RILEM Technical Letters (2025) 10: 58-67
https://doi.org/10.21809/rilemtechlett.2025.219

Opening Letter of RILEM TC SDM: The current situation of data and metadata management in construction materials research - Emerging demands and viable solutions

Tanja Manninger[1,*], Fabien Georget[2,3], Ravi Patel[4,5], Tulio Honorio[6], Gilberto Cidreira Keserle[7], Roman Wan-Wendner[8], Sandra Barbosa Nunes[9]

[1]Smart Minerals GmbH, Austria
[2]Institute of Building Materials Research, RWTH Aachen University, Germany
[3]Department of Civil and Building Engineering, Université de Sherbrooke, Canada
[4]Institute of Building Materials and Concrete Structures (IMB), Karlsruhe Institute of Technology (KIT), Germany
[5]Materials Testing and Research Institute Karlsruhe (MPA), Karlsruhe Institute of Technology (KIT), Germany
[6]Service de recherche en Corrosion et Comportement des Matériaux, Université Paris-Saclay, France
[7]Englobe Corp, Canada
[8]Department of Structural Engineering and Building Materials, Ghent University, Belgium
[9]Delft University of Technology, The Netherlands

Received: 08 April 2025 / Accepted: 04 August 2025 / Published online: 20 August 2025

Abstract

To meet growing demands of stakeholders of the construction materials research field, new practices and methods must be established in handling metadata and raw data. Modelling approaches, simulation calculations and a targeted use of machine learning can save time and resources and is increasingly used in the industry as a decision-making tool. These techniques will play a crucial role in achieving the Net-Zero CO_2 deadline of 2050. However, a better collaborative effort is required to ensure that data can be successfully reused. The task is challenging, as methods and strategies for data collection in the field of construction materials are diverse. The RILEM TC SDM (Scientific Metadata Management of Construction materials) aims to lay the foundation for a formal approach to metadata collection and management. As an initial step, a metadata collection framework and the associated input tool will be designed. Along with a best-practice guideline for the storage of raw data, this will help data producers establish a robust routine that aligns with the FAIR data principles, facilitating the data's reuse. The TC will provide the bridging element – the metadata file – that links the journal publication to the raw data. The metadata file can be easily stored and searched.

Keywords: Data management; Metadata; FAIR principles; Construction materials; Data Science.

1 Introduction: The need for data science

1.1 A shift from empirical science

To meet the strict deadline of net-zero CO_2 by 2050 set by many countries, additional strategies are necessary to accelerate the development of more eco-efficient cementitious materials while guaranteeing their performance [1–3]. In this context, data-driven science is expected to increasingly expedite the empirical material discovery process that currently governs cement and concrete science and standards [4–6]. The trial-and-error empirical processes way of exploring mix design space is too costly and labour-intensive [7] to accommodate the growing complexity of formulations, e.g. using ternary and quaternary blends and new and emerging SCMs [8], varieties of chemical admixtures and local variability of aggregate mineralogies, including recycled aggregates. A systematic development of composition-microstructure-property relationships with data-driven approaches is crucial for creating reliable performance-based approaches where the formulation is selected to target specific performance criteria, including sustainability criteria [9].

The generation of data in construction materials research is labour-intensive, requires to specialised (often heavy) equipment and, in some cases, can stretch over long timespans [10,11].

*Corresponding author: Tanja Manninger, E-mail: manninger@smartminerals.at

In the last decade, new approaches to knowledge generation were developed. The advancement of physical-chemical process simulation and new sensor technologies has reshaped current practices in the field. With the rise of machine learning approaches, which requires extensive, high-quality datasets for accurate output, new opportunities to extract knowledge from data have also emerged. Additionally, the growing application of physical-chemical reactions and properties modelling has further contributed to these changes [4,12,13].

1.2 Fast science, reduced experiments, early predictions

The generation of specific knowledge with as few experiments as possible is claimed to be necessary for efficiency, and minimizing further environmental impact. It is also desirable to make predictions about properties and plan further experiments based on the extracted data as early as possible [14–16]. While this approach can offer significant benefits, the large volumes of data can also present challenges in terms of curation, peer review, proper storage, and reuse. This process known as "Fast Science" has been criticized and contrasted with the concept of "Slow Science" [17–20], which focuses on higher quality but fewer data. However, in both cases, the curation and preservation of data according the FAIR principles [21] are crucial for progress and maintaining a feedback system [18,22,23].

The slowness of the empirical method is evident in the construction materials research field, where some tests require long data collection periods, sometime spanning several decades [10,11]. This timescale is incompatible with the rapidly evolving market for building materials, especially cementitious products. The reduction in clinker content in Portland cement leads to the introduction of increasingly complex formulations, whether through new supplementary cementitious materials (SCMs) or admixtures [24–26]. As a consequence, much empirical knowledge, and by extension standards, are no longer applicable without thorough evaluation [7].

1.3 Modelling of data, including machine learning approaches and AI's

Whether it is to accelerate experimental design, interpret experimental data, or uncover fundamental mechanisms, modelling approaches have played and will continue to play an important role in the development and applications of low-carbon cements. Many of these approaches rely on well-curated databases [27,28] for the calibration and validation of models. The construction of such databases is a massive undertaking and is often driven by isolated individual efforts. Starting from general datasets, these techniