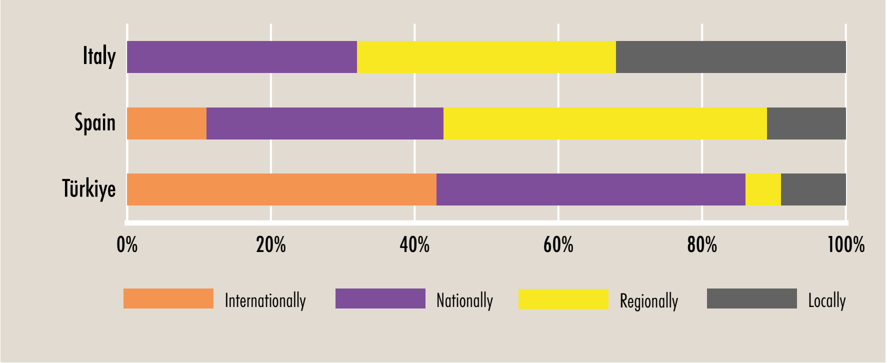
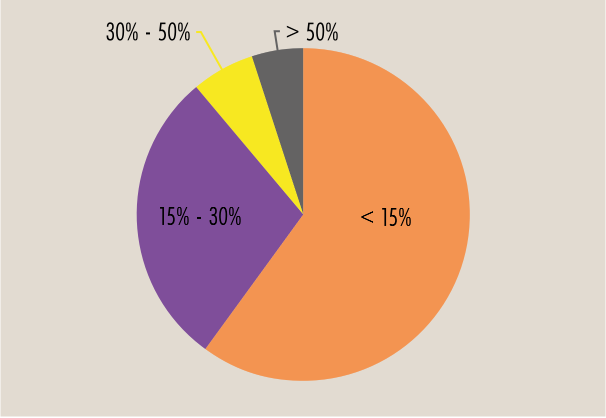


Figure 2.10
Amount of work related to concrete repair.



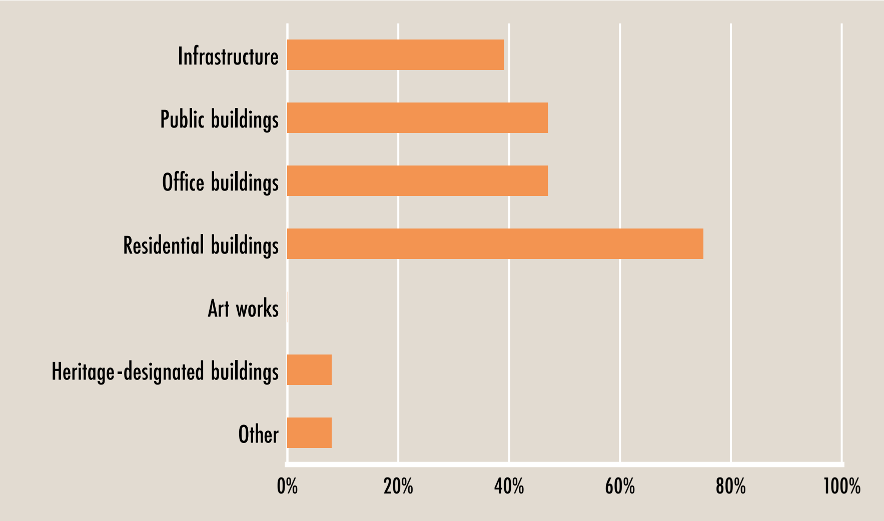


Figure 2.11
Types of concrete structures worked on by craftworkers.

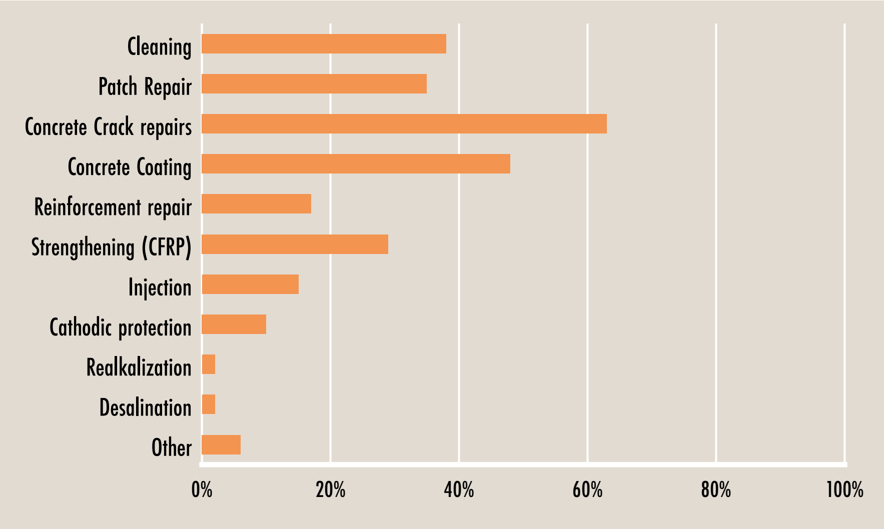


Figure 2.12
Type of repair regularly performed by craftworkers.

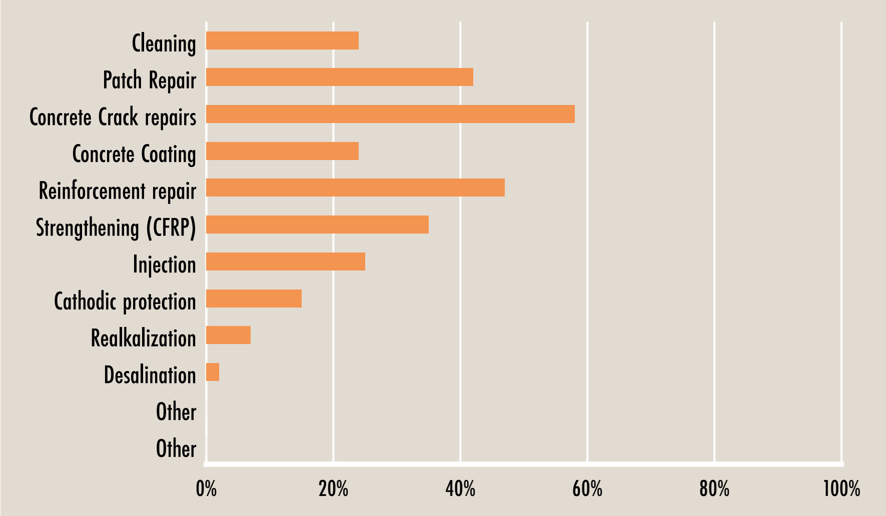
A significant portion (75%) of the respondents indicate that they have worked on residential buildings in terms of concrete structures (Fig. 2.11). Public and office buildings are each reported by 47% of respondents. Infrastructure projects are mentioned by 39% of respondents. A smaller segment (8%) worked on heritage-designated buildings.

The type of work performed by the respondents is diverse. The most commonly performed concrete repair tasks include crack repair (63% of all participants), concrete coating (48%), cleaning (38%) and patch repair (35%). However, CFRP-strengthening (29%), reinforcement repair (17%), and injection (15%) are also mentioned as commonly performed (Fig. 2.12).

78% of the respondents report that patch repair is less than 25% of their work. When executing patch repair, 41% of the respondents report not making mock-ups or test panels. Only 9% of the respondents indicate they will always make mock-ups and/or test panels. Almost half of the respondents (48%) indicate that mock-ups and/or test panels are occasionally made.

91% of the respondents expect receiving more training related to concrete repair would be beneficial. 58% of the respondents indicate that training on concrete crack repair would be

Figure 2.13
Topics for further training mentioned by craftworkers.



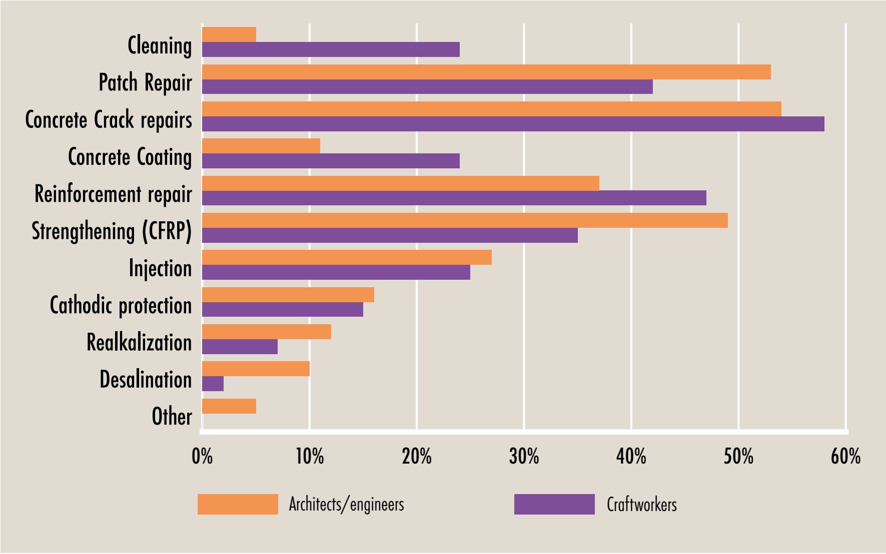
beneficial, 47% of the respondents point to reinforcement repair, and another 42% mention patch repair as a topic for further training (Fig. 2.13).

2.5 Discussion

Current work and potential training

Patch repair is–by far–the component of concrete repair mentioned the most by architects/engineers as a field they are working on (Fig. 2.14). Interestingly, it is only reported by a third of the respondents in the craftworkers category. Also, reinforcement repair has a high score among the architects/engineers and a low score among the craftworkers. Even though a little less clear, this is also the case for CFRP-strengthening. These numbers might suggest that those activities are general, everyday activities for many architects and engineers, whereas they are a specialist activity for the craftworkers. The larger involvement of the craftworkers in concrete crack repairs and concrete coating compared to the architects/engineers suggests that those are activities with less involvement of architects and/or engineers. Specific techniques

Figure 2.14
Comparison between the work of architects/engineers and craftworkers.



such as desalination, re-alkalisation and cathodic protection are neither among the main activities of the architects/engineers nor of the craftworkers.

The vast majority of all respondents (of both groups addressed) acknowledge the potential value for further training. Among various types of training, concrete crack repair, patch repair, reinforcement repair, and, particularly among the architects/engineers, CFRP-strengthening is indicated as a potential field for further training (Fig. 2.15). These techniques are also at the top of the list of dominating types of work. This suggests that among the respondents, a big part of the work is securing the structural safety of construction, and it is seen as an important area of expertise as they indicate that further training would be beneficial.

In terms of potential fields for further training, patch repair and CFRP-strengthening are more often named by architects/engineers than by the craftworkers. The craftworkers–compared to the architects/engineers–have a higher preference for training in coating and cleaning.

Although patch repair is at the top of the dominating types of work with the architects/engineers, only half of the respondents mentioned it as a potential field for further training. One can only guess what the underlying reasons are, but it could be that there is sufficient knowledge, it could imply that the architects/engineers do not see a big future in this work, or it might imply that patch repair is regarded as easy work, where little training is needed.

The responses might also indicate that among the respondents, there is a stronger emphasis on the structural aspects of concrete repair/maintenance than on the more architectural/esthetical aspects of concrete conservation, as cleaning, for example, is not mentioned as a potentially beneficial field of training by architects/engineers either. Another question is the difference between crack repair and patch repair. Is there a difference? Do all respondents apply the same definition, or are those techniques interpreted differently?

Regarding the benefits of further training centred around a specific topic one might question how respondents interpreted 'beneficial'. Does it imply "I'm good at it, but I want to get better", "I'm not used to it, but I want to learn", or even, "I think this is an interesting field where I could make a large profit in the future, so let's prepare"?

Theory and practice

Although the theory of good practice prescribes a profound analysis, preparation, testing and aftercare, the respondents indicate that daily practice is more diverse. The data indi-

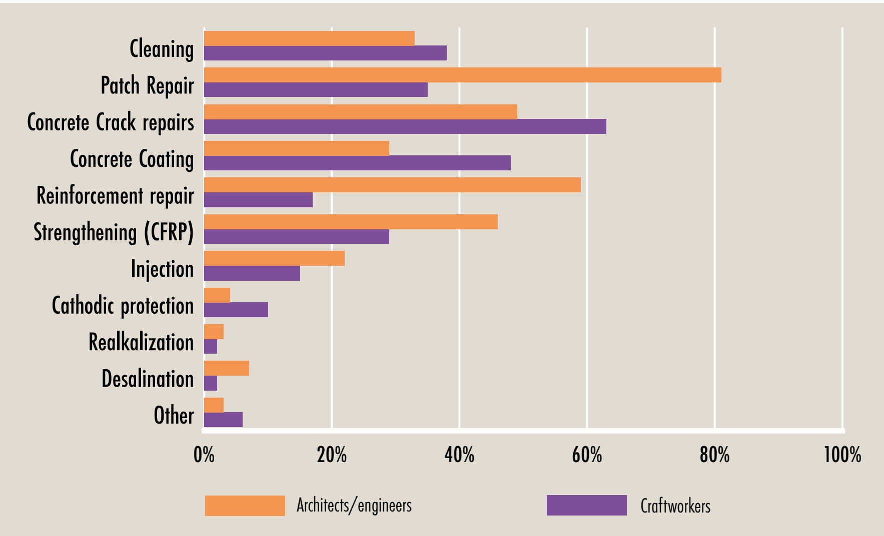


Figure 2.15
Comparison between the wanted education by architects/engineers and craftworkers.

cates that an initial assesment of a situation is not always executed, mock-ups are made only occasionally, and maintenance plans for aftercare are made in a limited number of cases. It is unclear from the data whether these actions are not taken at all or whether other companies are involved in these activities.

Representativeness

The dispersion of responses to the questionnaires indicates that the studied field is very broad and that people of many different backgrounds are working in concrete repair. The field seems highly specialised; there is no 'one engineer', 'one architect', 'one craftworker' or 'one restorer' that covers the whole range of concrete repair.

2.6 Conclusions and Recommendations

It is too ambitious to draw firm conclusions on a Europe-wide scale on potential skills gaps and knowledge mismatch from this particular questionnaire. The response to the questionnaires is too diverse, and this might be one of the most important conclusions from the study: the professional field of concrete repair both on the level of architect/engineers and on the level of craftworkers is dispersed and highly specialised.

In order to get a better understanding of the profession, its variants, and the potential skills gaps and knowledge mismatch, further labour market research is recommended to better identify different groups and subgroups of stakeholders in the field of concrete repair.

Further training in the field of concrete repair is almost unanimously regarded as beneficial by all respondents. There is a higher preference for training and education regarding the structural aspects and less for the more aesthetically oriented aspects.

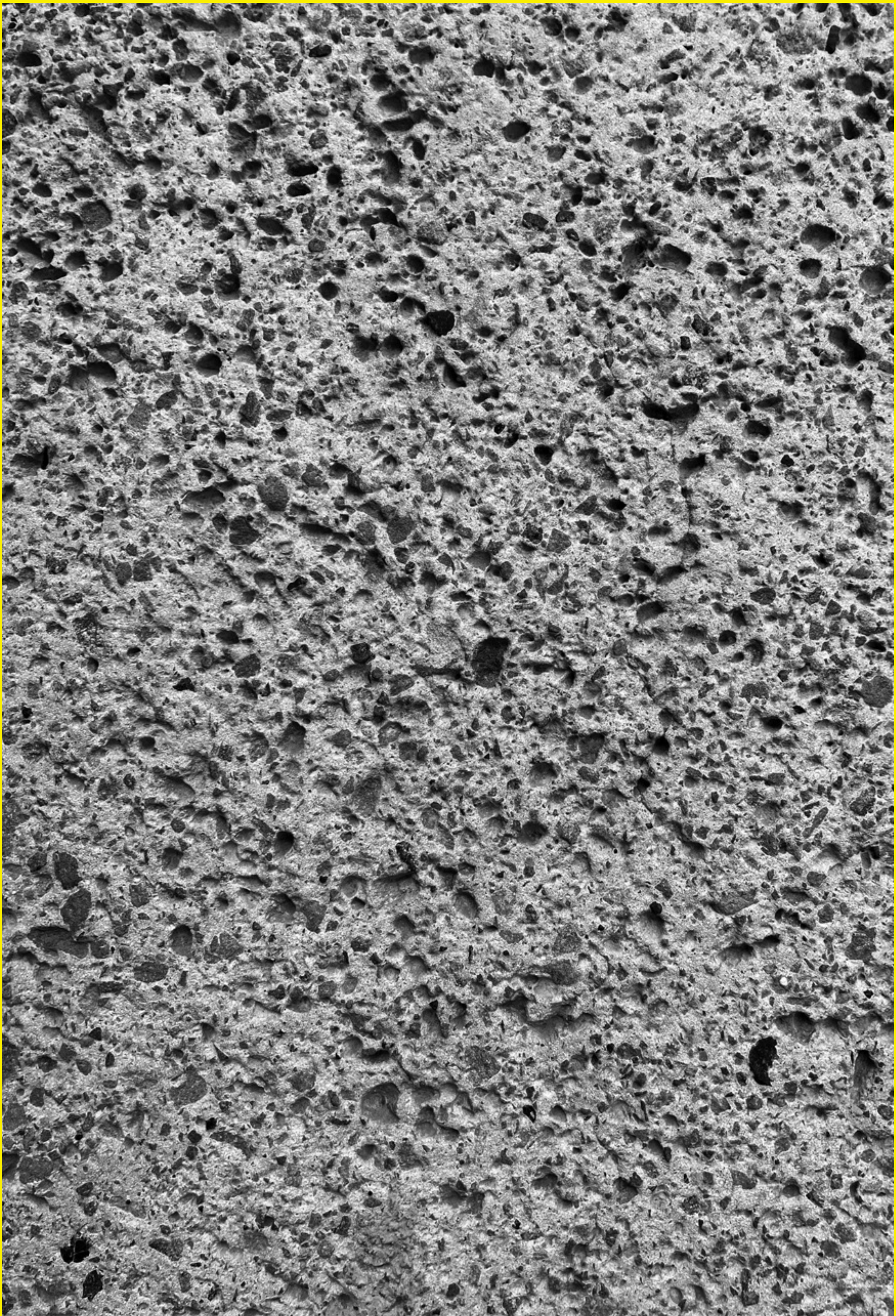
The collected data does not allow for a profound statistical analysis, but it clearly indicates that there are substantial differences between the studied countries (Italy, Türkiye and Spain) regarding the professional work in the field of concrete repair, both amongst architects/engineers and amongst craftworkers. This suggests that expanding the view towards other European countries would reveal even more differences.

In order to further and more thoroughly understand the professional field of concrete repair, based on the aforementioned conclusions, it is recommended to further study the European labour market in the construction industry and define and interpret the current practice per country as a basis for more general conclusions on a European level. Based on this sketch, more definite conclusions can be drawn regarding the type of work, the type of workforce, the education and training as well as the potential for growth in the professional field and the benefits of new education and training.

It is highly recommended to dive further into the meaning and potential interpretation of the responses regarding the type of executed work in relation to training that is regarded as beneficial.

Considering the high dispersion of work within the professional field of concrete repair, it is recommended to opt for a modular system of training and education that could be easily tailored to accommodate different needs.

Although trends were observed, it was not possible to do a quantitative statistical analysis of the data due to a low number of overall responses and within the separate groups (with the exception of the Italian engineers). The outcomes of the questionnaire were used as input for the interviews (Chapter 4) to further elaborate qualitatively.



3 STATE-OF-THE-ART ANALYSIS

3.1 Methodology

One of the primary goals of CONCRETO Lab is to identify the existing knowledge resources concerning the conservation of historic concrete to pinpoint potential skills gaps and mismatches, particularly regarding the conservation of concrete heritage. The first step in this endeavour was the creation of a database designed to be as comprehensive and up-to-date as possible. This database documents publications, programmes, and initiatives dedicated to historic concrete and focuses on conservation, repair and general methodologies.

The database focuses primarily on the European and Western context, but is not limited to English language resources. It builds upon the foundational work carried out within the Concrete Conservation project by the Getty Conservation Institute (GCI), particularly their 2015 *Conserving Concrete Heritage: An Annotated Bibliograph*y. It is also worth noting that a new version of this bibliography, scheduled for publication in early 2025, will serve as an indispensable reference for providing another complete and current overview of the subject. The new annotated bibliography has been developed to revise and fill any gaps in the 2015 bibliography, and add relevant references published since. The GCI's bibliography is focused on English language publications that can be useful resources to practitioners.

Beyond editorial materials, this study expands the scope by including key institutions and organisations involved in historic concrete conservation, detailing their contributions through specific committees, publications, research projects and conferences. Moreover, the study incorporates recent research projects dedicated to the topic, providing details about their main partners, as well as the reports and outcomes resulting from their efforts.

The starting point of desk research within this project is bibliographic research compiled post-2010, as a basis for broader initiatives on conserving 20th-century modern architecture. Additionally, bibliographies of significant research on historic concrete, such as Innovaconcrete (Horizon 2020[1]) and Concrete Conservation (GCI[2]), have been incorporated into the database.

The data collected in the initial work session has been systematically categorised into five macro typological categories (studies and research, organisations and conferences, industry standards, certifications and educational programmes). For each database entry, additional information, considered central to identifying skill gaps and mismatches in concrete conservation state of the art, has been gathered.

A research question served as the starting point for categorising the works into two groups, based on whether they addressed historic concrete repair or conservation. The goal is to evaluate how existing literature perceives interventions: are they seen as part of a comprehensive conservation strategy that acknowledges concrete as a vital component of cultural heritage? This approach integrates such interventions into broader conservation and restoration programmes. Alternatively, are they merely considered practical repairs, focused only

1 https://research-and-innovation.ec.europa.eu/funding/funding-opportunities/funding-programmes-and-open-calls/horizon-2020_en

2 https://www.getty.edu/projects/concrete-conservation/

on reinstating functionality? This distinction is crucial in understanding whether the treatment of concrete in heritage conservation is appreciated both for its historical significance and its functional value. Additionally, this data, coupled with chronological information, enables investigation into the temporal distribution of works dedicated to conservation or repair and potential trend variations over time.

Another crucial aspect of identifying potential knowledge gaps in the state-of-the-art regarding historic concrete relates to the target audience of the selected works. This effort aims to pinpoint one or more categories among the key players in building interventions who may have limited access to knowledge resources on the topic. By understanding which groups lack information, we can better address these gaps and improve the dissemination of critical conservation knowledge.

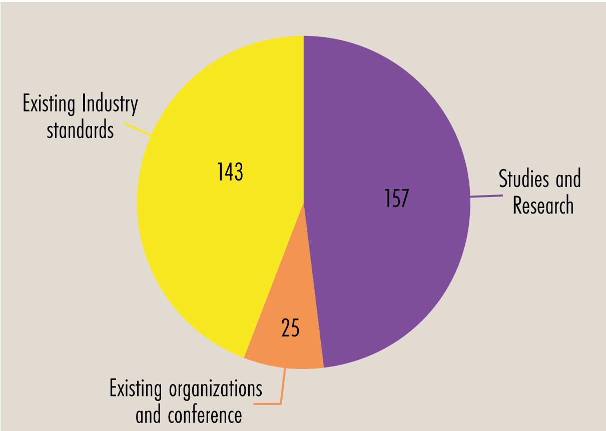
The final dataset entry addresses the actual accessibility of the work, indicating whether it is actually available to discern which knowledge tools are genuinely and freely accessible to those engaged in historic concrete conservation.

3.2 Data Analysis: State of the Art

In our analysis of the state of knowledge regarding the conservation of historical concrete, we compiled available information on active stakeholders in the sector, their activities, and academic, technical and scientific publications into a comprehensive database. We observed a good quantitative balance between industry standards and research studies (Fig. 3.1). This balance suggests that both the practical and research worlds consistently focus on the topic of historical concrete, although with different objectives. There appears to be a disproportionate number of publications compared to organisations and conferences dedicated to the topic, which can be explained by the different number of people involved in these activities.

A chronological analysis of the data shows that interest in historic concrete initially emerged through the activities of dedicated organisations and conferences before 1990 (Fig. 3.2). Several key institutions played a crucial role in fostering research, standardisation and awareness about concrete conservation. The American Concrete Institute (ACI), founded in 1905, has long been a reference for concrete research and engineering standards, with its Committee 120 – History of Concrete specifically focusing on documenting the evolution of concrete technology. The Eduardo Torroja Institute for Construction Sciences (IETcc), established in 1934, has been instrumental in research on concrete structures, durability and conservation methodologies. The Betonvereniging (Concrete Association of the Netherlands), founded in 1927, has significantly contributed to concrete technology education and industry training. In Europe, the Associazione Italiana Tecnico Economica del Cemento

Figure 3.1 State-of-the-art database typological distribution.



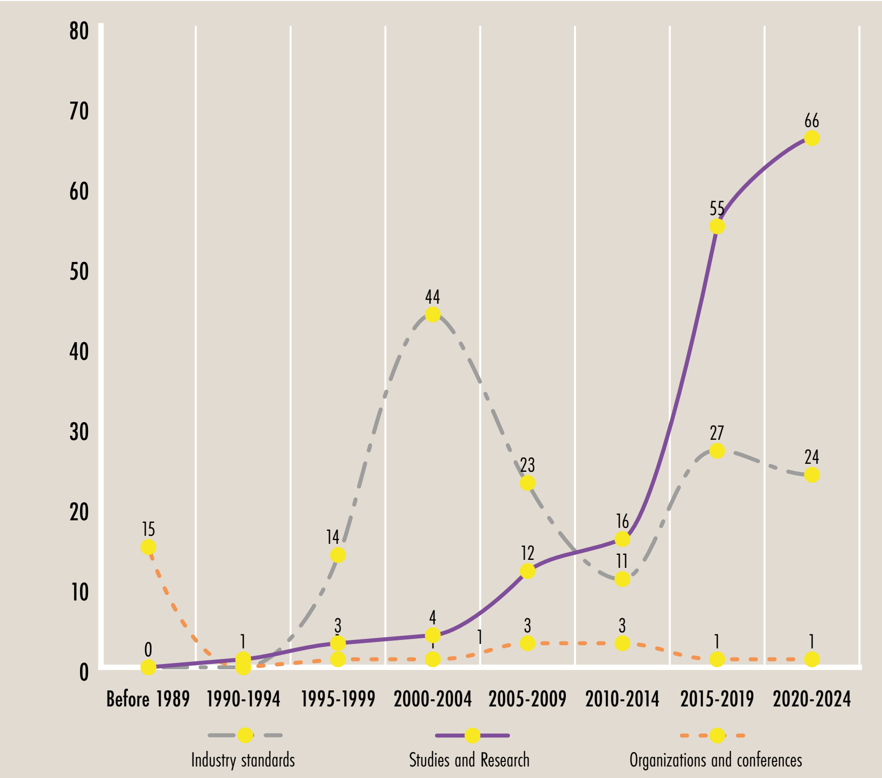


Figure 3.2
State-of-the-art database chronological distribution.

(AITEC) was established in 1959, representing the Italian cement industry and documenting advancements in historic concrete construction through its journal "L'Industria Italiana del Cemento", first published in 1929. Similarly, the International Council on Monuments and Sites (ICOMOS), founded in 1965, played a pivotal role in addressing the conservation of modern materials, with early discussions on concrete conservation emerging in ICOMOS bulletins and congresses in the late 1970s and 1980s. The Association for Preservation Technology International (APT), established in 1968, included modern concrete structures in its discussions on heritage preservation, with its APT Bulletin in the USA featuring research on 20th-century materials. The Twentieth Century Society (C20) was founded in 1979 to advocate for the preservation of modernist architecture, including exposed concrete buildings in the UK. Meanwhile, in France, the Laboratoire de Recherche des Monuments Historiques (LRMH) was established in 1967 and later created a dedicated Concrete Division (Pôle Béton), which became active in the research of historic concrete preservation. In 1988, the establishment of DOCOMOMO International marked a turning point in the field of modern architecture conservation, with its first international conference in The Netherlands held in 1990, bringing together experts on the preservation of reinforced concrete structures from the Modern Movement. These institutions and their early publications, congresses and initiatives laid the groundwork for the structured study, conservation and repair of historic concrete, influencing later developments in guidelines, research and standardisation efforts.

In the following decades, there was a rapid increase in the production of industry standards from 1990 to 2010, followed by a growing production of research studies, which peaked in the decade of 2010-2020. Among the earliest and most influential industry standards was the EN 1504 series (2004-2008), which established a comprehensive European framework for the protection and repair of concrete structures, defining material specifications and intervention techniques. Similarly, EN 12696 (2000) introduced cathodic protection methods to mitigate reinforcement corrosion, while the ACI 562 (2001, revised in later years) provided structured guidelines for the assessment, repair and rehabilitation of existing concrete structures.

Meanwhile, research efforts began to focus more on historic concrete conservation. The ICOMOS ISC20C publication "Béton(s), Cahiers d'ICOMOS France" (1999) brought international attention to the topic, while The Fair Face of Concrete (1998), a DOCOMOMO Preservation Technology Dossier, was one of the first efforts to define conservation strategies for exposed concrete. Studies such as Gaudette & Slaton's "Preservation Briefs 15: Preservation of Historic Concrete" (2007) and Jester's "Twentieth-Century Building Materials: History and Conservation" (2004) further reinforced the need for dedicated conservation approaches. By the late 2000s, key research contributions such as Heinemann et al.'s "Concrete: Too Young for Conservation?" (2008) critically examined the status of modern concrete as a heritage material. This period marked a fundamental shift from purely technical repair approaches toward a more balanced perspective that integrated conservation principles with practical intervention methods.

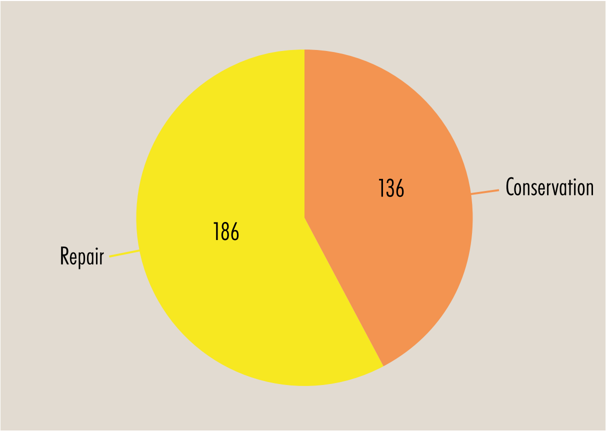
This timeline indicates the need for interventions on concrete compared to research. Consequently, intervention methods were defined before the theoretical foundations, leading to numerous interventions that were not methodologically well-supported. Today, the research world continues to be fertile in producing studies on interventions on historical concrete, while industry standards have not undergone significant changes.

The analysis of the relationship between the "conservation" and "repair" categories shows a slight predominance of repair interventions over conservation ones (Fig. 3.3).

However, a more detailed examination reveals that research studies tend to favour a conservation approach (34 vs.121), while industry standards are almost exclusively dedicated to repair and still exhibit many non-conservative approaches (Fig. 3.4). This highlights the need to develop more industry standards with a conservation approach and to reduce the gap between practice and research.

Examining the temporal distribution of the "conservation" and "repair" categories, we observe that the repair approach aligns with industry standards, while the conservation approach aligns with research studies. Industry standards peaked in the decade 2000-2010 and then declined (Fig. 3.4). Since 1990, the curves for conservation and repair have consistently increased, maintaining a stable proportion, except for the last decade, where a

Figure 3.3 Distribution of repair-oriented and conservation-oriented data.



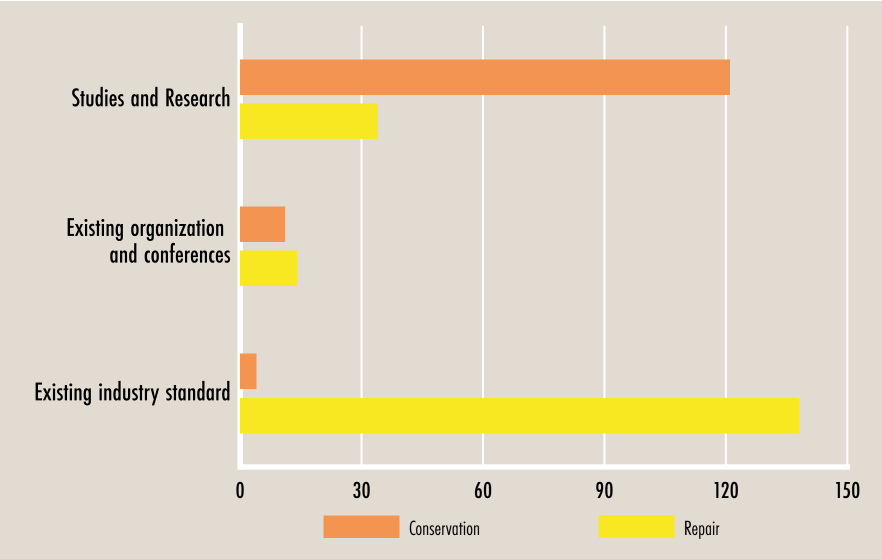


Figure 3.4
Repair-oriented sources and conservation-oriented sources per typological category.

decrease in conservation works and a slight increase in repair works are noted (Fig. 3.5).

Organisations and conferences on historical concrete demonstrate a balance between conservation and repair approaches (Fig. 3.6), as reflected in key institutions and events. For instance, DOCOMOMO International, established in 1988, actively promotes conservation-focused research through its DOCOMOMO Journal and conferences, while the International Concrete Repair Institute (ICRI), founded in the same year, primarily addresses repair and maintenance through its Concrete Repair Bulletin and technical guidelines. Similarly, APT fosters conservation discussions within its APT Bulletin, whereas the Concrete Solutions Conference Series (since 2003) and the International Conference on Concrete Repair, Rehabilitation and Retrofitting (ICCRRR, first held in 2005) have been more oriented toward repair methodologies. However, a clear divide exists between the academic and professional worlds: research studies and scholarly publications, such as those published by ICOMOS ISC20C, tend to emphasise conservation approaches, whereas professional

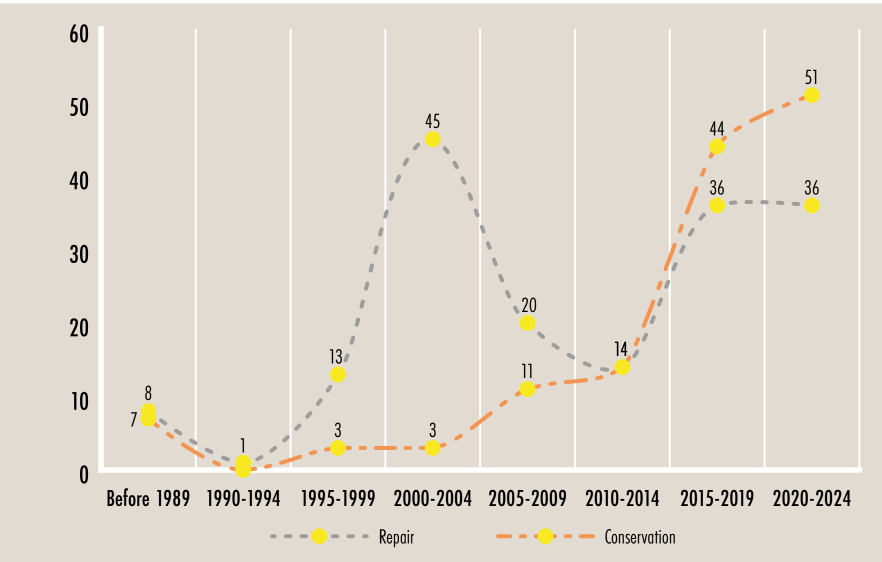


Figure 3.5
Repair-oriented sources and conservation-oriented sources over time.

Figure 3.6 Establishment of professional organisations and conference data in relation to repair and conservation.

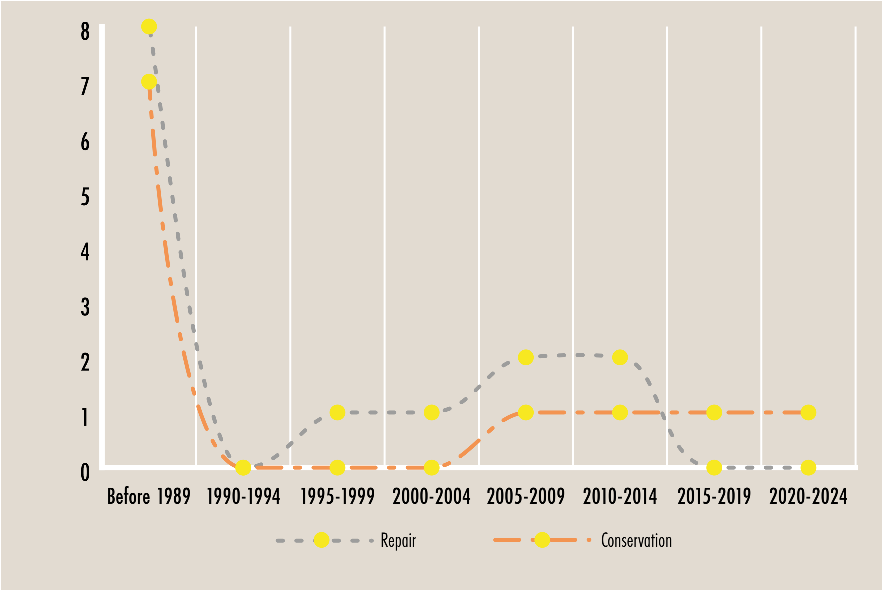
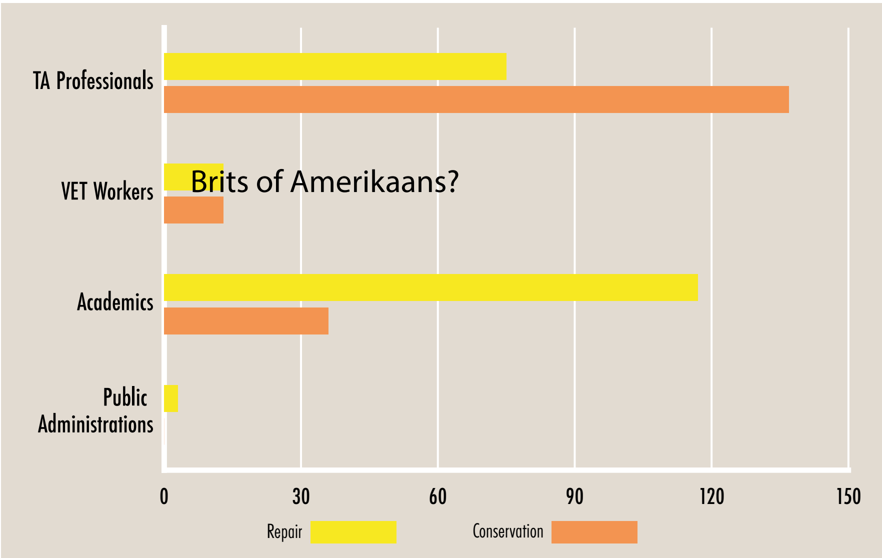


Figure 3.7 Targeted audience divided into repair-oriented and conservation-oriented.



guidelines and industry standards, like those issued by ACI and EN 1504 standards, are predominantly repair-focused (Fig. 3.7). Furthermore, research studies are almost exclusively generated within academia, addressing conservation theories and methodologies, while industry standards are designed for practitioners – engineers, architects and contractors – who require clear technical directives for repair (Fig. 3.8). This distribution highlights a significant disconnect between research and practice, underlining the need to improve knowledge transfer between these two domains. Bridging this gap would enable professionals to incorporate conservation principles into their repair strategies and ensure that academic research remains relevant and applicable to real-world interventions.

The quantitative analysis of the target audience for published works reveals an uneven distribution of materials. The majority is directed towards professionals (TA) with 212 publica-

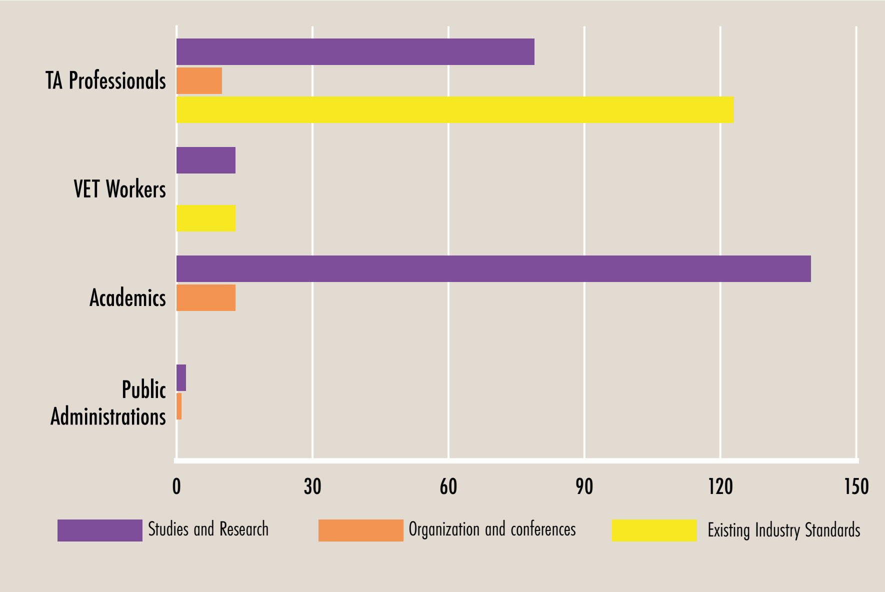


Figure 3.8
Targeted audience divided into typological division.

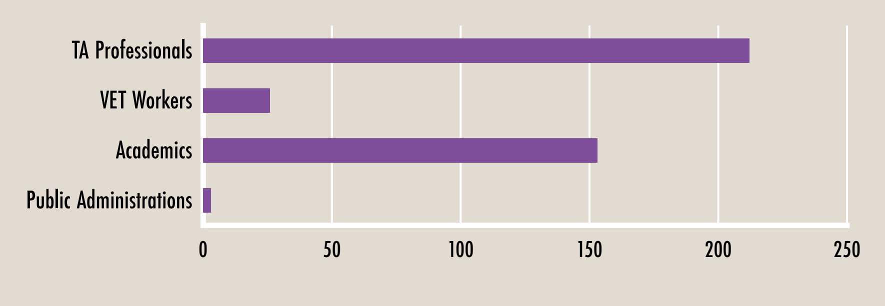


Figure 3.9
Target audience for published works.

tions, followed by academic scholars with 153 publications. However, significantly fewer works target vocational education and training (VET) workers (26 publications) and public administrations (only three publications) (Fig. 3.9). This is particularly striking because public administrations play a crucial role in regulating interventions on concrete structures, and VET workers are directly responsible for executing repairs and conservation work. The lack of publications and other resources aimed at these groups suggests an important gap in knowledge dissemination. To ensure better regulation and practical intervention, it is essential to increase the availability of materials and training specifically designed for public administrations and VET workers. Additionally, the high number of materials intended for technical professionals (TA) suggests that, despite the availability of resources, there may still be a lack of sufficient preparation in the field. This highlights the need for better integration between available knowledge and professional practice, ensuring that engineers, architects and contractors have access to both practical repair techniques and conservation-based approaches. Strengthening this connection between research, training and professional application is key to improving the quality and sustainability of interventions on historic concrete.

3.3 Skill Gaps and Mismatches

The analysis highlights several skill gaps and mismatches in conserving and repairing historic concrete. Firstly, there is a notable lack of specialised training programmes exclusively dedicated to the conservation of historic concrete. Currently, only a few initiatives, such as courses organised by the Dutch Concrete Association (Betonvereniging) and the Dutch National Restoration Center (Nationaal Restauratiecentrum), provide targeted training. Moreover, there is a general lack of data on existing training programmes, which suggests a significant educational gap that cannot be solely attributed to inadequate communication about available courses.

At the same time, while research on historic concrete has significantly increased over the past two decades, industry standards have not evolved accordingly. Despite advancements in research that could support their development, the production of new standards has declined. A crucial conceptual step is still missing: the establishment of a dedicated standard or a well-structured compilation of existing regulations specifically addressing the conservation of historic concrete. Unlike conventional repair approaches, historic concrete cannot simply be treated with the objective of restoring it to a 'like-new' condition, as this would undermine its cultural and material significance. This underscores the urgent need to update industry standards, integrating conservation-focused approaches that bridge the gap between academic research and professional practice.

Additionally, there is a clear division in focus between different organisations. Those dedicated to repair, such as ICRI (International Concrete Repair Institute) and ACI (American Concrete Institute), primarily focus on technical solutions and industry applications, with little emphasis on historic concrete. On the other hand, organisations with a conservation approach, such as DOCOMOMO International and ICOMOS, even when they establish specialised committees or guidelines dedicated to concrete conservation, struggle to counterbalance the dominant industry perspective, which tends to prioritise the structural function of concrete over its surface qualities – sometimes to the extent of overlooking them entirely.

Moreover, the durability of repair interventions is considered so paramount that no studies have been identified promoting the concept of planned conservation – an approach that would incorporate cyclical interventions to monitor and manage the long-term effectiveness of restoration efforts. Instead, current practices overwhelmingly emphasise achieving maximum durability in a single intervention rather than developing a systematic strategy for controlled maintenance over time.

Furthermore, public administrations and VET (Vocational Education and Training) workers receive insufficient attention in available educational resources. Public administrations play a key role in regulating conservation and repair practices, while VET workers are directly responsible for executing interventions. Yet, very few training materials are tailored to their needs. Addressing this gap would enhance informed decision-making at the policy level and improve practical intervention techniques.

Finally, the high volume of materials directed at technical professionals (TA), despite indications of insufficient preparation in the field, raises concerns about accessibility and applicability. This suggests a disconnect between professionals responsible for defining intervention projects and the resources available to them. Bridging this gap requires stronger collaboration between professional organisations, academia and industry bodies, ensuring that both theoretical research and practical expertise are effectively translated into real-world applications.

4 EXPERT REFLECTIONS

The third component of the CONCRETO Code Book research involved engaging with a range of experts to provide qualitative insights into the evolving field of historic concrete conservation. While Chapter 1 focused on quantitative data obtained through surveys, this chapter offers a deeper, more nuanced understanding of recent developments, emerging trends and critical gaps within the sector. The interviews aimed to capture the perspectives of professionals from various disciplines involved in concrete conservation, offering valuable first-hand knowledge of the challenges and opportunities within the field.

The interviews were structured around three core questions addressing **recent innovations**, **anticipated trends**, and **areas of improvement** in the field. The insights shared by these professionals contribute to the Code Book's understanding of the dynamic nature of concrete conservation and the evolving needs of this field.

4.1 Methodology

To ensure a comprehensive representation of the field, a range of key figures was identified, covering various sectors of the conservation world, including educators, concrete engineers, restorers, specialist contractors, architects and heritage professionals working in municipalities or at a legislative level.

Twenty experts were selected from four countries–Italy, Spain, the Netherlands and Türkiye–through project partners. The interviews were conducted via email in December 2024, with each participant responding to three questions:

- **Recent Developments**: Experts were asked to reflect on the most significant recent developments in concrete conservation, considering technological innovations, changes in education, legislative shifts, and evolving conservation approaches, and how these factors had influenced their work or the field as a whole.
- **Future Trends**: Participants were then asked to predict key trends or advancements they foresee in the near future within the field of concrete conservation, addressing how these trends could respond to emerging challenges in preservation.
- **Gaps in the Field**: Finally, experts provided their perspectives on what is currently missing or lacking in the field, whether in terms of tools, approaches, or support systems that could enhance conservation practices and education.

4.2 Answers received

From your professional experience, what do you consider to be the most significant recent developments in the field of concrete conservation? These might include technological innovations, new educational approaches, legislative changes, or shifts in conservation philosophy. How have these developments influenced your work or the field as a whole?

- With the new materials, it becomes more difficult to repair or reconstruct the way it was done with the old materials. The ASR community is very worried about the geopolymer concrete trend. This new type of material adds a lot of additional alkalies (Mario de Rooij)

- Concrete repair companies advertise that they perform concrete restoration in addition to repair. However, I get the impression (no numbers) that the focus is on the aesthetic side of a repair and less on the underlying degradation problems, and there is also less discussion about the material history. (Herdis Heinemann)
- More dedicated craftmanship (Timo Nijland)
- Sensors in the reinforcement allow us to take readings about possible humidity or corrosion inside the structure, which will result in better maintenance (Fatima Otero)
- On several occasions, the rapid rhythm of practice does not allow for in-depth theoretical research that should guide the practice itsel (Giuseppe Losurdo)
- Firstly, we have detected a profound change in attitude. Relevant standards, until the very recent Model Code 2020 or the upcoming new generation of Eurocodes, did not consider existing structures. Some other standards, like the EN-1054 for repair, were rather isolated in a non-consistent standard mainframe. By the beginning of the 21st century, we wrote that Conservation engineering is a task for brave engineers. The situation is still far from ideal, but we can detect considerable improvement. General knowledge has improved in only a few decades. (Javier Leon)
- Starting a training course for operators. (Alberto Capelli)
- As professionals who have been working on the balanced, harmonious and correct combination of traditional and new materials/technologies in the restoration and protection sector for about 20 years, we aim to develop a holistic protection methodology by considering the structure, its use, environmental and health conditions, and respecting the architectural identity of the structure, not only in terms of technical aspects but also within the scope of the designer's aesthetic purposes. Concrete protection generally exhibits a reactive approach and focuses on eliminating existing problems. However, it is important and necessary to develop proactive maintenance and protection strategies for more effective protection. In order to make the life cycle of concrete more efficient, protection measures should be taken before maintenance and repair. We have been using additives added to concrete during production as well as building materials that can be applied to the concrete surface after production is completed to increase resistance to water and weather conditions for many years. These nano-scale materials provide different features such as high durability, fire resistance, water repellency, delaying contamination, preventing reinforcement corrosion, minimising alkali reactions, providing acid and alkali resistance, bridging cracks, etc., while mostly preserving the material's natural appearance and texture. Effective mineral-based improvement, repair, consolidation and protection solutions for concrete deterioration, natural-matte-looking colouring solutions in the concrete's own colour and/or desired colour through mineral colour matching for concrete are also some of the subjects we work on (Müge Günel)
- It is particularly important to emphasise the content of the European standard EN 1504 - Products and systems for the protection and repair of concrete structures. (Juan Rodado)
- A very good development is the creation of the ERM URL 4005. It is increasingly applied to monuments and is much better tailored to restoration. The ERM URL 2003 is also inextricably linked to this. (Harry Viveen)
- In recent years, I believe there have been several significant developments in the field of concrete conservation. These developments primarily focus on technological innovations, educational approaches, and conservation philosophy. Regarding

conservation philosophy, there has been a noticeable shift in recent years. While concrete conservation used to focus mainly on completely restoring or rebuilding the original state of a structure, the emphasis is now shifting towards preservation and refunctionalisation. This philosophical change promotes a more sustainable approach to building conservation, aligning preserved structures with modern needs. (Süheyla Yılmaz)

- The education of professionals in concrete conservation has evolved significantly. Training programmes and workshops now address the specific needs of conserving 20th-century concrete heritage. (Özgün Özçakır)

INTERVIEWEES

Alberto Capelli	Free-lance restorer	Italy
Andrea Costa	Lombardia Regional Secretariat, Ministry of Culture	Italy
Aras Koyuncuoglu	Promer Engineering	Türkiye
Fatima Otero	Puentes Group	Spain
Giuseppe Losurdo	Studio Amati Architetti	Italy
Harry Viveen	Meesters In	The Netherlands
Herdis Heinemann	TNO	The Netherlands
Javier Leon	FHECOR Ingenieros Consultores	Spain
Joep van As	BiermanHenket Architecten	The Netherlands
José Antonio Martín-Caro Álamo	Department of Civil Engineering, Polytechnic University of Madrid	Spain
Juan Rodado	Puentes Group	Spain
Mario de Rooij	TNO	The Netherlands
Michiel van Hunen	Cultural Heritage Agency of the Netherlands	The Netherlands
Müge Günel	Letoon Architecture	Türkiye
Özgün Özçakır	Conservation Program, METU Faculty of Architecture	Türkiye
Pınar Aykaç	Conservation Program, METU Faculty of Architecture	Türkiye
Ronald Veltman	Van Hoogevest Architecten	The Netherlands
Sander Nelissen	WDJArchitecten	The Netherlands
Süheyla Yılmaz	Historical Bridges Division, Turkish Highways General Directorate	Türkiye
Timo Nijland	TNO	The Netherlands

What key trends or advancements do you anticipate in the near future within concrete conservation? How do you see these changes addressing the emerging challenges and needs of preservation?

- I see a negative trend as fewer people are trained to inspect concrete and evaluate complex situations (heritage and non-heritage care) and come together to work interdisciplinarily on structural engineering, material science, architecture and conservation. (Herdis Heinemann)

- In our opinion, the areas that are most likely to grow in upcoming years are materials for repair and strengthening, but also alternatives to de-icing agents, knowledge on corrosion processes–still not as developed as they should be–, cathodic protection systems, corrosion inhibitors, non-destructive testing equipment and procedures, research on degradation processes due to chemical attack (i.e. alkali-silica reaction), and education. Correspondingly, once the knowledge becomes progressively more consolidated, we expect better standards to support engineers. (Javier Leon)

- Smart concrete technologies will be used more in concrete production and later in concrete protection. With these technologies, problems such as moisture, corrosion, cracks, etc. in concrete will be detected earlier and can be solved with simple interventions at the beginning. Self-healing concrete technologies have been on the agenda for a long time. I believe that the use of concrete types that can heal cracks on their own will be used more in infrastructure projects, especially where repair costs are high. Nanotechnological materials, coatings and microorganisms that strengthen the microstructure of concrete and make it resistant to water, corrosion, acidic environments, and other negative external factors are changing and developing day by day. (Müge Günel)

- The need to treat our environment responsibly is making us increasingly realise that preserving values contributes positively to this. Why demolish if we can preserve and give a building a second life? (Harry Viveen)

- New material technologies, particularly smart materials and nanotechnology applications, will enable concrete to become more durable and self-healing. These materials will make concrete more resistant to environmental factors and reduce maintenance needs. In particular, for historical buildings, such innovative materials could provide less intrusive and more effective solutions beyond traditional repair methods. I believe these trends will help address emerging challenges in concrete conservation. (Süheyla Yılmaz)

- Participatory and community-centered approaches to conservation will likely gain prominence. This is particularly relevant in contexts where concrete heritage is often perceived as unappealing or "ugly". Involving the public in conservation processes will not only raise awareness but also foster a sense of shared responsibility and appreciation for preserving concrete heritage. This holistic approach will ensure that interventions are not only technically sound but also socially and contextually relevant. (Özgün Özçakır)

- A desirable trend would be a shift of interest from a few masterpieces of concrete architecture towards a strategy of preservation of a diffused patrimony. (Andrea Costa)

Based on your professional experience, what is currently missing or lacking in the field of concrete conservation? This might include specific tools, approaches, or support systems that would enhance the effectiveness of conservation practices, education, etc.

- What is missing on an in-depth level is the fundamental understanding. Many research papers show experimental trials and reporting without understanding what is going on. Especially with regard to long-term behaviour and advice, this path is much too narrow. (Mario de Rooij)

- One disadvantage is that concrete conservation as a field does not look back on decades of experience, so collective knowledge is lacking. The involved parties do not always understand the properties of the historical material, its varieties, concrete degradation, repair, etc. Longterm visions are missing, which not only includes the service life of the repair but also if and when more damage can be expected. A classic example is a local patch repair without investigating whether more corrosion can be expected in areas without damage within a certain time frame. I also notice that there is little to no discussion about the remaining technical life of the concrete; we might want to preserve monuments for future generations (>100 years), but do we predict/discuss the rate of degradation of the concrete in a listed monument and do we discuss what this would mean for our conservation /maintenance/monitoring? Is the problem a lack of knowledge in the sense professionals are not sufficiently trained as specialists for concrete conservation? And what is the minimal knowledge and experience one should have? (Herdis Heinemann)

- Lack of basic knowledge & appreciation; in some sense, old concrete is a new material (Timo Nijland)

- We are optimistic because technological research is giving more and more support to the philosophical approach. We find ourselves faced with a topic that is new in many aspects, with, on the one hand, the advantage of having in-depth knowledge of the construction technologies and materials used and, on the other, lacking a sufficient number of case studies that allow us to evaluate previous solutions over time. Therefore, it is still a very experimental field, which, however, does bring about interesting results, thanks to the ability to tackle all the technical problems of material conservation directly, which, until a few decades ago, seemed insurmountable. (Giuseppe Losurdo)

- New technologies developed in the field of concrete protection in recent years–such as self-healing concrete–are costly applications. To popularise such environmentally friendly and sustainable technologies and materials, lower-cost and economical solutions need to be developed. The applicability of these innovations, even in small-scale projects, should be ensured. More performance data is needed to monitor and evaluate the effectiveness of concrete protection technologies in the long term. Such new technologies have not yet been subjected to long-term tests, and as a result, we do not have full information about their longevity. (Müge Günel)

- What is underexposed is the aesthetic choices around repairs. It is very important that when carrying out repairs, the original image remains intact as much as possible. Currently, much of the focus is on technical repair (which is, of course, hugely important), with appearance often coming second. (Ronald Veltman)

- The demand for expertise regarding restoration and execution engineering is also rising. And this is where the challenge lies. Only a very limited number of concrete restoration companies look at an object from the perspective of a restorer. Concrete repair companies exist to a greater extent, but unfortunately, they regularly do not achieve the desired goal and often conduct unnecessary repairs with undesirable levels of finishing. Increasing awareness of URL 4005 will contribute positively to its development. In addition, more knowledge, appreciation, and an eye for preserved concrete among clients, building managers, owners, etc. is highly desirable. With this, restoration work can be valued better and earlier. I also find that the range of repair products within concrete restoration is very limited. Almost all products are developed for properties that are not/less relevant for restoration. (Harry Viveen)

- From our perspective, the main gaps can be summarised as follows: Awareness: people and, therefore, administrations do not tend to value concrete structures as cultural heritage, and there is a need for sensitisation.
    - Investment: lack of funds allocated to the assessment and repair, which is also linked to awareness. The industry is not so attractive moneywise.

- Knowledge/education: education programmes are very focused on new design and little on assessment and restoration practices.
- Standards–recommendations, guidelines. There is not much reference literature in the field to guide practitioners. (José Antonio Martín-Caro Álamo)

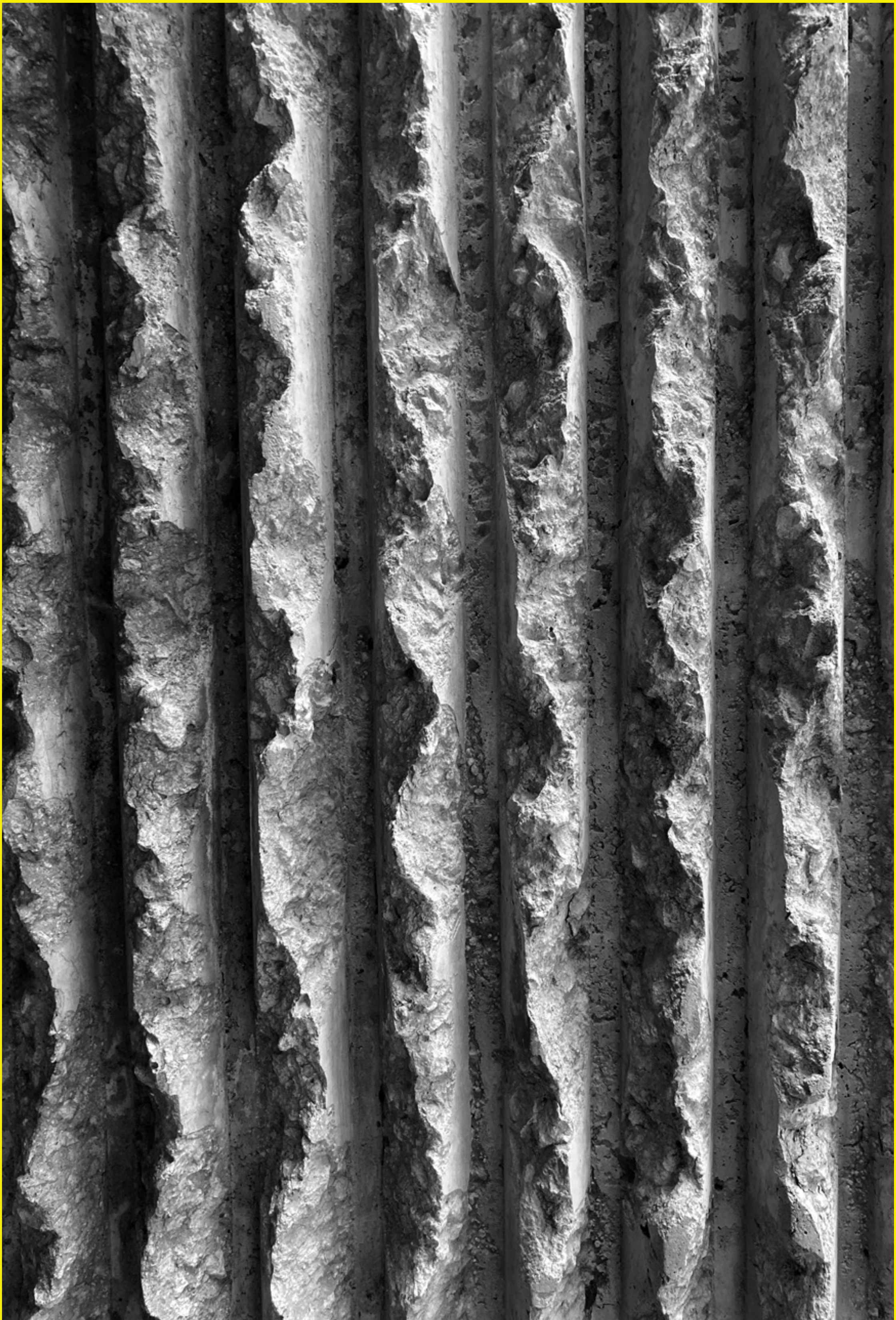
- Firstly, the lack of standards is a major issue. Shortcomings in education are also significant. Concrete conservation is an interdisciplinary field that combines engineering, architecture and history, so there is a need for more multidisciplinary training programmes. (Süheyla Yılmaz)
- The most significant gap in concrete heritage conservation lies in education and awareness. While there are specialised programmes for cultural heritage conservation, they often lack a dedicated focus on concrete heritage. Consequently, many practitioners are not equipped with the specialised knowledge required to address the unique challenges of modernist and brutalist architecture. Additionally, there is a broader lack of public awareness about the value of concrete heritage. As I mentioned in my response to Question 2, concrete structures are often perceived as unattractive by the general public, making it difficult to build consensus around their conservation. In this regard, professional organisations and NGOs have a crucial role to play in fostering awareness and advocacy for the preservation of reinforced concrete heritage. (Özgün Özçakır)

4.3 Conclusions

The experts interviewed state that the field of concrete conservation is evolving rapidly, integrating new materials, technologies and conservation approaches. The interviewees confirm that "concrete conservation" is not (yet) a fully grown expertise on its own. Many stakeholders with different backgrounds are currently involved in the process of conservation and rehabilitation of concrete buildings. All from their own perspective, some as specialist, some as generalist. The architects, engineers, restorers and craftsmen interviewed, all point at challenges in the process of concrete conservation. All reason from their own perspective, resulting in a wide spectrum of recommendations. Some of these recommendations even contradict each other, underlining the complexity and multifaced challenges of concrete conservation.

The following conclusions can be synthesised from the interviews:

- Recently, significant advancements in materials, methods and philosophical approaches in concrete conservation took place;
- Specific regulatory frameworks and standards for concrete conservation are needed and valuable;
- Concrete conservation calls for specialised workforce in all phases of the process.
- The interviewees call for better trained people working in concrete conservation;
- Concrete conservation is a balancing act between (structural) safety, durability and aesthetics.



5 CONCLUSIONS AND RECOMMENDATIONS

While the data collected from the questionnaires indicate a diverse and specialised professional landscape across Europe, a clear skill gap and knowledge mismatch remains elusive due to the fragmented nature of the responses. The in-depth reflections by experts confirm the diversity but neither point at a distinct aspect to be addressed to improve the green rehabilitation of European concrete Architecture. The study highlights that further research, such as labour market studies, is essential to better define subgroups within the profession and understand regional differences more thoroughly. However, the unanimous call for more training opportunities indicates a broad consensus that further education in concrete conservation is vital.

The analysis of the state of the art reveals the importance of creating and/or updating industry standards, fostering connections between research and practice, and developing tailored training programmes to address the specific needs of the field. The interviewed experts point out that standards and regulatory frameworks are gradually adapting to address existing structures, yet inconsistencies persist, highlighting the need for a more unified approach. Training initiatives and specialised courses are beginning to equip professionals with the necessary skills, but a widespread lack of knowledge about historical concrete materials and degradation mechanisms continues to hinder effective conservation efforts. Holistic conservation strategies that combine traditional and modern materials, supported by technological advancements such as nanotechnology and self-healing concrete, offer promising solutions for long-term durability.

The interviews further emphasise the need for a balanced approach, where innovative materials and techniques complement traditional conservation practices. While new materials like geopolymer concrete hold promise, concerns about their compatibility with historical structures highlight the necessity of maintaining a strong connection to the craft and principles of traditional restoration. Interdisciplinary training and collaboration between research institutions, practitioners and policymakers are paramount in creating a sustainable, informed approach to historic concrete conservation.

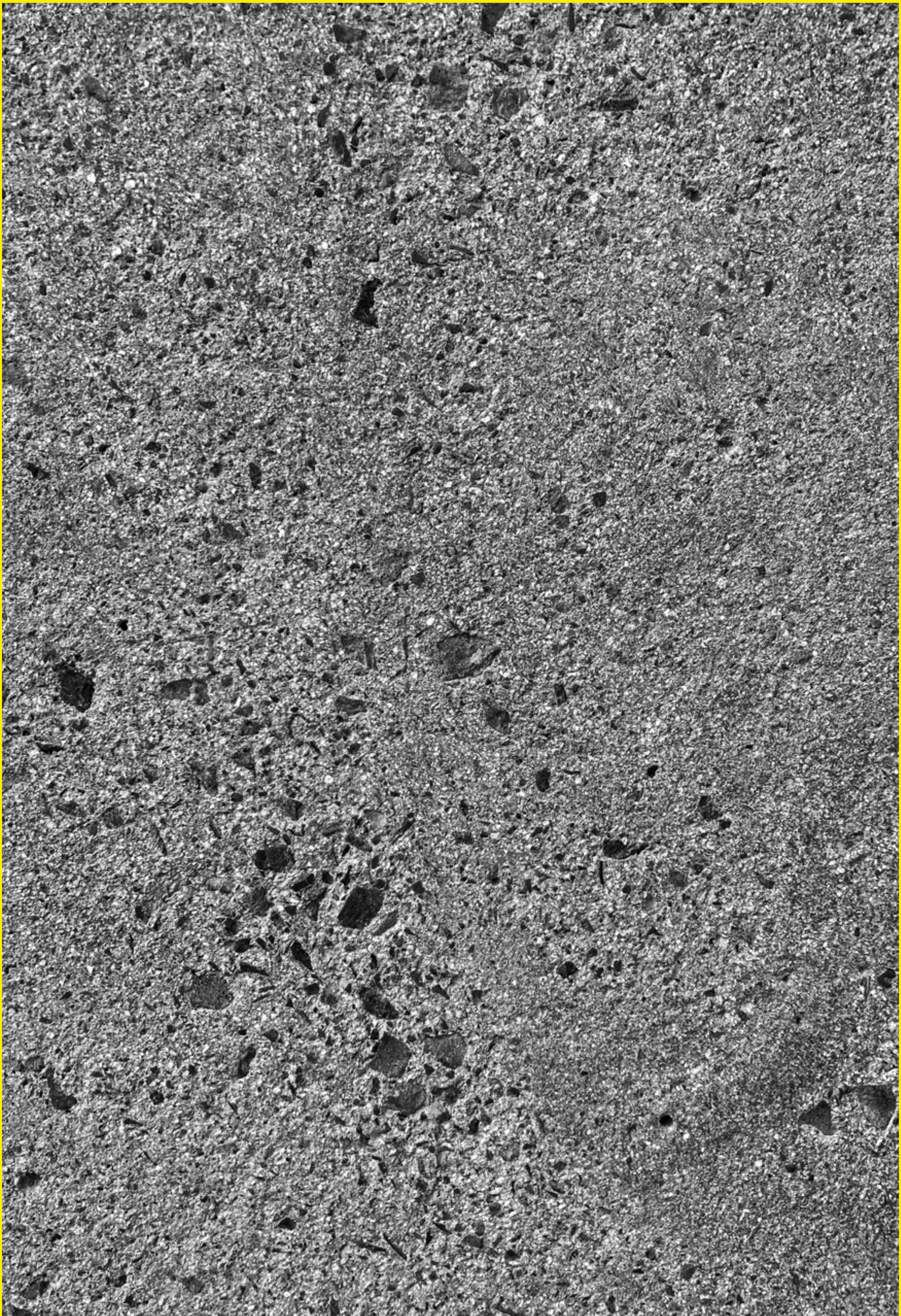
The findings of this research emphasise several critical gaps in the current approach to the conservation and repair of historic concrete. The key issues identified include the lack of dedicated training programmes, the absence of comprehensive regulatory frameworks and industry standards, the imbalance between repair- and conservation-oriented institutions and insufficient attention to long-term maintenance strategies. Furthermore, the neglect of public administrations and VET workers in educational resources contributes to inefficiencies in policy implementation and on-site conservation efforts.

To address these challenges, some recommendations are proposed:

- Expand the questionnaire to a wider audience to better understand the diverse professional landscape for concrete conservation and rehabilitation of concrete buildings.
- Develop specialised and accessible training programmes for architects, engineers, restorers and VET workers, focusing on both conservation theory and practical application.

- Establish comprehensive conservation standards and regulatory frameworks dedicated to concrete conservation, integrating existing repair techniques in order to address cultural and material authenticity.
- Bridge the gap between research and practice trough promoting joint research initiatives and professional training events.
- Enhance the role of public administrations, ensuring better regulatory oversight of conservation projects.

In conclusion, the field is at a critical juncture, and moving forward, the field calls for training and a unified approach to standards. By addressing the identified gaps in knowledge, promoting more targeted educational initiatives, and fostering collaboration across disciplines, the conservation of historic concrete can evolve into a more effective and sustainable field.



6 APPENDICES

APPENDIX A QUESTIONNAIRE

This appendix presents the data collected through the questionnaires developed in the research. It includes the questionnaire templates distributed to both architects/engineers and craftworkers, as well as the full datasets gathered from each group.

The aim of this appendix is to provide a comprehensive overview of the data that informed the study, offering insights into the responses from professionals in both fields.

A.1 TEMPLATE QUESTIONNAIRE ARCHITECTS-ENGINEERS

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1. Name

2. Surname

3. Age

4. City of residence

5. What is your highest education level?

☐ Primary Education
☐ Compulsory Secondary Education
☐ Vocational Educational Training - Basic Level
☐ Vocational Educational Training - Intermediate Level
☐ Vocational Educational Training - Higher Level
☐ Bachelor's Degree
☐ Master's Degree or comparable
☐ Doctorate
☐ Other

6. Field of Engineering degree

☐ Civil-Environmental Engineering
☐ Industrial-manufacturing Engineering
☐ ICT Engineering
☐ No Engineering degree

7. Do you consider yourself an architect, an engineer or both?

☐ Architect
☐ Engineer
☐ Architect-engineer

8. Do you work as…?

☐ Employee
☐ Employee and Professional
☐ Only Professional

9. What is your Main geographical area of activity *(Choose only one answer)*

☐ Locally
☐ Regionally
☐ Nationally
☐ International

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CONCRETO ACADEMY

10. What is the size of the company (1 if self-employed) *(Choose only one answer)*

☐ 1
☐ <10
☐ 10-50
☐ 50-100
☐ >100

11. Considering you job activity do you usually o from time to time deal with maintenance and restoration of concrete materials?

☐ Yes (go on with the interview)
☐ No (stop the interview)

12. Do you possess any training or certifications specifically related to concrete repair and concrete maintenance?

☐ Yes
☐ No

If yes, indicate where and what type of training or certifications received specific to concrete work *(max 2 answers)*:

☐ Specific University courses
☐ Doctorate
☐ Vocational training course connected to my job
☐ Specific certification of professional skills recognized by an official agency

13. What percentage of your work is related to concrete repair/conservation/ retrofitting/maintenance? *(Choose only one answer)*

☐ Less than 15%
☐ 15% - 30%
☐ 30% - 50%
☐ More than 50%

7. What type of concrete structures have you worked on? *(you can choose multiple)*

☐ Infrastructure
☐ Residential buildings
☐ Office buildings
☐ Public buildings
☐ Art works
☐ Heritage-designated buildings
☐ None
☐ Other

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ACADEMY

8. Indicate the type of concrete repair that you regularly perform: *(you can choose multiple)*

☐ Cleaning
☐ Patch Repair
☐ Concrete Coating
☐ Concrete Crack repairs
☐ Reinforcement repair
☐ Injection
☐ Cathodic protection
☐ Realkalization
☐ Desalination
☐ Strengthening (CFRP)
☐ Other

9. What is your knowledge of concrete assessment techniques? *(Choose only one answer)*

☐ Limited - I have little to no knowledge of concrete assessment techniques.
☐ Basic - I am familiar with some common concrete assessment techniques but may need further training.
☐ Intermediate - I have a good understanding of various concrete assessment techniques.
☐ Advanced - I possess extensive knowledge and experience in a wide range of concrete assessment technique

10. When involved in concrete repair work, is an initial assessment carried out? *(Choose only one answer)*

☐ Yes
☐ No
☐ Sometimes

11. Indicate what type of assessment you mainly do (or subcontract) for a concrete structure: *(Choose only one answer)*

☐ Visual Inspection only
☐ Visual + Non-destructive testing (example steel reinforcement layout, carbonation, chlorides)
☐ Destructive testing (cores, probes, corrosion testing)
☐ Combination of all the above

12. When developing a repair strategy for your project, how often do you include a maintenance plan? *(Choose only one answer)*

☐ Always
☐ Frequently
☐ Occasionally
☐ Rarely

13. During the course of a project, do you typically conduct field inspections while the work is ongoing? *(Choose only one answer)*

☐ Yes
☐ No

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14. Do you think it would be beneficial to receive more training in concrete repair/conservation/ retrofitting/maintenance? *(Choose only one answer)*

☐ Yes
☐ No

If yes, which type. (*Max. 3 answers)*:

☐ Cleaning
☐ Patch Repair
☐ Concrete Coating
☐ Concrete Crack repairs
☐ Reinforcement repair
☐ Injection
☐ Cathodic protection
☐ Realkalization
☐ Desalination
☐ Strengthening (CFRP)
☐ Other

15. Are you available for an interview regarding the topic of concrete repair/conservation/retrofitting/maintenance?

☐ Yes
☐ No

16. Do you want to receive direct updates from the CONCRETO-ACADEMY, if yes, please provide your email-address

17. Please add anything that you want to share regarding concrete repair/conservation/ retrofitting/maintenance

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A.2 TEMPLATE QUESTIONNAIRE CRAFTWORKERS

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1. Name

2. Surname

3. Age

4. City of residence

5. What is your highest education level?

- ☐ Primary Education
- ☐ Compulsory Secondary Education
- ☐ Vocational Educational Training - Basic Level
- ☐ Vocational Educational Training - Intermediate Level
- ☐ Vocational Educational Training - Higher Level
- ☐ Bachelor's Degree
- ☐ Master's Degree or comparable
- ☐ Doctorate
- ☐ Other

6. What is your main area of activity *(Choose only one answer)*

- ☐ Locally
- ☐ Regionally
- ☐ Nationally
- ☐ International

7. Do you work as a self-employed or in a company?

- ☐ Self employed
- ☐ For a company

7. What is the size of the company (1 if self-employed) *(Choose only one answer)*

- ☐ 1
- ☐ <10
- ☐ 10-50
- ☐ 50-100
- ☐ >100

8. How many years of working experience do you have? *(Choose only one answer)*

- ☐ Less than five years
- ☐ 5-10 years
- ☐ 10-15 years
- ☐ More than 15 years

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9. Do you possess any training or certifications specifically related to concrete repair, concrete retrofitting, concrete conservation and/or concrete maintenance? *(Choose only one answer)*

- [ ] Yes
- [ ] No

10. If yes, indicate where and what type of training or certifications received specific to concrete work:

11. Do you consider yourself a conservator/restorer, a craftsman or other?

- [ ] Conservator/restorer
- [ ] Craftsman
- [ ] Other

12. What percentage of your work is related to concrete repair/conservation/retrofitting/maintenance? *(Choose only one answer)*

- [ ] Less than 15%
- [ ] 15% - 30%
- [ ] 30% - 50%
- [ ] More than 50%

13. What type of concrete structures have you worked on? *(you can choose multiple)*

- [ ] Infrastructure
- [ ] Residential buildings
- [ ] Office buildings
- [ ] Public buildings
- [ ] Art works
- [ ] Heritage-designated buildings
- [ ] None
- [ ] Other

14. Indicate the type of concrete repair that you regularly perform: *(you can choose multiple)*

- [ ] Cleaning
- [ ] Patch Repair
- [ ] Concrete Coating
- [ ] Concrete Crack repairs
- [ ] Reinforcement repair
- [ ] Injection
- [ ] Cathodic protection
- [ ] Re-alkalization
- [ ] Desalination
- [ ] Strengthening (CFRP)
- [ ] Other

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15. What percentage of your concrete work includes patch repair? *(Choose only one answer)*

- ☐ Less than 25%
- ☐ 25% - 50%
- ☐ 50% - 75%
- ☐ More than 75%

16. When performing a patch repair, do you carry out mock-ups or test panels? *(Choose only one answer)*

- ☐ Yes, always
- ☐ No, never
- ☐ Occasionally

17. Do you think it would be beneficial to receive more training in concrete repair/conservation retrofitting/maintenance? *(Choose only one answer)*

- ☐ Yes
- ☐ No

If yes, which type. Max. 3 answers:

- ☐ Cleaning
- ☐ Patch Repair
- ☐ Concrete Coating
- ☐ Concrete Crack repairs
- ☐ Reinforcement repair
- ☐ Injection
- ☐ Cathodic protection
- ☐ Re-alkalization
- ☐ Desalination
- ☐ Strengthening (CFRP)
- ☐ Other (name)

18. In your professional view, what kind of skills/training would be beneficial (in general) to speed up the rehabilitation of European concrete architecture?

19. Are you available for an interview regarding the topic of concrete repair/conservation/retrofitting/maintenance?

- ☐ Yes
- ☐ No

20. Do you want to receive direct updates from the developments in CONCRETO-ACADEMY, if yes, please provide your email-address

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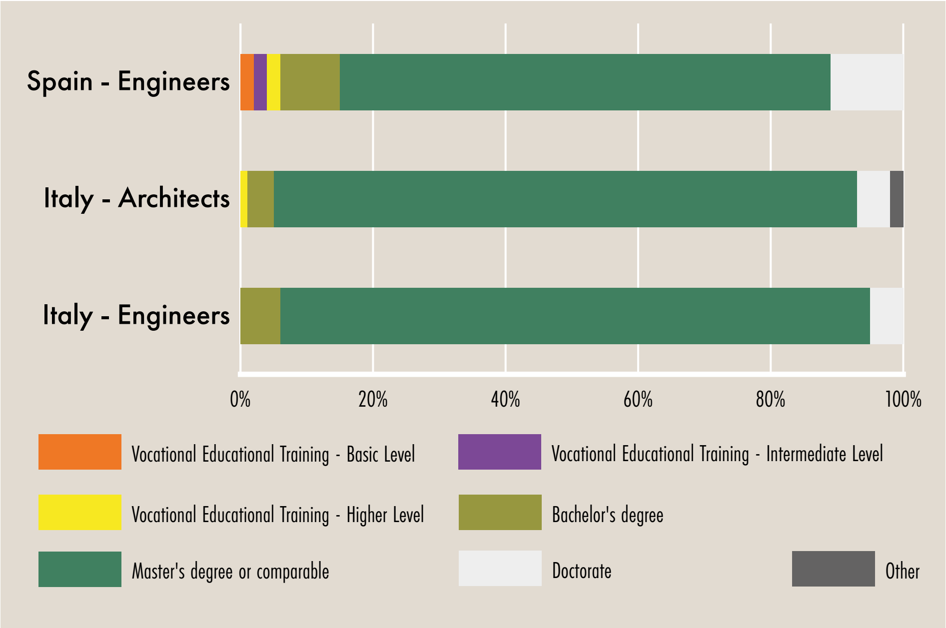
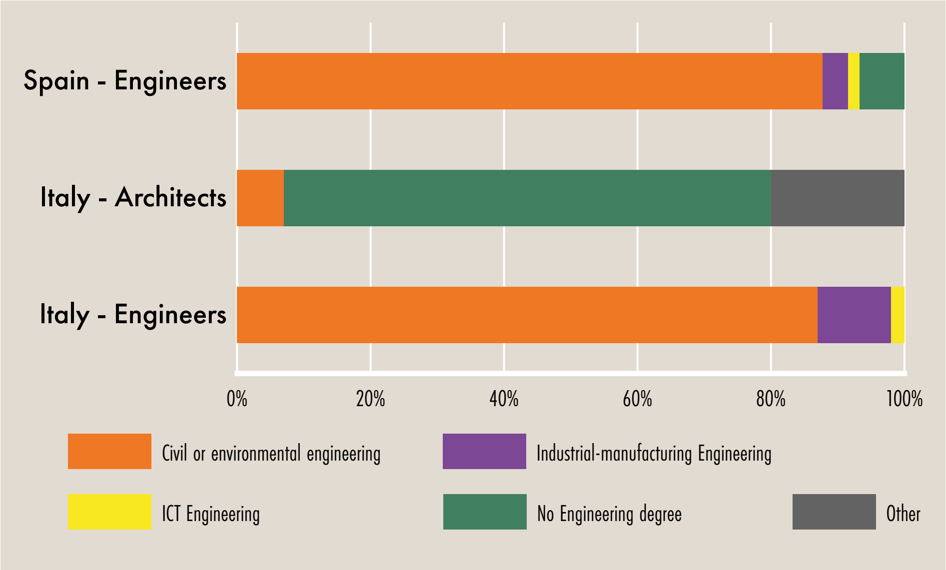
A.3 FULL DATA ARCHITECTS-ENGINEERS

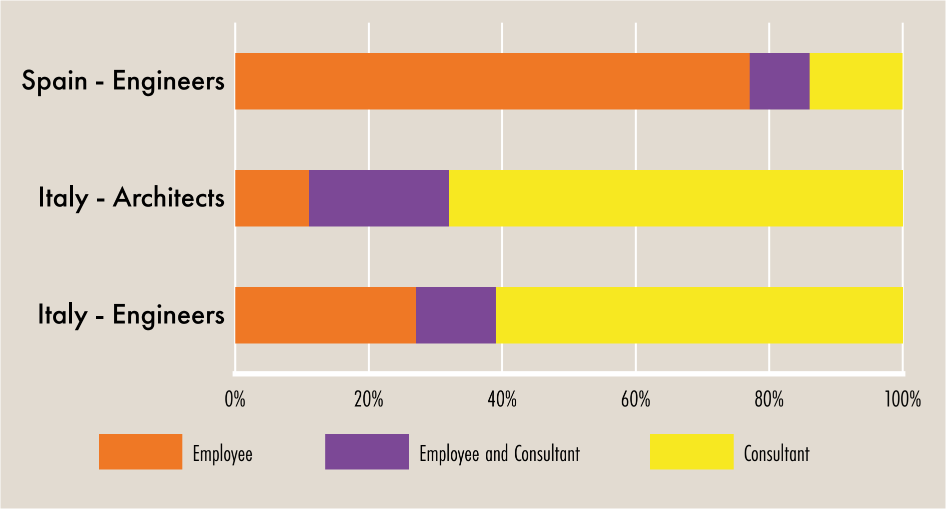
What is your highest education level?



Field of Engineering degree

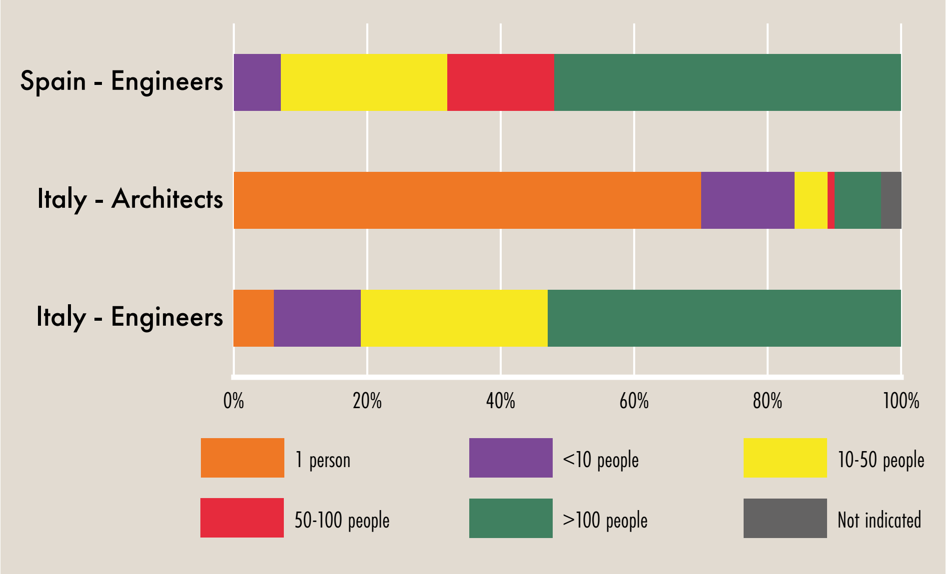


Do you work as ...?

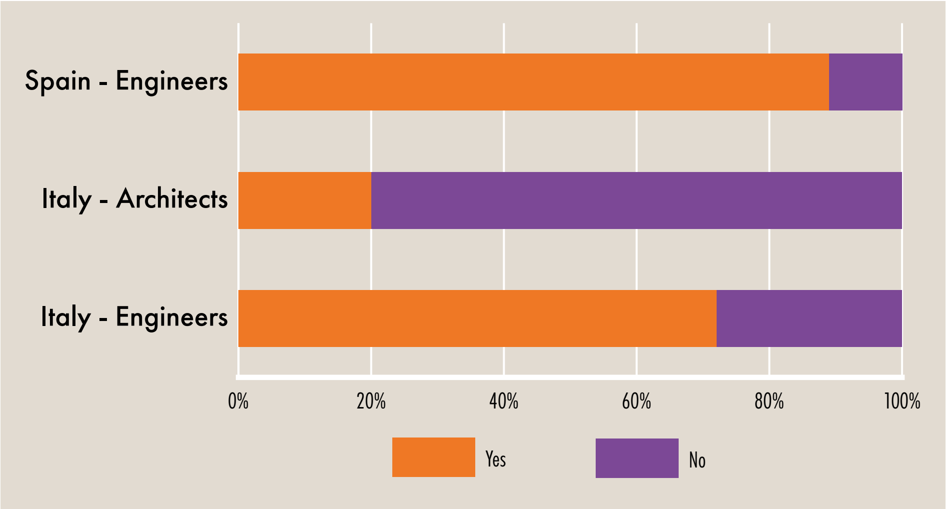


What is your main geographical area of activity?

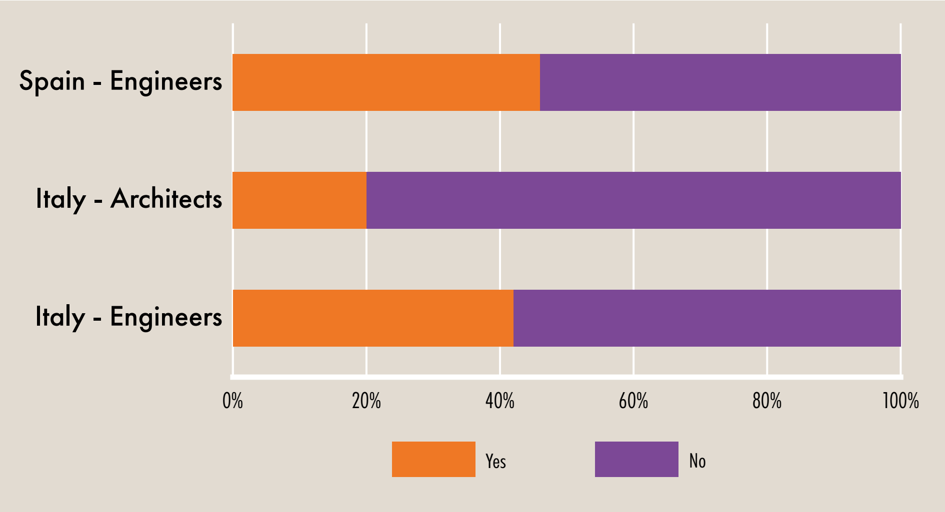
What is the size of the company (1 if self-employed)?



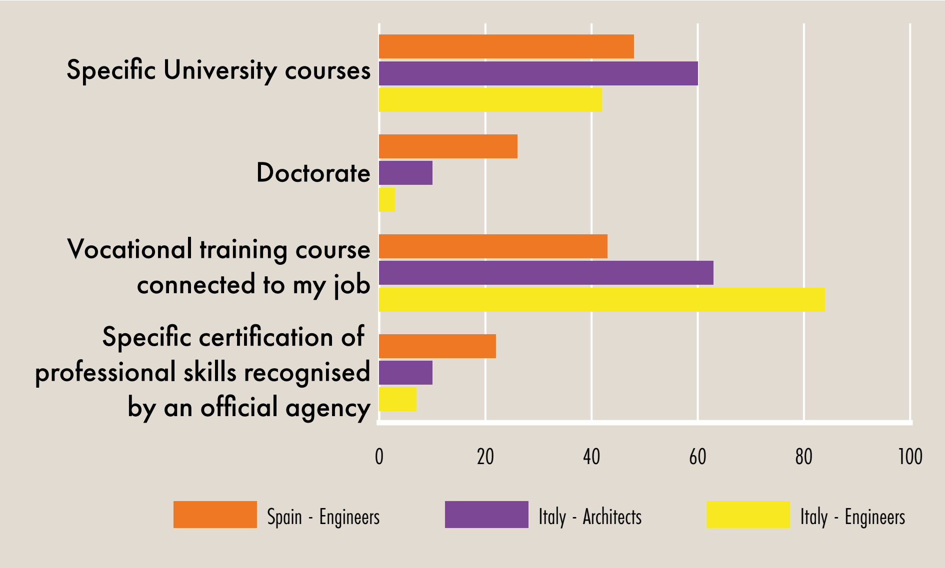
Considering your job activity do you usually do from time to time deal with maintenaince and restoration of concrete materials?



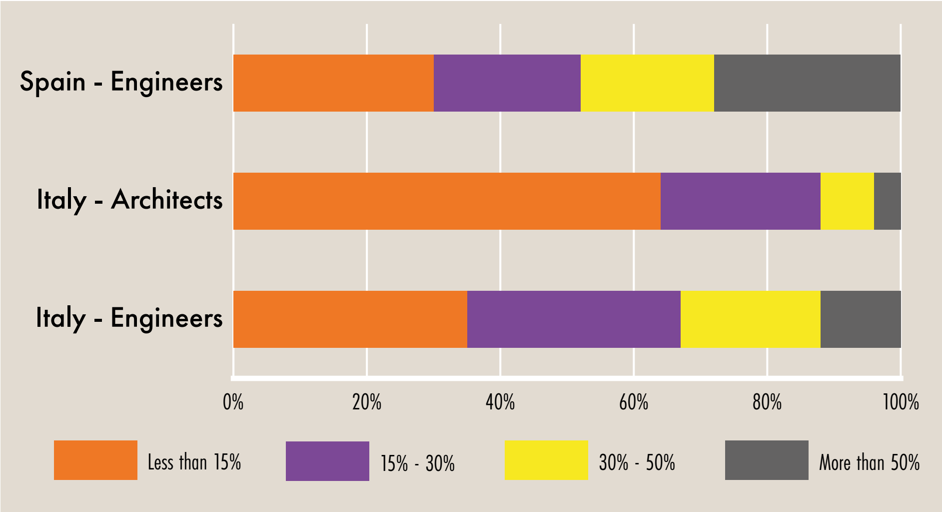
Do you possess any training or certifications specifically related to concrete repair and concrete maintenance?



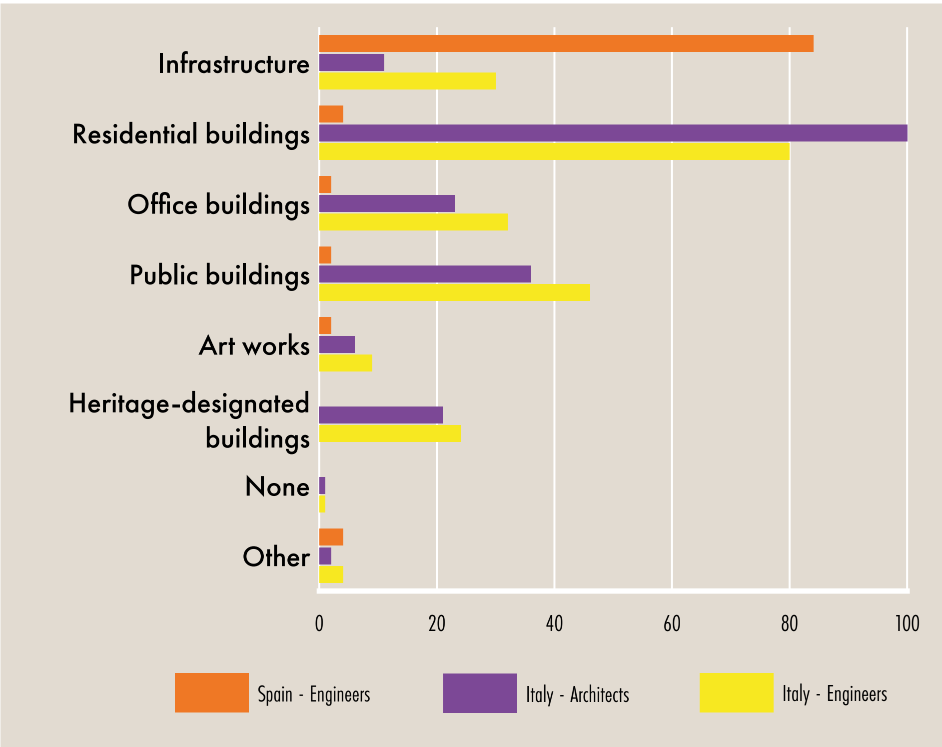
If yes, indicate where and what type of training or certifications received specific to concrete work.



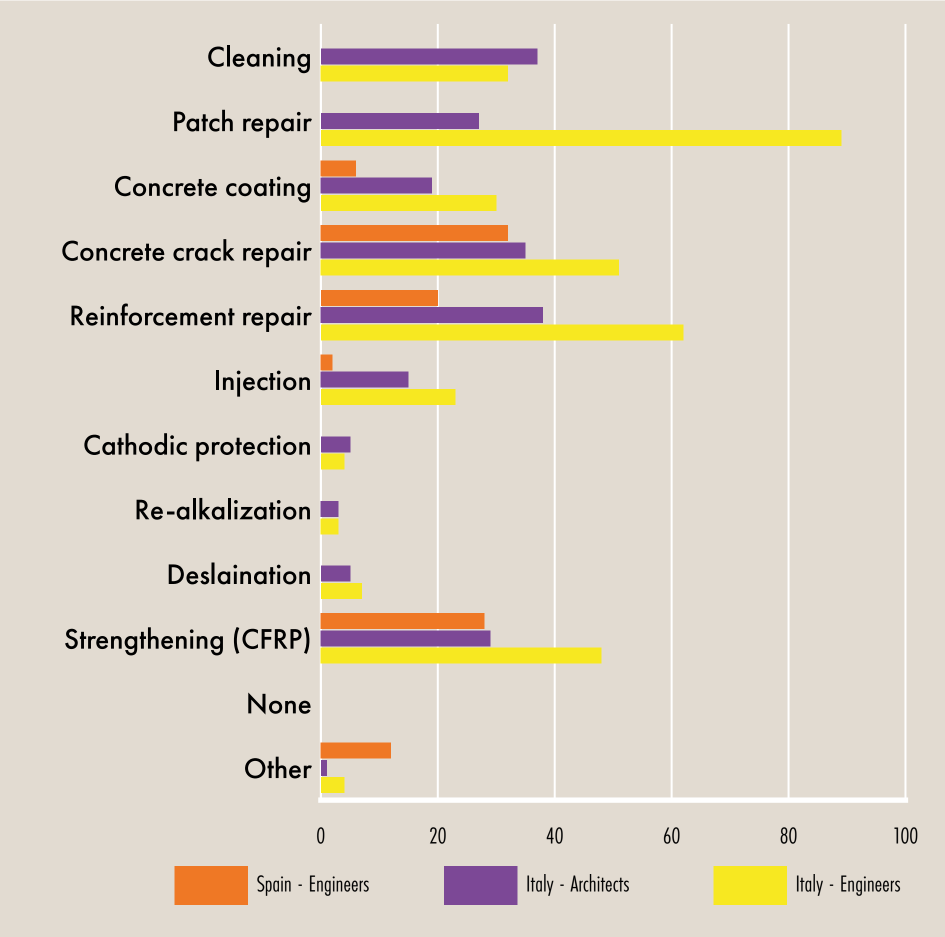
What percentage of your work is related to concrete repair/conservation/retrofitting/maintenance?



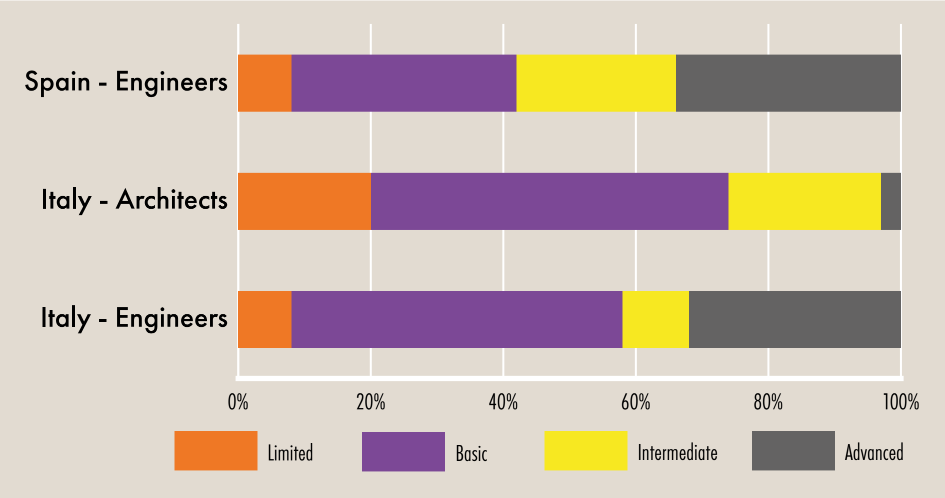
What type of concrete structures have you worked on?



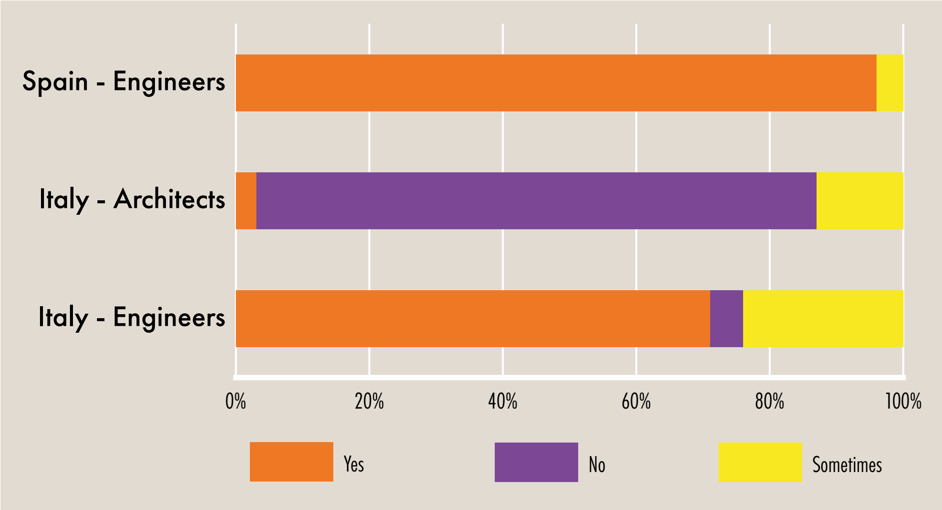
Indicate the type of concrete repair that your regularly perfom.



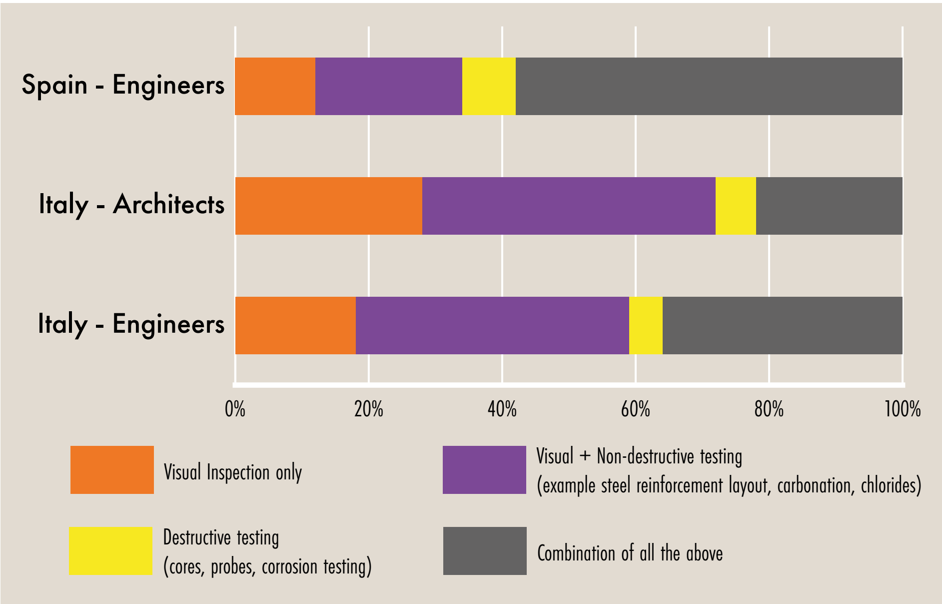
What is your knowledge of concrete assessment techniques?



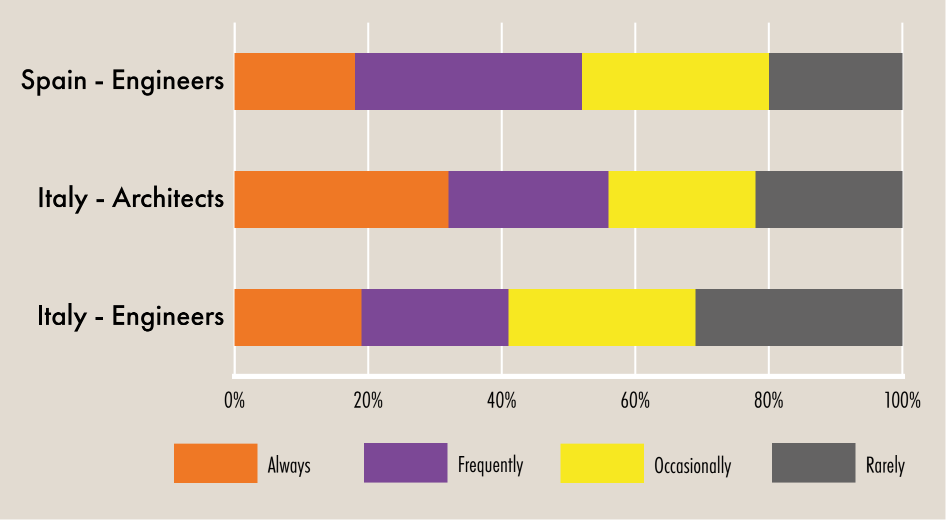
When involved in concrete repair work, is an initial assessment carried out?



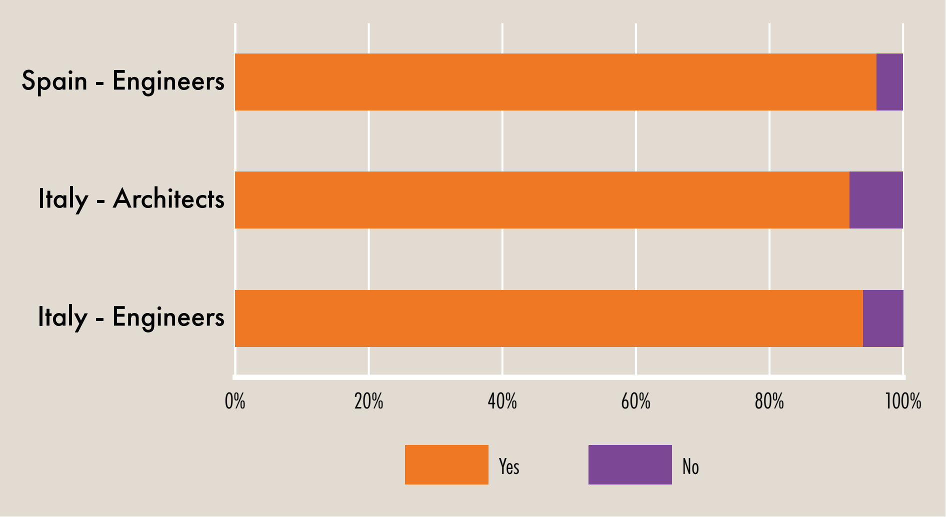
Indicate what type of assessment you mainly do (or subcontract) for a conrete structure.



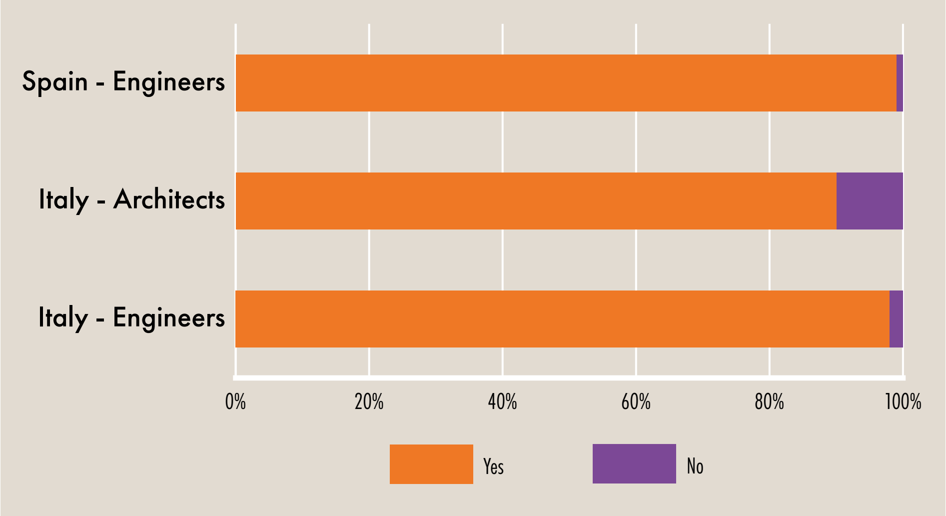
When devoloping a repair strategy for you project, how often do you include a maintenance plan?



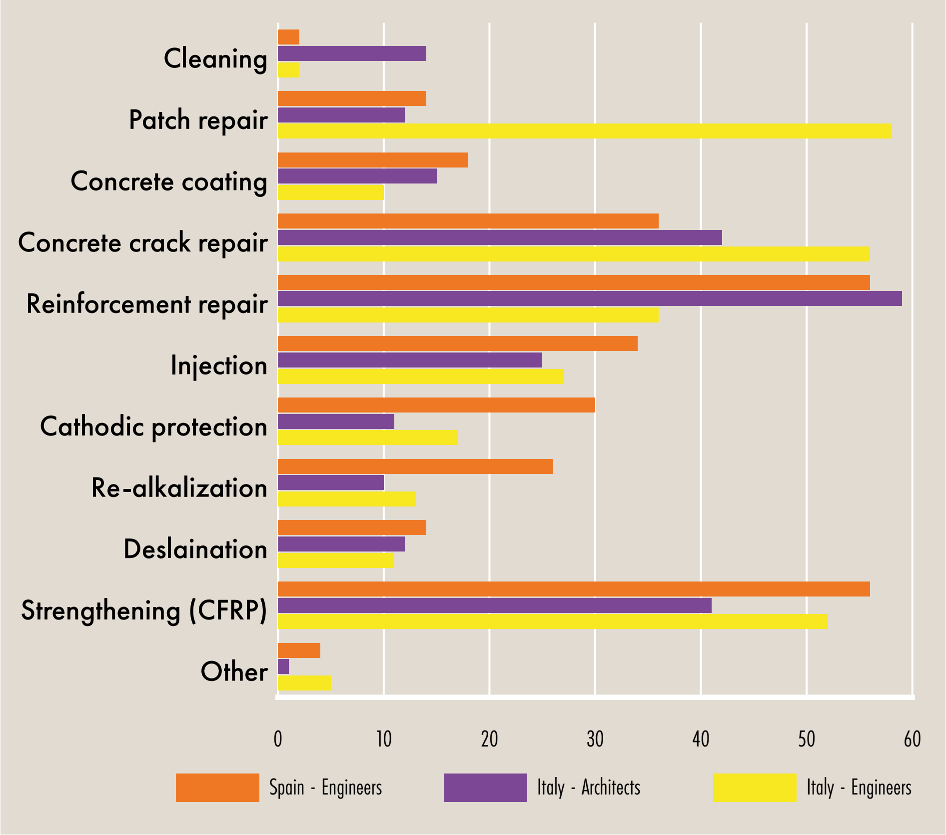
During the course of a project, do you typically conduct fiel inspections while the work is ongoing?



Do you think it would be beneficial to receive more training in concrete repair/conservation/retrofitting/maintenance?

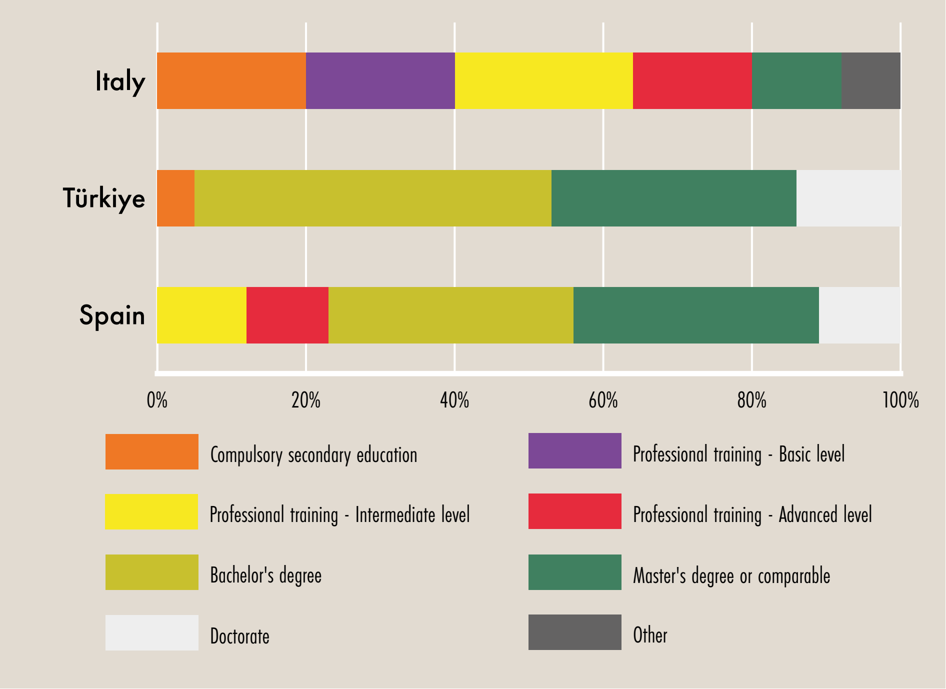


If "Yes", which type of training?

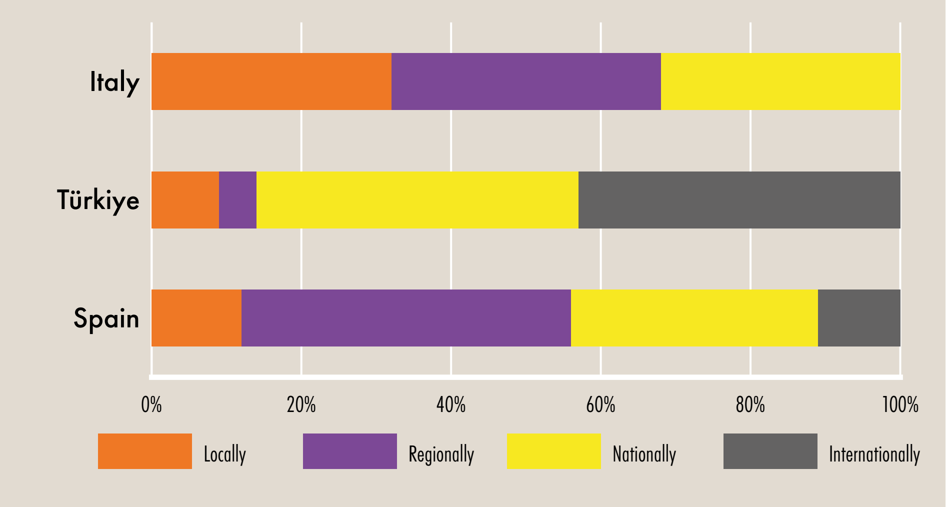


A.4 FULL DATA CRAFTWORKERS

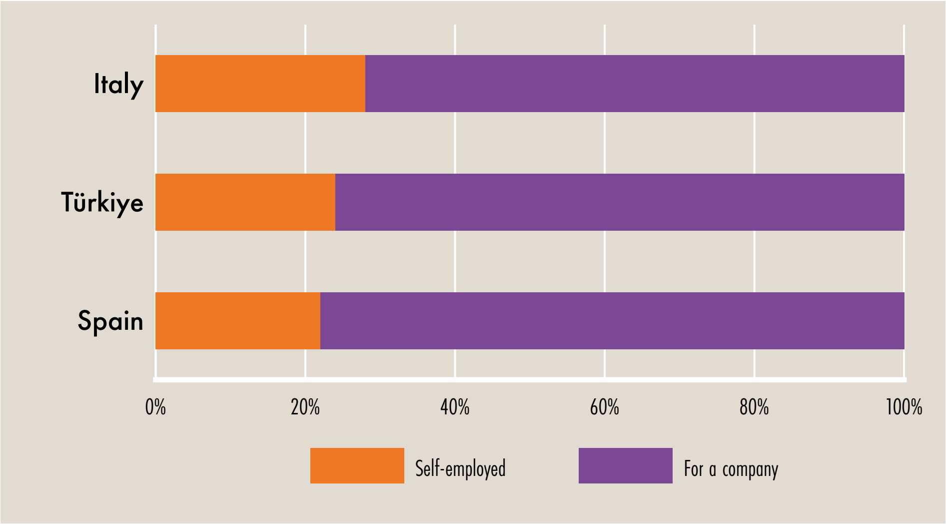
What is your highest education level?



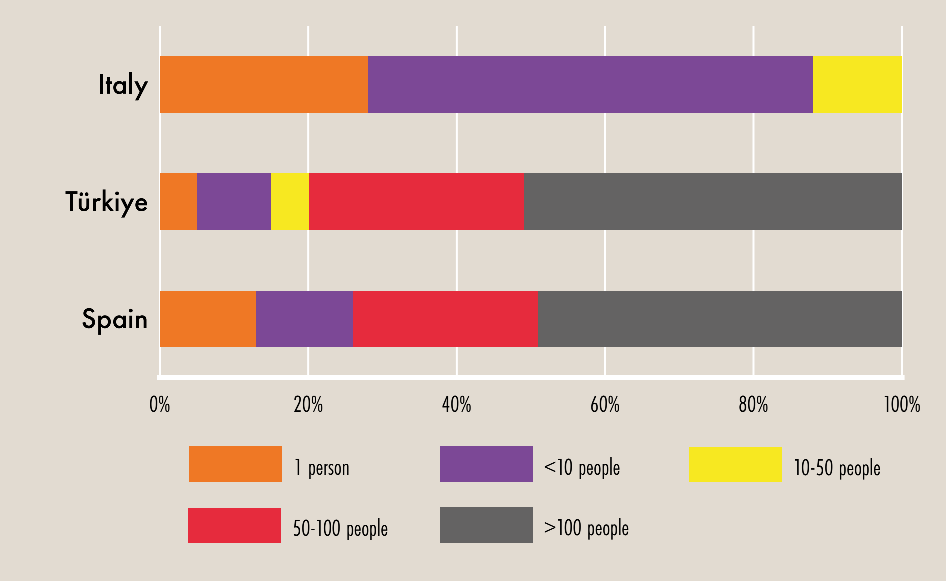
What is your main area of activitiy?



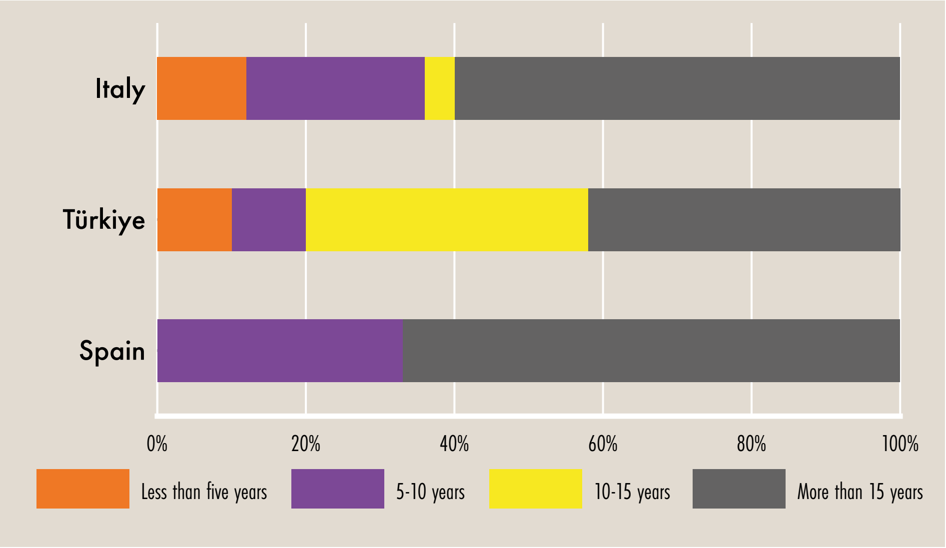
Do you work as a self-employed or in a company?



What is the size of the company?

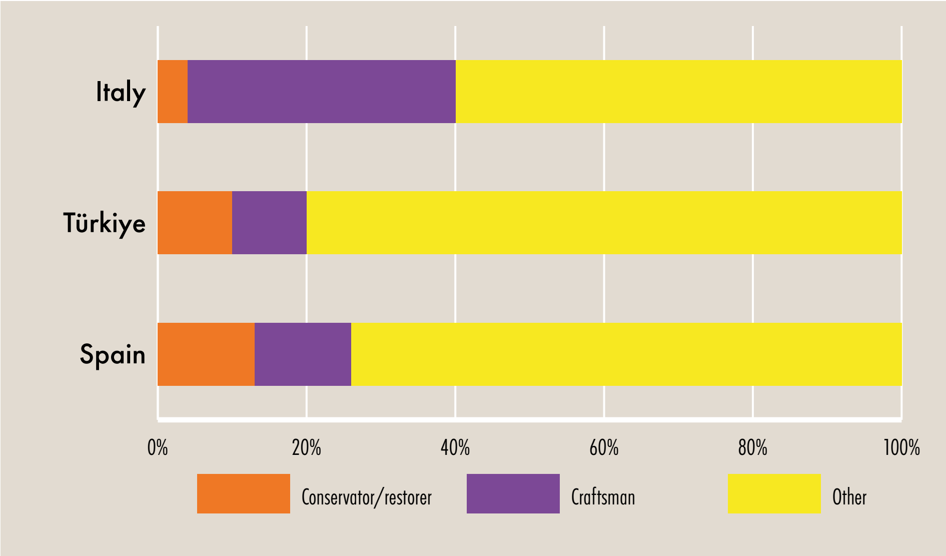


How many years of working experience do you have?

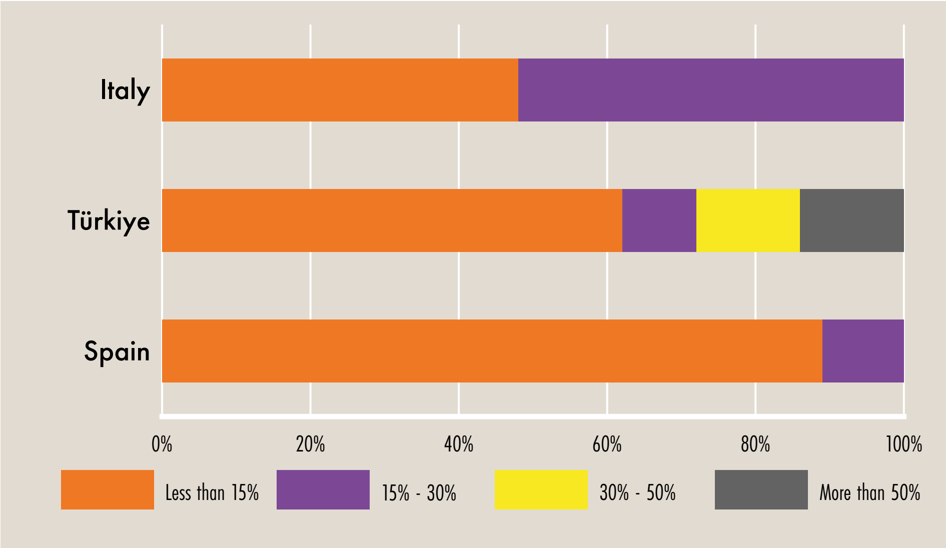


Do you possess any training or certifications specifically related to concrete repair, concrete retrofitting, concrete conservation and/or concrete maintenancen?

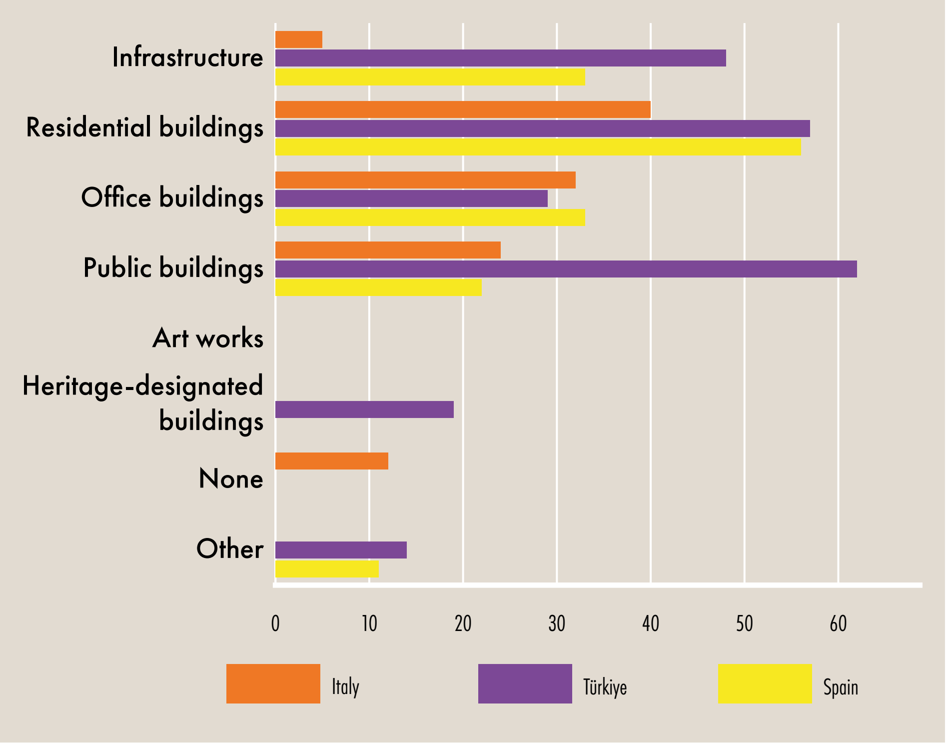
Do you consider yourself a conservator/restorer, a craftsman or other?



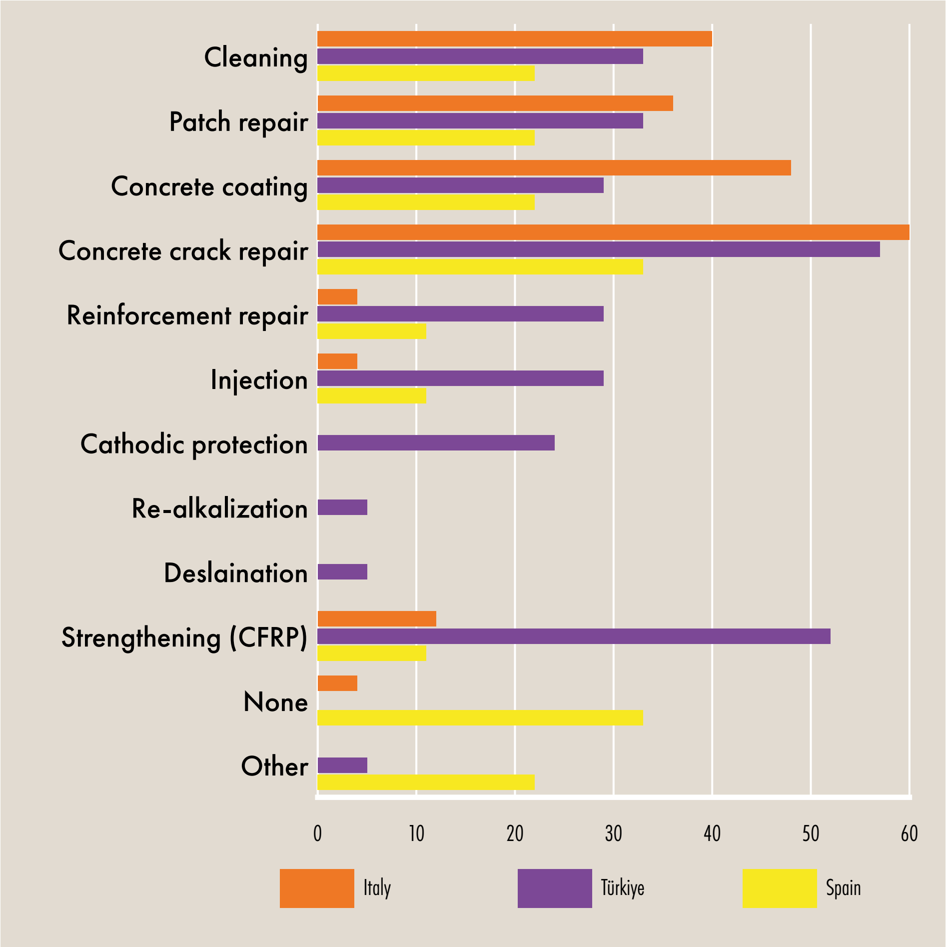
What percentage of your work is related to concrete repair/ conservation/retrofitting/maintenance?



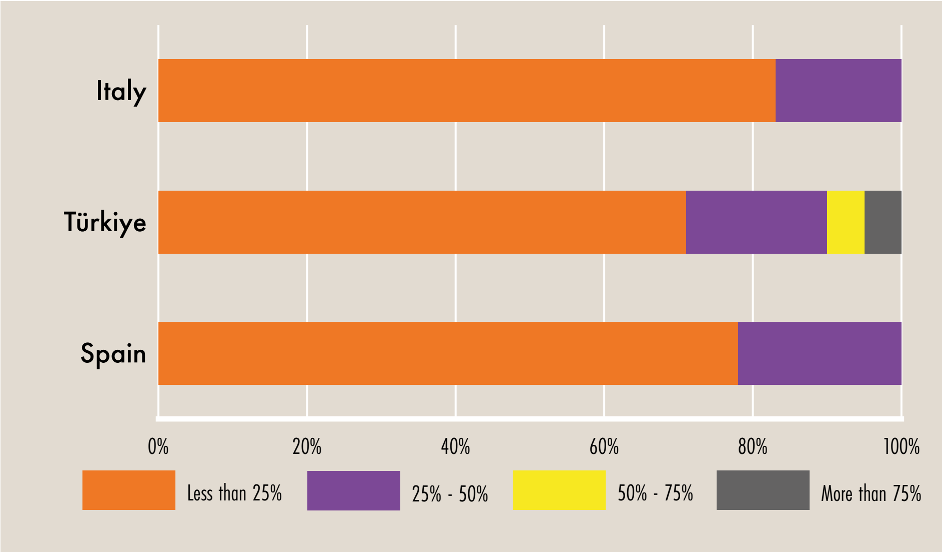
What type of concrete structures have you worked on?



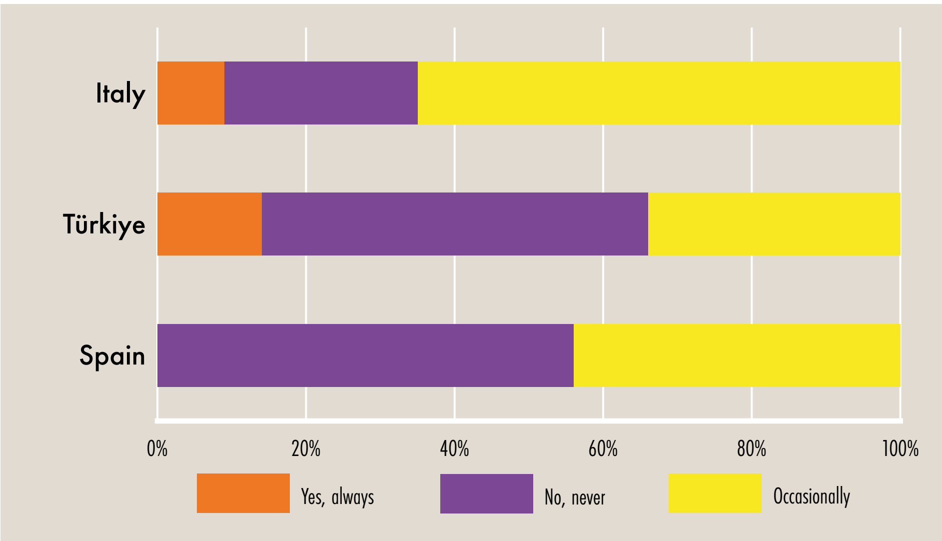
Indicate the type of concrete repair that you regularly perfom.



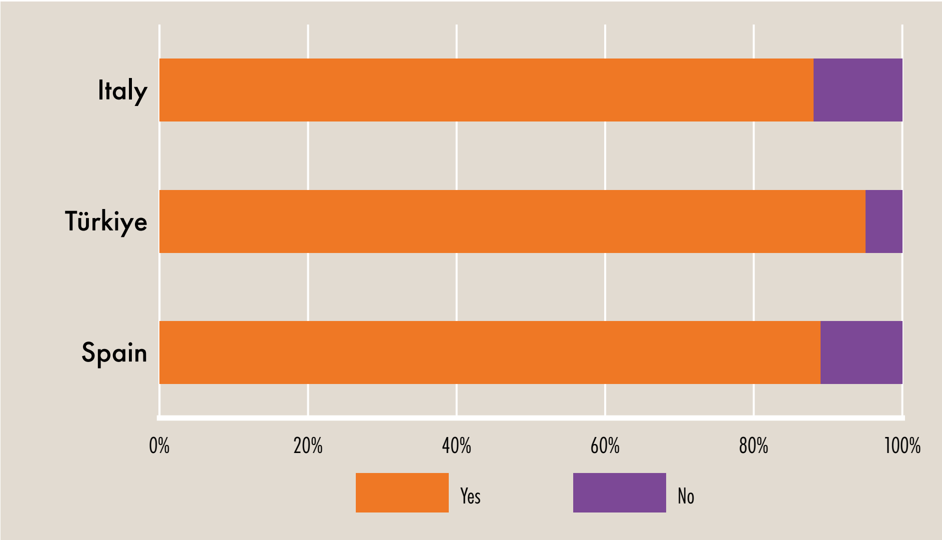
What percentage of your concrete work includes patch repair?



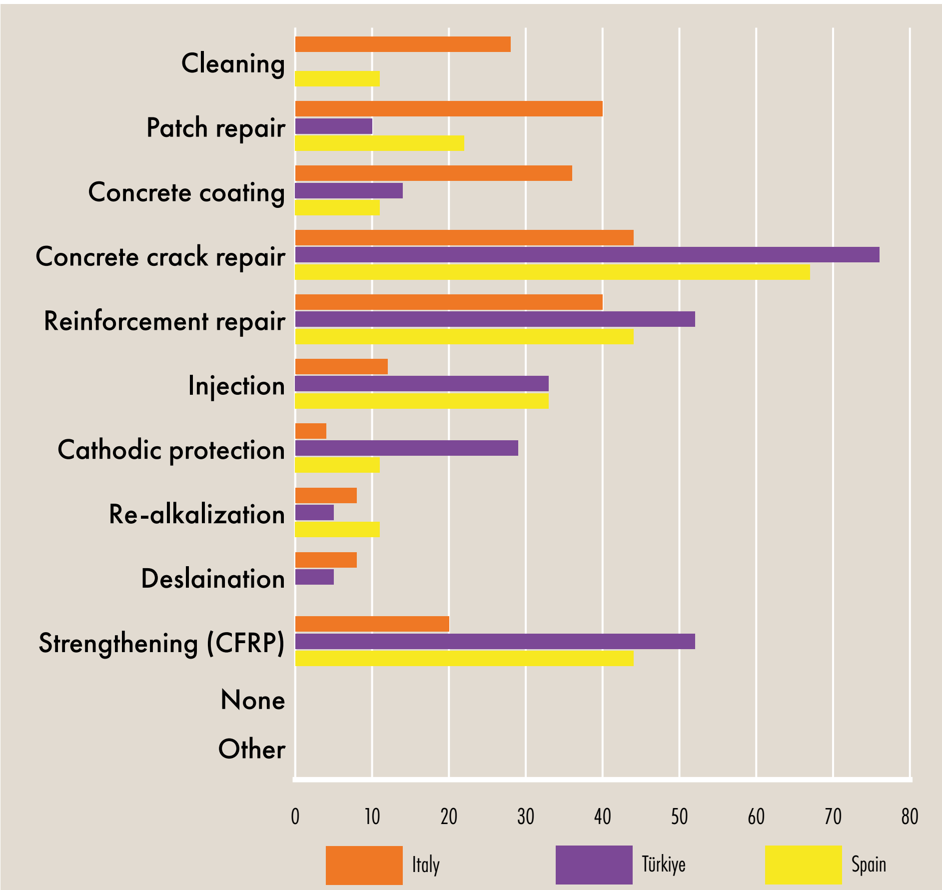
When performing a patch repair, do you carry out mock-ups or test panels?



Do you think it would be beneficial to receive more training in concrete repair/conservation/retrofitting/maintenance?



If "Yes", which type?



In your professional view, what kind of skills/training would be beneficial (in general) to speed up the rehabilitation of European concrete architecture?

- Concrete pathology and its treatment.
- Training in relation to the ageing of concrete.
- Reuse and renovation of concrete structures.
- Pathologies of mortars and concrete.
- Detection, typology and causes of injuries in concrete.
- Knowing concrete degradation and all useful intervention methods.
- Skills for recovering degraded concrete.
- Knowledge of various intervention methods for degraded concrete.
- Conduct training courses for practitioners.
- Study lime-based concrete.
- The correct arrangement, dosage, application, and use of concrete to avoid possible concrete injuries.
- The use of recycled concrete that reduces the carbon footprint in the life cycle of the construction.
- Knowledge of industrialisation and prefabrication.

APPENDIX B STATE OF THE ART ON CONSERVATION OF HISTORIC CONCRETE

This appendix presents all the recent resources, research and standards collected in the state-of-the-art review on historic concrete conservation. It is structured into sections, each highlighting the significant contributions to the field. Starting with key institutions and organisations involved in research and policy-making, this appendix shows the inventory of the most relevant research projects and international charters that shaped and continue to shape concrete conservation practices globally.

It also explores a range of academic studies on the deterioration mechanisms of concrete, diagnostic techniques and the approaches adopted for conservation. These are followed by specialised congresses that promoted and continue to promote knowledge exchange and provide insight into the latest developments in the field.

The latter part of appendix B presents industry standards, offering an in-depth look at the guidelines, reports and technical notes that guide diagnostic practices and conservation interventions.

B.1 INSTITUTES AND ORGANISATIONS

Appendix B1 lists associations and institutes that have addressed and continue to address the topic of concrete repair or conservation, either through a committee or a project explicitly dedicated to it. Other initiatives, proprietary research projects or the publication of journals or bulletins specifically dedicated to the conservation of historic concrete are also included. The list is organised by country, in alphabetical order, starting with the international organisations.

INTERNATIONAL

APT - The Association for Preservation Technology (1968)

The Association for Preservation Technology (APT) is an international organisation dedicated to the preservation of built heritage, established in 1968. It brings together professionals from various disciplines, including architects, engineers, conservators, architectural historians, archaeologists and other experts in the field. APT's mission is to advance appropriate traditional and new technologies to care for, protect and promote the longevity of the built environment and to cultivate the exchange of knowledge throughout the international community.

Modern Heritage Technical Committee

The Technical Committee on Modern Heritage (TC-MH) is constituted to promote the understanding and management of the 20th-century heritage and to foster the development of the full range of philosophical, design and technical issues necessary to ensure our ability to sustain this legacy.

APT Bulletin

A quarterly academic journal published by the Association for Preservation Technology International that contains several articles devoted to the conservation of historic concrete, and in 2017 released a special number (vol. 48, n.1) entirely focused on concrete, with particular attention to diagnostics and intervention strategies.

Status: available online

DOCOMOMO - Documentation and Conservation of buildings, sites and neighborhoods of the Modern Movement (1988)

International organisation dedicated to the documentation and conservation of architecture, landscapes and urban areas of the Modern Movement. It was founded in 1988 in the Netherlands and has grown to become a global network of professionals and academics who aim to promote the appreciation, conservation and re-use of modernist architecture.

Dossiers DOCOMOMO ISC/T

Proceedings produced by the International Specialist Committee on Technology of DOCOMOMO. These documents are often used as resources to guide conservation practices and research in the field of modern architecture. In April

1997, a dossier was published specifically focused on the conservation of historical concrete buildings: "The Fair Face of Concrete, Conservation and Repair of Exposed Concrete"; one of the first efforts aimed at exchanging knowledge related to interventions on historic concrete.

Status: available online

DOCOMOMO Journal

The open-access, international, peer-reviewed journal of DOCOMOMO, dealing with the conservation of architecture, places and sites of the Modern Movement. It contains several articles specifically focused on approaches to historical concrete conservation.

Status: available online

fib - International Federation for Structural Concrete (1998)

International organisation dedicated to advancing the technical, economic, aesthetic and environmental performance of concrete structures and on research, development, and the dissemination of knowledge related to concrete and concrete structures. The fib was formed in 1998 by the merger of the Euro-International Committee for Concrete (the CEB) and the International Federation for Pre-stressing (the FIP). These predecessor organisations existed independently since 1953 and 1952, respectively.

The fib provides a platform for experts from around the world to collaborate on developing standards, guidelines and technical reports that promote best practices in the design, construction and maintenance of concrete structures.

fib Bulletins

The fib Bulletins cover a wide range of topics related to concrete and concrete structures, including reports on the latest research in concrete technology and structural concrete, guidelines and best practices for the design, construction and maintenance of concrete structures, case studies, state of the art reports, updates and discussions on the development of international codes and standards for concrete structures. Bulletins are aimed at professionals in the field, including engineers, researchers and academics, providing them with valuable information to enhance their knowledge and practice in structural concrete.

Status: available online for fib members

ICOMOS - International Council on Monuments and Sites (1965)

A professional organisation dedicated to the conservation and protection of the world's cultural heritage. It has an advisory role to UNESCO and plays a significant role in the development of international policies and guidelines for heritage conservation.

ISC20C - International Scientific Committee on Twentieth Century Heritage (2005)

Established in 2005, the ICOMOS Twentieth Century Heritage International Scientific Committee focuses its efforts on conserving and celebrating mid to late-twentieth-century places that are most at risk through lack of recognition and protection. The committee coordinates a range of projects, conferences, declarations and publications to address these issues.

In 2017, the ISC20C finalised the international standard **Approaches for the Conservation of the Twentieth Century Heritage** (known as the Madrid-New Delhi Document) set of guidelines developed to address the conservation of heritage structures made of concrete. The document aims to provide a framework for best practices in the preservation, restoration and maintenance of modern concrete structures, recognising their historical, cultural and architectural significance.

Patrimoine du XXe siècle (20th Century Heritage) - ICOMOS France

The working group focuses on recent heritage, particularly concrete heritage. Within this framework, the group organises a series of conferences on concrete restoration. Following a successful initial conference in Grenoble in 2017, the discussions continued in Venice in 2019. A partnership project is currently underway with ICOMOS Brazil.

In November 2017 in Grenoble, ICOMOS France organised the international conference "Restaurer les bétons: la masse et l'épiderme" (Restoring Concrete: Mass and Skin) as part of the event "200 Years of Concrete", followed by the publication of the proceedings in Béton(s), No. 29 of the Cahiers d'ICOMOS France, as an update to the previous Cahiers ICOMOS Béton from 1999. The interest generated by this conference encouraged ICOMOS France to propose new editions in Europe and beyond. For this second edition, ICOMOS France and the HeModern ClusterLAB at the IUAV University of Venice decided to collaborate and provide an opportunity to compare French and Italian research and experiences. They organised the 2019 conference "Restaurare il cemento: materia e struttura - Restaurer les bétons : matière et structure" (*Restoring Concrete: Material and Structure*), the Venetian edition of the Grenoble event.

RILEM - Réunion Internationale des Laboratoires et Experts des Matériaux, systèmes de construction et ouvrages (1947)

The International Union of Laboratories and Experts in Construction Materials, Systems and Structures was founded in 1947; it is a non-governmental scientific association.

The mission of RILEM is to advance scientific knowledge related to construction materials, systems and structures and to encourage the transfer and application of this knowledge world-wide. This mission is achieved through collaboration of leading experts in construction practice and science, including academics, researchers, industrialists, testing laboratories and authorities. RILEM research is developed via technical committees and knowledge is spread via RILEM conferences.

Future Technical Committee on Historic concrete - Identification, diagnosis and conservation

The purpose of the Technical Committee will be to summarise the existing literature and provide recommendations regarding ancient cement variety and specific identification methodologies; specific decays of historic concrete and good practices in terms of diagnosis and long-term monitoring; restoration strategies and their durability.

RILEM Recommendations

Over 200 RILEM Technical Recommendations have been produced by RILEM Technical Committees. Many of these recommendations have been adopted in research and practice and are used by international standardisation bodies as a basis for their work (e.g., RILEM. 1993. Technical Recommendation 124 SRC, Guidelines to Repair Strategies for Concrete Structures Damaged by Reinforcement Corrosion).

AUSTRALIA

Concrete Institute of Australia (1970)

The Concrete Institute of Australia (CIA) is a professional association in Australia dedicated to advancing concrete technology and practice, established in 1970. It provides resources, training and networking opportunities for professionals involved in the concrete industry, including engineers, architects, researchers and contractors. The CIA aims to promote excellence in the design, construction and maintenance of concrete structures through knowledge sharing, technical guidelines and professional development.

FRANCE

LRMH - Laboratoire de Recherche des Monuments Historiques (1967)

Founded in 1967, the LRMH is the Research Laboratory for Historical Monuments in France. It is a specialised institution dedicated to the study, conservation and restoration of historical monuments and cultural heritage. Key functions of the LRMH include scientific research, technical support, analysis and diagnostics, development of conservation methods and training and dissemination.

LRMH Pôle Béton

The concrete division of the Laboratoire de Recherche des Monuments Historiques, focusing specifically on research and development of methodologies and technologies related to concrete used in historic buildings. More specifically, two research areas have been developed in recent years: the study of conservation methods for historic concrete, including cleaning of dirt, removal of biological coverings, treatment of steel corrosion, and desalination of glass panels and the study of diagnostic techniques for steel corrosion in historic concrete.

From 2014 to 2017, the Pôle Béton participated in the research project Redmonest, coordinated by the Eduardo Torroja Institute for Construction Science (IETCC), with the aim of developing a real-time management system to evaluate the corrosion process of ancient concrete exposed to natural ageing. (For more information, see the Projects chapter).

GERMANY

WTA - International Association for Science and Technology of Building Maintenance and Monuments Preservation (1977)

The International Association for Science and Technology of Building Maintenance and Monuments Preservation (WTA) is a global organisation dedicated to advancing knowledge and practice in the fields of building maintenance and the preservation of historical monuments. Founded in Germany in 1977, WTA serves as a platform for professionals, researchers and institutions involved in the conservation and restoration of buildings and monuments.

Technical Commission 5 - Concrete

The work in the Technical Commission Concrete focuses on special topics and details of the specialist area "Maintenance of concrete"; in the future, increasingly from the point of view of monument conservation. The commission publishes recommendations and status reports in German with additional and more detailed information on the existing regulations as well as on regulations still to be expected in the field of concrete. Another important focus of the commission's activities is the transfer of knowledge on concrete, which is reflected, among other things, in the annual international WTA Colloquium on Concrete Maintenance.

ITALY

AITEC - Associazione Italiana Tecnico Economica del Cemento (1959)

AITEC is the Italian Technical and Economic Association of Cement, established in 1959. It is an industry association that represents the interests of companies involved in the production and distribution of cement and related materials in Italy, protecting the technical and economic interests of the Italian concrete industry, both in national and international frameworks.

IIC – L'Industria Italiana del Cemento (1929)

Founded in 1929 by the initiative of the Society for the Promotion of Cement Applications and the National Federation of the Italian Cement, Lime and Gypsum Industry, "L'industria Italiana del Cemento" (The Italian Industry of Concrete) documents the history of concrete construction in Italy, with particular attention on case studies on historic concrete conservation. After a publication stop (2010-2021), they restarted publishing in November 2021.

Status: not available online

SPAIN

ARPHO - Asociación nacional de Reparación, Refuerzo y Protección del Hormigón (2010)

ARPHO, or the Asociación de Reparación, Refuerzo y Protección del Hormigón, is a Spanish association dedicated to the repair, reinforcement and protection of concrete structures. It aims to promote professionalism within the industry and support the conservation and maintenance of concrete structures. The association provides guidelines, organises events, and offers resources for best practices in concrete repair and protection. ARPHO participates in various technical forums and collaborates with other industry organisations to advance knowledge and standards in the field of concrete maintenance.

The Eduardo Torroja Institute for Construction Sciences (1934)

The Eduardo Torroja Institute for Construction Sciences (IETcc) is a leading Spanish research institution focused on advancing construction science, founded in 1934. Named after engineer Eduardo Torroja, it specialises in materials science, structural engineering, building technologies, sustainability and building physics. The institute collaborates with industry, academia and government to promote innovation and develop construction standards, while also providing professional training and education. Originally focused on concrete research, the institute now also works on other construction materials but retains its strong focus on concrete.

Materiales de Construcción

International scientific journal published in English. It is the national reference journal on this subject. The open-access, international, peer-reviewed journal of IETcc contains several articles specifically focused on approaches to historical concrete conservation.

Status: available online

UNITED KINGDOM

C20 - Twentieth Century Society (1979)

Founded as a direct response to growing interest in C20th architecture and to complement the preservation work of the Victorian Society, the organisation focuses on preservation and education about British 20th-century architecture through numerous campaigns, events (including guided tours, conferences and lectures) and books and a thrice-yearly magazine, C20 (status: not available online).

CRA – Concrete Repair Association (1989)

Established in 1989, the CRA is a professional body representing the interests of contractors, manufacturers, distributors and consultants involved in the repair, maintenance and protection of concrete structures. The CRA aims to promote high standards of practice and professionalism within the industry, providing guidelines, technical information, and training for its members. The association also works to advance the knowledge and understanding of concrete repair techniques and to support the development and dissemination of best practices.

CRA Advice notes

Technical guidance documents to aid the specifier or engineer in providing useful information, including preparing contract documentation, choosing products or a contractor, and measuring work that has been undertaken.

Structural Concrete Alliance (2014)

Established in February 2014, the Structural Concrete Alliance brings together the Concrete Repair Association (CRA), Corrosion Prevention Association (CPA), and Sprayed Concrete Association (SCA) to provide a single coordinated voice for the asset protection and repair industry. It brings together contractors, manufacturers, distributors, consultants, test houses and equipment suppliers, offering a source of information and advice for all involved in the repair, refurbishment and management of concrete infrastructure and the protection from corrosion of a wide range of structures.

USA

ACI - American Concrete Institute (1905)

An international professional organisation dedicated to research, development and dissemination of technical knowledge regarding concrete and related materials, as well as the practices of design, construction and maintenance of reinforced concrete structures. The ACI was founded in 1905 during a convention in Indianapolis. The work of the ACI committees in the field of existing concrete, in their guidelines, reports and technical standards, is mostly dedicated to the repair of concrete structures.

Committee 120 – History of concrete

An internal committee specifically focused on developing and reporting information on the history of concrete with the goal of sponsoring a convention session every 18 months on the History of Concrete.

Committee 546 – Repair

The mission of the committee on repair is to develop and report information on means and methods of repair and strengthening of existing concrete and masonry structures. The 546 Committee published the guide Concrete Repair in 1996, revised it in 2004 and 2014, then updated it in December 2023 (ACI PRC-546-23, which supersedes ACI 546R-14). The Committee also published the guide Materials Selection for Concrete Repair in 2006, revised in 2014. The last version was published in February 2024 (ACI PRC-546.3-23, which supersedes ACI 546.3R-14).

Committee 562 – Evaluation, Repair and Rehabilitation of Concrete Structures

The mission of the committee is to develop and maintain code requirements for the evaluation, repair and rehabilitation of existing concrete buildings through the ACI 562 Code requirements for assessment, rehabilitation and repairs to concrete structures (ACI 562-21 supersedes ACI 562-19, was adopted November 10, 2021, and published November 2021), developed to provide design professionals a code for the assessment of the damage and deterioration, and the design of appropriate repair and rehabilitation strategies.

Committee 563 - Specifications for Repair of Structural Concrete in Buildings

The aim of the committee is to develop and maintain specifications for the repair of existing structural concrete by drafting Specifications for Repair of Concrete in Buildings (ACI SPEC-563-18, adopted in August 2018 and published in September 2018).

ACI University

ACI Certificate Programs, delivered through ACI University, encourage concrete professionals to gain in-depth knowledge about particular topics in concrete materials, design, repair, or construction by following a defined online course of study.

GCI - Getty Conservation Institute (1985)

The Getty Conservation Institute (GCI) is an organisation focused on conservation and research in the field of cultural heritage worldwide. GCI is committed to promoting the understanding, conservation and appreciation of cultural heritage through research, training, documentation and practical conservation activities.

Keeping It Modern (2014)

A multi-project initiative of the Getty Conservation Institute (GCI) specifically dedicated to helping professionals and communities preserve 20th-century buildings around the world through research and conservation plans.

Conserving Modern Architecture Initiative (2012)

Started in 2012, this initiative is a project of the Getty Conservation Institute aimed at advancing practical methods for identifying, conserving and preserving buildings, structures, landscapes, urban areas and materials of the 20th-century built heritage.

Concrete Conservation (2014)

A project to promote the conservation of concrete heritage to ensure sustainable and technically appropriate results that preserve the cultural significance of historical concrete. In 2015, the first outcome of the project was published: Conserving Concrete Heritage: An Annotated Bibliography. Since then, they published Conservation Principles for Concrete of Cultural Significance (2020).

ICRI - International Concrete Repair Institute (1988)

In May of 1988, the International Association of Concrete Repair Specialists was founded, attended by 66 repair specialists, to address the lack of standards and guidelines for concrete repair. In 1993, the name was changed to International Concrete Repair Institute.

Nowadays, it is a professional association dedicated to improving the quality of concrete repair, restoration and protection. The organisation provides guidelines, standards, educational resources and certification programs to professionals in the concrete repair industry.

Concrete Repair Bulletin (CRB)

The Concrete Repair Bulletin (CRB), a bimonthly magazine of the International Concrete Repair Institute (ICRI), reaches concrete repair specialists worldwide, featuring technical articles on the repair, protection and restoration of concrete structures and surfaces.

Status: available online

THE NETHERLANDS

Betonvereniging (1927)

Betonvereniging (concrete association) is a Dutch organisation that focuses on promoting knowledge about concrete and stimulating its application. Founded in 1927, the association aims to provide a learning and connecting environment where those involved in the concrete industry can gain and exchange knowledge, insights and experience.

Maintenance and Repair Courses

Betonvereniging offers a variety of courses under the category of "Onderhoud en Reparatie" (Maintenance and Repair). These courses are designed to enhance the skills and knowledge of professionals involved in the concrete industry, covering topics such as concrete technology, inspection techniques, repair methods, and the application of innovative materials and technologies. The target audience of these courses are VET workers in the field, TA professionals, and public administration employees.

ERM – Erkende Restauratiekwaliteit Monumentenzorg (2020)

The goals of ERM (Foundation for the Preservation of Monuments Quality), active since 2020, are to ensure high-quality restoration and conservation of cultural heritage. They aim to develop and promote standards, guidelines and certifications that enhance the expertise and professionalism within the restoration industry, ensuring that historic monuments and structures are preserved with the utmost care and integrity for future generations.

Their guidelines comprise both technical and ethical aspects of historical materials.

Among their practical guidelines (URL – Uitvoeringsrichtlijn) on interventions in historical buildings, (https://www.stichtingerm.nl) URL 2003 and URL 4005 deal with the restoration of historical concrete.

NRC – Nationaal Restauratie Centrum (1988)

The NRC is a prominent institution specialising in the conservation and restoration of cultural heritage. Its goal is to promote knowledge of restoration techniques, crafts and monument care, with training courses for carpenters, masons, plasterers, painters and glaziers, contractors, supervisors, civil servants of monument care and building supervision, architects and students. The NRC also develops and publishes manuals on various subjects, which–per book–provide an overview of the available knowledge.

Training course – Restoration of historic concrete

The NRC organises a one-day course focusing on the "Restoration of Historical Concrete" (Herstel van Historisch Beton), designed to provide training and knowledge on the techniques and methods used to restore historical concrete structures from a conservation point of view. The course is aimed at professionals involved in conservation, restoration and construction who are working with historical concrete structures. This might include architects, engineers and restoration specialists. Participants will learn about the specific challenges involved in repairing and preserving concrete that has historical or architectural significance. This includes understanding the deterioration processes, selecting appropriate restoration materials, and applying suitable repair techniques.

RCE - Cultural Heritage Agency of the Netherlands (2009)

The Cultural Heritage Agency of the Netherlands (RCE) was founded in 1875 and re-organised in 2009 in its current structure and is part of the Ministry of Education, Culture and Science. It is dedicated to preserving and managing cultural heritage, such as monuments and historical buildings, archaeology, natural landscapes, and movable heritage, such as collections. The RCE has conducted extensive studies on art-historical objects and valuable artworks; currently, the research department places a strong emphasis on modern materials and objects.

Concrete Knowledge Base (Kennisbank)

The section on concrete from the Cultural Heritage Agency of the Netherlands (RCE) provides a detailed overview of the material, focusing on different aspects of concrete in the context of cultural heritage conservation. The work is divided into four sections: **concrete overview**, which provides an introduction to concrete, including its history, properties and uses; **concrete inspection**, which includes guidelines, methods and best practices for assessing the condition of concrete structures; **concrete restoration and implementation**, which discusses methods and techniques for restoring and implementing concrete buildings; **concrete maintenance and repair**, which focuses on maintaining and repairing concrete, detailing best practices and materials with a lot of images and examples; **concrete damage**, which examines types of damage that concrete structures can sustain and how to diagnose and address these issues. These pages are in Dutch and are aimed at VET workers and TA professionals. The content is fully available online, providing valuable resources for those involved in the field of concrete conservation.

B.2 RESEARCH PROJECTS

List of research projects with multiple partner participation, funded by EU and non-EU programmes, specifically devoted to the conservation of historical architectural heritage in concrete. Each project lists the main partners involved in the research, along with the main results achieved, documented in their publications or platforms developed to disseminate the outcomes of the work. Listed in chronological order, from the newest to the oldest.

REcube (2021-2024)

A project within the Erasmus+ programme, "REcube: REthink, REvive, REuse – Transmitting the knowledge for the green regeneration of the European Concrete Heritage", aims to create and transmit a common vision for the conservation of European modern concrete architecture. By disseminating new interdisciplinary conservation techniques and best practices, the project encourages the professional world to adopt a more holistic, green and culturally aware approach to modern heritage.

Coordinator: Politecnico di Milano.

Main Partners: Università degli Studi di Napoli Federico II (Italy), Universite Libre de Bruxelles (Belgium), Middle East Technical University (Türkiye), Budapesti Muszaki es Gazdasagtudomanyi Egyetem (Hungary), Universidad Politecnica de Madrid (Spain), Hafencity Universität Hamburg (Germany), Pln Foundation (Belgium), Icomos-Consiglio Italiano dei Monumenti e dei Siti (Italy), TU Delft (the Netherlands), Universidade do Minho (Portugal), Università degli Studi di Roma La Sapienza (Italy), Politecnico di Torino (Italy).

Conservation of Historic Concrete Structures (2020-2022)

A research project developed by the Department of Conservation of the University of Gothenburg and financed by the Swedish National Heritage Board. The project's results are presented in the anthology "Betong" (Concrete), published in 2022 in Swedish. It conveys up-to-date research and concrete guidance in matters relating to the care and maintenance of historic concrete structures. Divided into nine chapters, it covers the material's composition and background, its architectural and constructive properties, the most common examination methods and damage, as well as proven methods for renovating, restoring and conserving.

Coordinator: Department of Conservation – University of Gothenburg

Partners: Swedish National Heritage Board

CONSECH20 (2019-2022)

"CONSErvation of 20th-century concrete Cultural Heritage in urban changing environments" was a European project supported by the JPI CH Heritage in Changing Environments programme. The goal of CONSECH20 was to develop innovative approaches for conserving and protecting 20th-century concrete heritage buildings against evolving urban impacts, considering both technical and social aspects. CONSECH20 focused on urban contexts with divergent geographical, cultural, political and economic features. Case studies in Cyprus, the Czech Republic, Italy and The Netherlands were selected. The aim was to gather a representative selection of architectural styles, materials, structural systems, conservation state, social relevance, etc. Public, municipal and state-owned buildings with social interest, mostly built until 1960, were primarily considered. A total of 48 buildings were surveyed during the project, and all of the information gathered can be found in the CONSECH20 Database.

Coordinator: Institute of Theoretical and Applied Mechanics of the Czech Academy of Sciences

Partners: Institute of Sociology of the National Academy of Sciences of Belarus, University of Cyprus, University of Genova, TU Delft.

INNOVAConcrete (2018-2021)

A research project funded by the European Union's Horizon 2020 research and innovation programme aimed at developing innovative solutions for conserving 20th-century concrete-based cultural heritage. One of the research outcomes was the "100 from the 20th selection", a selection of 100 relevant examples of 20th-century concrete buildings that span the 28 European Union countries. The most important results obtained with the evolution of this web platform are: a public website to present a strong scientific background for the architectural community where they can find information on several topics such as knowledge, heritage, experts, research, evaluation and maintenance guidelines and other tools and resources; replace a manual process with a web form-based process to evaluate concrete-based cultural heritage. Another fundamental outcome of the research is *The Cádiz Document, InnovaConcrete Guidelines for the Conservation of Concrete Heritage*, which provides guidance for the conservation of concrete heritage with respect to its cultural, historical, aesthetic, social and technological values that define its significance. The document is particularly devoted to conservation and restoration practitioners and other professionals.

Coordinator: Universidad de Cadiz, Spain

Main partners: Consiglio Nazionale delle Ricerche (Italy), Agencia Estatal Consejo Superior de Investigaciones Cientificas (Spain), Polytechneio Kritis (Greece), Fundacion Tecnalia Research & Innovation (Spain), Rina Consulting Spa (Italy), Ministero Della Cultura (Italy), Technische Universiteit Delft (Netherlands), Technische Universitat Darmstadt (Germany), Consorzio Interuniversitario per lo Sviluppo dei Sistemi a Grande Interfase (Italy), Studiecentrum voor Kernenergie / Centre d'Etude de l'Energie Nucleaire (Belgium), Conseil International des Monuments et des Sites Association (France), Viomichanikis Erevnas Technologikisanaptyxis Ergastiriakon Dokimon Pistopiisis Kai Piotitas Ae (Greece), Ionvac Process Srl (Italy), Nanotecmarin Gmbh (Germany).

MonumentenKennis (2015-2023)

MonumentenKennis (Building Conservation Knowledge) is a cooperation project from partners in the Netherlands and Flanders. The aim of the project was twofold: to develop and to transfer knowledge on building conservation, with a focus on historic materials. Knowledge development and transfer occurred mainly via the MDCS Monument Diagnosis and Conservation System, with its damage atlases (both in English and Dutch) freely available online. One of these atlases is fully devoted to concrete, divided into damage to concrete and reinforcement. This a resource for identifying, categorising and understanding different types of damage that can occur to concrete buildings. It serves as a guide for preservation and restoration efforts by offering detailed descriptions and visual examples of various types of structural and surface damage.

Main partners: The Netherlands Heritage Organisation (RCE), TU Delft, Netherlands Organisation for Applied Scientific Research (TNO) and KU Leuven.

Redmonest (2014-2016)

European screening on the conservation state of concrete buildings in Spain, France and Belgium, founded with the JPI CH Heritage in Changing Environments programme. The project's main objective was to develop a real-time management system to evaluate the corrosion process of ancient concrete exposed to natural ageing (including several weathering mechanisms, such as carbonation and chloride-induced corrosion, as well as climate impact). The system has been the basis of Early Warning Systems (EWS) for the particular application of ancient concrete. The EWS were the essential tools for handling the natural and social threats that affect the protection of tangible heritage.

Coordinator: Eduardo Torroja Institute for Construction Science (Spain)

Main Partners: Laboratoire de Recherche des Monuments Historiques (France), ELab Scientific srl - CNR (Italy), Istituto per la Conservatione la Valorizzazione dei Bei Culturali - CNR (Italy), Centre Scientifique et Technique de la Construction (Belgium), University of Liège - Département ArGEnCo (Belgium).

B.3 INTERNATIONAL CHARTERS AND DOCUMENTS

List of international charters and documents focused on the conservation of historical concrete and, more broadly, on the preservation of "modern" architecture, only selected where there is a specific reference to architectural heritage in concrete. Listed in chronological order, from the newest to the oldest.

ICOMOS International Committee on Twentieth Century Heritage. 2021. *The Cádiz document: InnovaConcrete guidelines for conservation of concrete heritage. Project Report.* ICOMOS International, Charenton-le-Pont, France. https://isc20c.icomos.org/policy_items/complete-innovaconcrete/

ICOMOS International Scientific Committee on Twentieth Century Heritage. 2017. *Approaches to the Conservation of Twentieth - Century Cultural Heritage: Madrid - New Delhi Document.* https://openarchive.icomos.org/id/eprint/2682/1/MNDD_ENGLISH.pdf

B.4 STUDIES AND RESEARCH

Catalogue of academic publications specifically focused on the conservation of architectural heritage in concrete, categorised into thematic macro-groups:

- general framework (publications on the understanding of interventions in historical architectural heritage in concrete),
- deterioration mechanisms (exploring material degradation mechanisms),
- diagnostic techniques (methods for assessing the condition of historic concrete),
- approaches to conservation (specific approaches to interventions in historic concrete heritage, including guidelines and conservation and management plans),
- specialist congress-series (sequential congresses exclusively dedicated to interventions on existing concrete, with a primary emphasis on material repair),
- intervention techniques (addressing specific methods for repair or conservation of historic concrete, focusing on material integrity).

This appendix encompasses various formats such as books, articles, journals, conference proceedings, training day outcomes, guides, case studies, reports, conservation and management plans and dossiers. The publications are listed in chronological order, from the newest to the oldest.

B.4.1 General framework

Somer, Kees, and Ronald Stenvert. 2024. Bouwmaterialen 1940-1990, Nai010.

Georgiou, Antroula, and Ioannis Ioannou. 2021. "State of the Art on European Regulations concerning fire, seismic stability, energy efficiency and environmental comfort, used as directives for preparing conservation proposals". Consech20 Reports, Working Package 4.

Musso, Stefano F., Giovanna Franco, Rita Vecchiattini, and Federica Pompejano. 2021. "Open Access Transdisciplinary Online Platform Multimedia database and site – Manual". Consech20 Reports, Working Package 3.

Pardo Redondo, Gabriel, Giovanna Franco, Antroula Georgiou, Ioannis Ioannou, Barbara Lubelli, Stefano F. Musso, Silvia Naldini, Cristiana Nunes, and Rita Vecchiattini. 2021. "State of Conservation of Concrete Heritage Buildings: A European Screening". Infrastructures 6(8): 109.

Pardo Redondo, Gabriel, S. Naldini, and B. Lubelli. 2021. "Decay Patterns and Damaging Processes of historic Concrete: A Survey in the Netherlands". P. Roca, L. Pelà, and C. Molins (Eds), Proceedings of the XII International Conference on Structural Analysis of Historical Constructions (SAHC), Barcelona, 29 Sept. – 1 Oct. 2021: 105-116.

Campagna, Barbara A. 2020. "Redefining Brutalism." APT Bulletin: The Journal of Preservation Technology, 51(1): 25–36.

Dusek, Ondrej, and Cristiana Lara Nunes. 2020. "Concrete Heritage Protection in the Czech Republic. Conservation and re-use: actors, tasks and approach". Consech20 Report, Working package 1.

Hadji, Michael, Antroula Georgiou, and Ioannis Ioannou. 2020. "Historic concrete buildings in the Republic of Cyprus, conservationa and re-use: actors, tasks and approach." Consech20 Report, Working package 1.

Musso, Stefano F., Giovanna Franco, Rita Vecchiattini, and Federica Pompejano. 2020. "Historic concrete buildings in Italy, Conservation and re-use: actors, tasks and approach". Consech20 Report, Working package 1.

Musso, Stefano F., Giovanna Franco, Rita Vecchiattini, and Federica Pompejano. 2020. "List of DBMS on modern architecture." Consech20 Reports, Working Package 3.

Naldini, Silvia, Gabriel Pardo Redondo, and Barbara Lubelli. 2020. "Historic concrete buildings in Netherlands, Conservation and re-use: actors, tasks and approach". Consech20 Report, Working package 1.

Conservation of concrete. Conservation Perspectives, GCI Newsletter, 34(2), 2019.

Béton(s). Restaurer le Bétons. La Masse et l'Épiderme. Seminaire et colloque internationaux, 23-24 novembre 2017. Cahier icomos France 29, 2018.

Special Issue on Concrete. APT Bulletin: The Journal of Preservation Technology, 48(1), 2017.

Forty, Adrian. 2016. Concrete and Culture: A Material History. London: Reaktion Books Ltd.

Blanchard, Romain, Myriam Bouichou, Teddy Congar and Elisabeth Marie-Victoire. 2015. "Concrete cultural heritage in France. Inventory and state of conservation", in AA.VV. (Eds.), Concrete repair, rehabilitation and retrofitting IV, Leipzig, DE: 343-350.

Custance-Baker, Alice, Gina Crevello, Susan Macdonald, and Kyle Normandin. 2015. Conserving Concrete Heritage: An Annotated Bibliography. Los Angeles: Getty Conservation Institute.

Marie-Victoire, Elisabeth, and Myriam Bouichou. 2014-2017. REDMONEST: Monitoring Dynamic Network for Existing Structures of Concrete Cultural Heritage. Instituto Eduardo Torroja de la Construcción y del Cemento, Centre Scientifique et Technique de la Construction. Université de Liège: Cercle des partenaires du patrimoine.

Jester, Thomas C. 2014. Twentieth-Century Building Materials: History and Conservation. Los Angeles: Getty Conservation Institute.

Piferi, Claudio. 2014. "Il ripristino architettonico dei paramenti in calcestruzzo a vista: lo Unity Temple di Wright-Oak Park (Illinois)". Catalano, A. and Sansone, C. (Eds.). Progetto e tecnologia per il costruito. Galazzano: Imready. 245-255.

Custance-Baker, Alice, and Susan Macdonald. 2015. Conserving Concrete Heritage Experts Meeting: the Getty Center, Los Angeles, California, June 9–11, 2014. Los Angeles: Getty Conservation Institute.

Vanlaethem, France, James Ashby, and Andrew Waldron. 2008. Le Patrimoine Moderne au Canada. Docomomo International.

Hermans, Taco, Michiel van Hunen, and Huub van de Ven. 2006. Monumenten in Beton, ontwikkeling en herstel van historisch beton. Artikelen voor het Betonsymposium op 11 oktober 2006 in het Groot Handelsgebouw te Rotterdam. Rijksdienst voor Archeologie, Cultuurlandschap en Monumenten.

Béton armé: Expérimentation, Création, Réhabilitation. Paris: Docomomo International, 2003.

Exposed concrete. DOCOMOMO Journal 17, 1997. https://doi.org/10.52200/docomomo.17

B.4.2 Deterioration Mechanisms of Historic Concrete

Dimova, Silvia, Cristina Silvia Polo López, and Maria Luisa Sousa (ed). 2024. Impact of climate change on the corrosion of the European reinforced concrete building stock. Luxembourg: Publications Office of the European Union.

Damage Atlas: Concrete. 2023. MDCS - Monument Diagnosis and Conservation System: Project by TNO, TU Delft and the Dutch Rijksdienst voor het Cultureel Erfgoed. https://mdcs.monumentenkennis.nl/damageatlas/7/material

Courard, Luc, Zengfeng Zhao, and Frédéric Michel. 2020. "Influence of hydrophobic product nature and concentration on carbonation resistance of cultural heritage concrete buildings." Cement and Concrete composites. 115.

Mays, Geoff C. 2019. Durability of concrete structures: investigation, repair, protection. CRC Press.

Felitti, Matteo, and Lucia Rosaria Mecca. 2018. Il degrado delle strutture in calcestruzzo armato: diagnosi, monitoraggio e soluzioni per il recupero. Santarcangelo di Romagna: Maggioli.

Coppola, Luigi, and Alessandra Buoso. 2015. Il restauro dell'architettura moderna in cemento armato. Milan: Hoepli.

Coppola, Luigi, Alessandra Buoso, and Attilio Pizzigoni. 2015. Il restauro dell'architettura moderna in cemento armato: Alterazione e dissesto delle strutture in c.a., diagnostica, interventi di manutenzione e adeguamento antisismico, materiali, tecniche e cantieristica. Milano: Hoepli.

Griffin, Isobel. 2013. Deterioration mechanisms of historic cement renders and concrete. PhD, University of Edinburgh.

Di Biase, Carolina. 2009. Il degrado del calcestruzzo nell'architettura del Novecento. Santarcangelo di Romagna: Maggioli.

Bruschi, Greta, Paolo Faccio, Sergio Pratali Maffei, and Paola Scaramazza. 2005. Il calcestruzzo nelle architetture di Carlo Scarpa: Forme, alterazioni, interventi. Bologna: Compositori.

Rijksdienst voor de Monumentenzorg. 2004. "Beton Schade en analyse". Info, Restauratie en beheer, 40: 1-8.

Pedeferri, Pietro, and Luca Bertolini. 2000. La durabilità del calcestruzzo armato. Milano: McGraw-Hill libri Italia.

Marie-Victoire, Élisabeth. 1996. Les altérations visibles du béton: Définitions et aide au diagnostic. Champs-sur-Marne: Cercle des partenaires du patrimoine.

B.4.3 Diagnostic Techniques

Boccacci, Giulia, Francesca Frasca, Chiara Bertolin and Anna Maria Siani. 2024. "Diagnosis of Historic Reinforced Concrete Buildings: A Literature Review of Non-Destructive Testing (NDT) Techniques". Procedia Structural Integrity. 55: 160-167.

Mendoza, M., Esponda, M., Muciño-Vélez, A., Leal-Menegus, A., Del Cueto Ruiz-Funes, J. I., and Ruiz-Gómez, N. C. 2023. "Digital tools and technologies in the preservation of historic concrete shells." Proceedings of IASS Annual Symposia. 14: 1-12. International Association for Shell and Spatial Structures (IASS).

Georgiou, Antroula, Maria M. Hadjimichael, and Ioannis Ioannou. 2021. "Conservation of 20th Century Concrete Heritage Structures in Cyprus: Research and Practice". P. Roca, L. Pelà and C. Molins (ed). Proceedings of the XII International Conference on Structural Analysis of Historical Constructions (SAHC), Barcelona, 29 Sept. – 1 Oct. 2021:82-93.

Fan, Liang, and Yi Bao 2021. "Review of fiber optic sensors for corrosion monitoring in reinforced concrete". Cement and Concrete Composites. 120 (7):104029.

Pardo Redondo, Gabriel, and Silvia Naldini. 2021. "Merged Report on In-Depth Case Studies." Consech20 Reports, Working Package 2.

Khadra, Mahdi, Elisabeth Marie-Victoire, Myriam Bouichou, Christian Crémona, and Stéphanie Vildaer. 2019. "New warning sensors to detect corrosion risk in reinforced concrete". MATEC Web of Conferences, Concrete Solutions 2019 – 7th International Conference on Concrete Repair, 289.

Pardo Redondo, Gabriel, Barbara Lubelli, and Silvia Naldini. 2019. "State of the Art Report on new technologies to monitor, conserve and restore the materiality of modern buildings in a compatible, durable and sustainable way." Consech20 Reports, Working Package 2 – Task (i).

Bouichou, Myriam, Elisabeth Marie-Victoire, Héloïse Jourdan, Benoit Thauvin, Ronan Queguigner, Roberto Olmi, and Cristiano Riminesi. 2018. "Measurement of water content and salinity index in concrete by evanescent field dielectrometry." Journal of Cultural Heritage, 34(2).

Bungey, John H., and Michael G. Grantham. 2018. Testing of concrete in structures. 4th ed. London: CRC Press.

Gilmore, Alice Louise, and Frank Matero. 2018. "Performance Testing of Acid Stains on Historic Concrete." APT Bulletin: The Journal of Preservation Technology, 49(4): 5–15.

Harrer, Ann, and Paul Gaudette. 2017. "Practice Points 16: Assessment of Historic Concrete Structures." APT Bulletin: The Journal of Preservation Technology, 48(4):29–36.

Jinrui, Zhang, Liu Chao, Sun Ming, and Li Zongjin. 2017. "An innovative corrosion evaluation technique for reinforced concrete structures using magnetic sensors". Construction and Building Materials, 135:68-75.

Riminesi, Cristiano, Elisabeth Marie-Victoire, Myriam Bouichou, and Riccardo Olmi. 2017. "Diagnostics and monitoring of moisture and salt in porous materials by evanescent field dielectrometry." Steffen Laue cur. Proceedings of SWBSS 2017, Potsdam, 20-22 Settembre 2017. Potsdam: Verlag der Fachhochschule Potsdam: 49-56.

Lollini, Federica, Elena Redaelli, and Luca Bertolini. 2016. "Corrosion assessment of reinforced concrete elements of Torre Velasca in Milan, Case Studies". Construction Materials, 4: 55-61.

Buchner, Laura N., and Raymond M. Pepi. 2015. "Restoration of the Cast-in-Place Concrete at the New York Hall of Science." APT Bulletin: The Journal of Preservation Technology, 46(2/3): 54-63.

Crevello, Gina. 2015. "Data Interpretation and Early Corrosion Test Program for Historic Concrete Buildings." APT Bulletin: The Journal of Preservation Technology, 46(1): 1–8.

Morabito, Giovanni, and Stefano Podestà. 2015. Edifici storici in conglomerato cementizio armato: vulnerabilità e verifica sismica, Flaccovio, Palermo.

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B.4.4 Approaches to the Conservation of Historic Concrete

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B.4.4.1 Conservation and Management Plans

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LDN Architects. The Hill House: Research and Development Project. Keeping it Modern grant, Getty Foundation, 2022.

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Fondazione Politecnico di Milano. The National Schools of Art of Cuba Conservation Management Plan. Keeping it Modern grant, Getty Foundation, 2020.

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Highland Green Foundation Inc. First Presbyterian Church of Stamford, CT: Conservation Management Plan. Keeping it Modern grant, Getty Foundation, 2020.

PEC University of Technology, Chandigarh. Conservation Management Plan for Government Museum and Art Gallery Chandigarh. Keeping it Modern grant, Getty Foundation, 2020.

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B.4.5 Conferences

Listed are those conference cycles exclusively dedicated to concrete, particularly focusing on interventions on existing buildings. For this reason, conferences that are of great importance to the field of historical built heritage conservation, such as ICCH (International Congress on Construction History), IDC (International DOCOMOMO Conference), or SAHC (Structural Analysis of Historic Constructions), have not been included.

CONCREEP

Focusing on creep, shrinkage and durability of concrete, the Concreep series of conferences is organised by IA-CONCREEP, International Association of Concrete Creep. The aim of the conference series is to meet the needs of a growing community of researchers and scientists in the concrete sector.

Past conferences: 1958 Munich (Germany), 1968 Munich (Germany), 1978 Leeds (United Kingdom), 1986 Northwestern University, Evanston (USA), 1993 Technical University of Catalonia, Barcelona (Spain), 2001 Massachusetts Institute of Technology, Cambridge (USA), 2005 Ecole Centrale de Nantes (France), 2008 Ise-Shima (Japan), 2013 Massachusetts Institute of Technology, Cambridge (USA), 2015 Vienna University of Technology, Vienna (Austria), 2020 Northwestern University, Evanston (USA), 2024 TU Delft, Delft (Netherland). No proceedings available online.

CONCRETE: Architecture and Technique

The "CONCRETE - Architecture and Technique" congress series is an international conference focusing on the field of historical concrete conservation. Organised by Università degli Studi del Molise with Concrete Project, the series addresses various themes, including material history, technology, building process, materials and recovery, with a particular structural point of view. The conferences bring together researchers, practitioners and professionals to exchange ideas and discuss technologies, methodologies and materials that enhance the durability, sustainability and performance of concrete conservation practice.

Past conferences: Catalano, Agostino, and Camilla Sansone (ed.). 2009. The building techniques: 1. international congress: technological development of concrete: tradition, actualities, prospects. Napoli: Luciano. Venue: Termoli (Italy)

Catalano, Agostino, and Camilla Sansone (ed.). 2012. Il calcestruzzo per l'edilizia del nuovo millennio. Progetto e tecnologia per il costruito: atti 2. Congresso internazionale concrete, Campobasso. Ripalimosani: AGR. Venue: Termoli (Italy)

Catalano, Agostino, and Camilla Sansone (ed). 2014. Progetto e tecnologia per il costruito tra il 20 e 21 secolo, atti 3. Congresso internazionale concrete2014, Termoli, 25 e 26 settembre. Galazzano: IMREADY (RSM). Venue: Termoli (Italy)

2016 Termoli (Italy), no proceedings available on line

2018 Termoli (Italy), no proceedings available on line

La Mantiam, E. (ed). 2022. Atti del Convegno CONCRETE2021. Criteri di manutenzione degli edifici esistenti e di nuova progettazione nel XXI secolo, Venezia, 11-12 marzo 2022. UniMol. Venue: Venezia Mestre (Italy)

International Conference on Concrete Repair, Rehabilitation and Retrofitting (ICCRRR)

Conference series organised by the South African Research Programme in Concrete Materials (based at the Universities of Cape Town and The Witwatersrand) and the Material Science Group at Leipzig University and The Leipzig Institute for Materials Research and Testing (MFPA) in Germany. Conferences focussing on the repair, rehabilitation and retrofitting of concrete structures, particularly on instrastructure. They are a platform for researchers, engineers, practitioners and professionals from academia and industry to exchange knowledge, present research findings, discuss challenges and explore solutions related to concrete repair and maintenance.

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Concrete solutions - International Conference on Concrete Repair, Durability and Technology

The Concrete Solutions Conference series is a British, Italian and French joint venture comprising GR Technologie Ltd. of the UK, the University of Padova, Italy (Galileo's University) and INSA Rennes, France. The conference is co-sponsored by the ACI and supported by the UK's Concrete Society, the Institute of Concrete Technology, and the Corrosion Prevention Association.

Past conferences: 2003 Saint-Malo (France), no proceedings available online

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B.4.6 Intervention Techniques

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B.5 INDUSTRY STANDARDS

Maintenance and conservation of buildings are often bound to legal conditions that refer to compliance with standards and codes. These standards and codes are collected in this appendix, together with guidelines and other specific documents regarding conditions under which maintenance and conservation should take place. The focus lies on the European/ international context, leaving out the many national examples.

B.5.1 Diagnostic Techniques

B.5.1.1 Guide and Guidelines, Reports and Codes

2022 ICRI 210.3R-2022 - Guide for Using In-Situ Tensile Pulloff Tests to Evaluate Concrete Surface Repairs and Bonded Overlays

2021 ACI 562-21 - Assessment, Repair, and Rehabilitation of Existing Concrete Structures - Code and Commentary (ACI CODE-562-21)

2021 562MAN-20 - Guide to the Code for Assessment, Repair, and Rehabilitation of Existing Concrete Structures

2021 210.4R-2021 - Guide for Non-destructive Evaluation Methods for Condition Assessment, Repair, and Performance Monitoring of Concrete Structures

2019 ACI PRC-364.1-19: Guide for Assessment of Concrete Structures Before Rehabilitation

B.5.1.2 Standards

2023 EN 12390-19:2023 - Testing of hardened concrete - Part 19: Determination of electrical resistivity

2021 EN 12504-2:2021 - Testing concrete in structures - Part 2: Non-destructive testing - Determination of rebound number

2021 ISO 16711:2021 - ISO 22040:2021 - Life cycle management of concrete structures

2021 ISO 16711:2021 - Requirements for seismic assessment and retrofit of concrete structures

2021 EN 12390-18:2021 - Testing hardened concrete - Part 18: Determination of the chloride migration coefficient

2020 EN 12390-12:2020 - Testing hardened concrete - Part 12: Determination of the carbonation resistance of concrete - Accelerated carbonation method

2019 EN 12390-8:2019 - Testing hardened concrete - Part 8: Depth of penetration of water under pressure

2019 ISO 16836:2019 - Non-destructive testing — Acoustic emission testing — Measurement method for acoustic emission signals in concrete

2019 ISO 16837:2019 - Non-destructive testing — Acoustic emission testing — Test method for damage qualification of reinforced concrete beams

2019 ISO 16838:2019 - Non-destructive testing — Acoustic emission testing — Test method for classification of active cracks in concrete structures

2018 EN 12390-10:2018 - Testing hardened concrete - Part 10: Determination of the carbonation resistance of concrete at atmospheric levels of carbon dioxide

2015 EN 12390-11:2015 - Testing hardened concrete - Part 11: Determination of the chloride resistance of concrete, unidirectional diffusion

2014 ISO 16311-2:2014 - Maintenance and repair of concrete structures — Part 2: Assessment of existing concrete structures

2011 EN 772-11:2011 - Methods of test for masonry units - Part 11: Determination of water absorption of aggregate concrete, autoclaved aerated concrete, manufactured stone and natural stone masonry units due to capillary action and the initial rate of water absorption of clay masonry units

2010 EN 15304:2010 - Determination of the freeze-thaw resistance of autoclaved aerated concrete

2009 EN 480-10:2009 - Admixtures for concrete, mortar and grout - Test methods - Part 10: Determination of water soluble chloride content

2008 EN 1504-9:2008 - Products and systems for the protection and repair of concrete structures - Definitions, requirements, quality control and evaluation of conformity - Part 9: General principles for the use of products and systems

2007 EN 13577:2007 - Chemical attack on concrete - Determination of aggressive carbon dioxide content in water

2007 EN 15361:2007 - Determination of the influence of the corrosion protection coating on the anchorage capacity of the transverse anchorage bars in prefabricated reinforced components of autoclaved aerated concrete

2007 EN 1367-1:2007 - Tests for thermal and weathering properties of aggregates - Part 1: Determination of resistance to freezing and thawing

2006 EN 480-14:2006 - Admixtures for concrete, mortar and grout - Test methods - Part 14: Determination of the effect on corrosion susceptibility of reinforcing steel by potentiostatic electro-chemical test

2005 EN 480-12:2005 - Admixtures for concrete, mortar and grout - Test methods - Part 12: Determination of the alkali content of admixtures

2005 EN 480-5:2005 - Admixtures for concrete, mortar and grout - Test methods - Part 5: Determination of capillary absorption

2002 EN 990:2002 - Test methods for verification of corrosion protection of reinforcement in autoclaved aerated concrete and lightweight aggregate concrete with open structure

1999 EN 1767:1999 - Products and systems for the protection and repair of concrete structures - Test methods - Infrared analysis

1999 EN 772-10:1999 - Methods of test for masonry units - Part 10: Determination of moisture content of calcium silicate and autoclaved aerated concrete units

1997 CR 12793:1997 - Measurement of the carbonation depth of hardened concrete

1997 EN 1170-6:1997 - Precast concrete products - Test method for glass-fibre reinforced cement - Part 6: Determination of the absorption of water by immersion and determination of the dry density

B.5.2 Intervention Techniques

B.5.2.1 Guide and Guidelines

2023 ICRI 210.5-2023 - Guide for Selecting and Specifying Reinforcing Bar Cleaning Levels

2022 ICRI 320.3R Cementitious Repair Material Data Sheet - Guide

2022 ACI PRC-364.3-22: Cementitious Repair Material Data Sheet - Guide

2021 ICRI 110.3-2021 Guide Specifications for Cementitious Bonded Overlay

2020 ICRI 110.2-2020 - Guide Specifications for Epoxy Injection

2020 ACI PRC-549.6-20: Guide to Design and Construction of Externally Bonded Fabric-Reinforced Cementitious Matrix (FRCM) and Steel-Reinforced Grout (SRG) Systems for Repair and Strengthening Masonry Structures

2020 ACI PRC-546.2-20: Guide to Underwater Repair of Concrete

2019 ICRI 320.1R-2019 - Guide/Guideline for Selecting Application Methods for the Repair of Concrete Surfaces

2019 ICRI 510.2-2019 - Guide for Use of Penetrating Surface Applied Corrosion Inhibitors for Corrosion Mitigation of Reinforced Concrete Structures

2018 ACI 563-18 - Specifications for Repair of Concrete in Buildings

2018 ICRI 320.2R-2018 - Guide for Selecting and Specifying Materials for Repair of Concrete Surfaces

2016 110.1-2016 - Guide Specifications for Structural Concrete Repair: Section 030130

2016 ICRI 330.2-2016 - Guide Specifications for Externally Bonded FRP Fabric Systems for Strengthening Concrete Structures

2016 ICRI 210.1R-2016 - Guideline for Verifying Field Performance of Epoxy Injection of Concrete Cracks

2014 ACI PRC-546.3-14 Guide to Materials Selection for Concrete Repair

2014 ICRI 320.5R-2014 - Pictorial Atlas of Concrete Repair Equipment

2013 ICRI 510.1-2013 - Guide for Electrochemical Techniques to Mitigate the Corrosion of Steel for Reinforced Concrete Structures

2012 ICRI 320.6-2012 - Evaluation and Repair of Unbonded Post-Tensioned Concrete Structures

2007 ACI PRC-224.1-07 Causes, Evaluation, and Repair of Cracks in Concrete Structures

2005 ACI PRC-309-05: Guide for Consolidation of Concrete

B.5.2.2 Standards

2022 ISO 18319-2:2022 - Fibre reinforced polymer (FRP) reinforcement for concrete structures — Part 2: Specifications of CFRP strips

2020 EN 14038-2:2020 - Electrochemical realkalization and chloride extraction treatments for reinforced concrete - Part 2: Chloride extraction

2017 EN 1766:2017 - Products and systems for the protection and repair of concrete structures - Test methods - Reference concretes for testing

2017 EN 1504-10:2017 - Products and systems for the protection and repair of concrete structures - Definitions, requirements, quality control and evaluation of conformity - Part 10: Site application of products and systems and quality control of the works

2015 ISO 18319:2015 - Fibre-reinforced polymer (FRP) reinforcement for concrete structures — Specifications of FRP sheets

2016 EN 1504-8:2016 - Products and systems for the protection and repair of concrete structures - Definitions, requirements, quality control and AVCP - Part 8: Quality control and Assessment and verification of the constancy of performance (AVCP)

2016 EN 14038-1:2016 - Electrochemical realkalization and chloride extraction treatments for reinforced concrete - Part 1: Realkalization

2014 ISO 16311-4:2014 - Maintenance and repair of concrete structures — Part 4: Execution of repairs and prevention

2014 ISO 16311-3:2014 - Maintenance and repair of concrete structures — Part 3: Design of repairs and prevention

2013 EN 1504-5:2013 - Products and systems for the protection and repair of concrete structures - Definitions, requirements, quality control and evaluation of conformity - Part 5: Concrete injection

2007 EN 14629:2007 - Products and systems for the protection and repair of concrete structures - Test methods - Determination of chloride content in hardened concrete

2006 EN 1504-6:2006 - Products and systems for the protection and repair of concrete structures - Definitions, requirements, quality control and evaluation of conformity - Part 6: Anchoring of reinforcing steel bar

2006 EN 1504-7:2006 - Products and systems for the protection and repair of concrete structures - Definitions, requirements, quality control and evaluation of conformity - Part 7: Reinforcement corrosion protection

2006 EN 13412:2006 - Products and systems for the protection and repair of concrete structures - Test methods - Determination of modulus of elasticity in compression

2006 EN 14497:2004/AC:2006 - Products and systems for the protection and repair of concrete structures - Test methods - Determination of the filtration stability

2006 EN 14630:2006 - Products and systems for the protection and repair of concrete structures - Test methods - Determination of carbonation depth in hardened concrete by the phenolphthalein method

2006 EN 15183:2006 - Products and systems for the protection and repair of concrete structures - Test methods - Corrosion protection test

2006 EN 15184:2006 - Products and systems for the protection and repair of concrete structures - Test methods - Shear adhesion of coated steel to concrete (pull-out test)

2006 EN 1544:2006 - Products and systems for the protection and repair of concrete structures - Test methods - Determination of creep under sustained tensile load for synthetic resin products (PC) for the anchoring of reinforcing bars

2006 EN 1881:2006 - Products and systems for the protection and repair of concrete structures - Test methods - Testing of anchoring products by the pull-out method

2005 EN 1504-1:2005 - Products and systems for the protection and repair of concrete structures - Definitions, requirements, quality control and evaluation of conformity - Part 1: Definitions

2005 EN 1504-3:2005 - Products and systems for the protection and repair of concrete structures - Definitions, requirements, quality control and evaluation of conformity - Part 3: Structural and non-structural repair

2005 EN 1771:2004/AC:2005 - Products and systems for the protection and repair of concrete structures - Test methods - Determination of injectability and splitting test

2004 EN 1504-2:2004 - Products and systems for the protection and repair of concrete structures - Definitions, requirements, quality control and evaluation of conformity - Part 2: Surface protection systems for concrete

2004 EN 1504-4:2004 - Products and systems for the protection and repair of concrete structures - Definitions, requirements, quality control and evaluation of conformity - Part 4: Structural bonding

2004 EN 12614:2004 - Products and systems for the protection and repair of concrete structures - Test methods - Determination of glass transition temperatures of polymers

2004 EN 12617-2:2004 - Products and systems for the protection and repair of concrete structures - Test methods - Part 2: Shrinkage of crack injection products based on polymer binder: volumetric shrinkage

2004 EN 12618-2:2004 - Products and systems for the protection and repair of concrete structures - Test methods - Part 2: Determination of the adhesion of injection products, with our without thermal cycling - Adhesion by tensile bond strength

2004 EN 12618-3:2004 - Products and systems for the protection and repair of concrete structures - Test methods - Part 3: Determination of the adhesion of injection products, with or without thermal cycling - Slant shear method

2004 EN 12637-1:2004 - Products and systems for the protection and repair of concrete structures - Test methods - Compatibility of injection products - Part 1: Compatibility with concrete

2004 EN 13295:2004 - Products and systems for the protection and repair of concrete structures - Test methods - Determination of resistance to carbonation

2004 EN 13396:2004 - Products and systems for the protection and repair of concrete structures - Test methods - Measurement of chloride ion ingress

2004 EN 14406:2004 - Products and systems for the protection and repair of concrete structures - Test methods - Determination of the expansion ratio and expansion evolution

2004 EN 14497:2004 - Products and systems for the protection and repair of concrete structures - Test methods - Determination of the filtration stability

2004 EN 14498:2004 - Products and systems for the protection and repair of concrete structures - Test methods - Volume and weight changes of injection products after air drying and water storage cycles

2004 EN 1771:2004 - Products and systems for the protection and repair of concrete structures - Test methods - Determination of injectability and splitting test

2003 EN 12617-1:2003 - Products and systems for the protection and repair of concrete structures - Test methods - Part 1: Determination of linear shrinkage for polymers and surface protection systems (SPS)

2003 EN 12618-1:2003 - Products and systems for the protection and repair of concrete structures - Test methods - Part 1: Adhesion and elongation capacity of injection products with limited ductility

2003 EN 12637-3:2003 - Products and systems for the protection and repair of concrete structures - Test methods - Compatibility of injection products - Part 3: Effect of injection products on elastomers

2003 EN 13062:2003 - Products and systems for the protection and repair of concrete structure - Test method - Determination of thixotropy of products for protection of reinforcement

2003 EN 13529:2003 - Products and systems for the protection and repair of concrete structures - Test methods - Resistance to severe chemical attack

2003 EN 13578:2003 - Products and systems for the protection and repair of concrete structure - Test Method - Compatibility on wet concrete

2003 EN 13584:2003 - Products and systems for the protection and repair of concrete structures - Test methods - Determination of creep in compression for repair products

2003 EN 13894-1:2003 - Products and systems for the protection and repair of concrete structures - Test methods - Determination of fatigue under dynamic loading - Part 1: During cure

2003 EN 14068:2003 - Products and systems for the protection and repair of concrete structures - Test methods - Determination of watertightness of injected cracks without movement in concrete

2002 EN 13579:2002 - Products and systems for the protection and repair of concrete structures - Test methods - Drying test for hydrophobic impregnation

2002 EN 13580:2002 - Products and systems for the protection and repair of concrete structures - Test Methods - Water absorption and resistance to alkali for hydrophobic impregnations

2002 EN 13581:2002 - Products and systems for the protection and repair of concrete structures - Test method - Determination of loss of mass of hydrophobic impregnated concrete after freeze-thaw salt stress

2002 EN 13687-1:2002 - Products and systems for the protection and repair of concrete structures - Test methods - Determination of thermal compatibility - Part 1: Freeze-thaw cycling with de-icing salt immersion

2002 EN 13687-2:2002 - Products and systems for the protection and repair of concrete structures - Test methods - Determination of thermal compatibility - Part 2: Thunder-shower cycling (thermal shock)

2002 EN 13687-3:2002 - Products and systems for the protection and repair of concrete structures - Test methods - Determination of thermal compatibility - Part 3: Thermal cycling without de-icing salt impact

2002 EN 13687-4:2002 - Products and systems for the protection and repair of concrete structures - Test methods - Determination of thermal compatibility - Part 4: Dry thermal cycling

2002 EN 13687-5:2002 - Products and systems for the protection and repair of concrete structures - Test methods - Determination of thermal compatibility - Part 5: Resistance to temperature shock

2002 EN 13733:2002 - Products and systems for the protection and repair of concrete structures - Tests methods - Determination of the durability of structural bonding agents

2002 EN 13894-2:2002 - Products and systems for the protection and repair of concrete structures - Test methods - Determination of fatigue under dynamic loading - Part 2: After hardening

2002 EN 12192-1:2002 - Products and systems for the protection and repair of concrete structures - Granulometry analysis - Part 1: Test method for dry components of pre-mixed mortar

2002 EN 12617-3:2002 - Products and systems for the protection and repair of concrete structures - Test methods - Part 3: Determination of early age linear shrinkage for structural bonding agents

2002 EN 12617-4:2002 - Products and systems for the protection and repair of concrete structures - Test methods - Part 4: Determination of shrinkage and expansion

2002 EN 13057:2002 - Products and systems for the protection and repair of concrete structures - Test methods - Determination of resistance of capillary absorption

2002 EN 13294:2002 - Products and systems for the protection and repair of concrete structures - Test methods - Determination of stiffening time

2002 EN 13395-1:2002 - Products and systems for the protection and repair of concrete structures - Test methods - Determination of workability - Part 1: Test for flow of thixotropic mortars

2002 EN 13395-2:2002 - Products and systems for the protection and repair of concrete structures - Test methods - Determination of workability - Part 2: Test for flow of grout or mortar

2002 EN 13395-3:2002 - Products and systems for the protection and repair of concrete structures - Test methods - Determination of workability - Part 3: Test for flow of repair concrete

2002 EN 13395-4:2002 - Products and systems for the protection and repair of concrete structures - Test methods - Determination of workability - Part 4: Application of repair mortar overhead

2000 EN 1877-1:2000 - Products and systems for the protection and repair of concrete structures - Test methods - Reactive functions related to epoxy resins - Part 1: Determination of epoxy equivalent

2000 EN 1877-2:2000 - Products and systems for the protection and repair of concrete structures - Test methods - Reactive functions related to epoxy resins - Part 2: Determination of amine functions using the total basicity number

1999 EN 12188:1999 - Products and systems for the protection and repair of concrete structures - Test methods - Determination of adhesion steel-to-steel for characterisation of structural bonding agents

1999 EN 12189:1999 - Products and systems for the protection and repair of concrete structures - Test methods - Determination of open time

1999 EN 12192-2:1999 - Products and systems for the protection and repair of concrete structures - Granulometry analysis - Part 2: Test method for fillers for polymer bonding agents

1999 EN 12615:1999 - Products and systems for the protection and repair of concrete structures - Test methods - Determination of slant shear strength

1999 EN 12636:1999 - Products and systems for the protection and repair of concrete structures - Test methods - Determination of adhesion concrete to concrete

1999 EN 1542:1999 - Products and systems for the protection and repair of concrete structures - Test methods - Measurement of bond strength by pull-off

1998 EN 12190:1998 - Products and systems for the protection and repair of concrete structures - Test methods - Determination of compressive strength of repair mortar

1998 EN 1543:1998 - Products and systems for the protection and repair of concrete structures - Test methods - Determination of tensile strength development for polymers

1998 EN 1770:1998 - Products and systems for the protection and repair of concrete structures - Test methods - Determination of the coefficient of thermal expansion

1998 EN 1799:1998 - Products and systems for the protection and repair of concrete structures - Test methods - Tests to measure the suitability of structural bonding agents for application to concrete surface

B.5.2.3 Technical Notes, Reports and Specifications

2023 ISO/TS 16774-2:2023 - Test methods for repair materials for water-leakage cracks in underground concrete structures — Part 2: Test method for chemical resistance

2023 ISO/TS 16774-3:2023 - Test methods for repair materials for water-leakage cracks in underground concrete structures — Part 3: Test method for water (wash out) resistance

2023 ISO/TS 16774-4:2023 - Test methods for repair materials for water-leakage cracks in underground concrete structures — Part 4: Test method for adhesion on wet concrete surface

2022 CEN/TR 17172:2022 - Validation testing program on chloride penetration and carbonation standardized test methods

2020 ISO/TR 16475:2020 - General practices for the repair of water-leakage cracks in concrete structures

2019 CEN/TR 17310:2019 - Carbonation and CO2 uptake in concrete

2018 ACI PRC-364.16-18: TechNote: Physical Properties and Characteristics Affecting the Sensitivity to Cracking of Cementitious Repair Materials

2017 ISO/TS 16774-1:2017 - Test methods for repair materials for water-leakage cracks in underground concrete structures — Part 1: Test method for thermal stability

2017 ISO/TS 16774-5:2017 - Test methods for repair materials for water-leakage cracks in underground concrete structures — Part 5: Test method for watertightness

2017 ISO/TS 16774-6:2017 - Test methods for repair materials for water-leakage cracks in underground concrete structures — Part 6: Test method for response to the substrate movement

2015 ACI PRC-364.13-15: TechNote: Repair for Reinforcement with Shallow Cover

2015 ACI PRC-364.11-15: TechNote: Managing Alkali-Aggregate Reaction Expansion in Mass Concrete

2015 ACI PRC-364.3-15 Treatment of Exposed Epoxy-Coated Reinforcement in Repair Technote

2012 CEN/TR 16349:2012 - Framework for a specification on the avoidance of a damaging Alkali-Silica Reaction (ASR) in concrete

The CONCRETO Code Book presents a comprehensive study of the current state of skills, knowledge, and best practices in the conservation of historic concrete architecture. Although it is impossible to assess how much concrete is used in European buildings, in light of the data presented in this study, it is clear that the amount is enormous and that we share a societal responsibility to take good care of it with regard to cultural heritage preservation but also to renovation and adaptation of buildings to our current and future needs.

Developed by CONCRETO Lab within the CONCRETO Academy project, this work focuses on identification of skill gaps, assessing existing standards, and providing a foundation for improved training and professional development in the field.

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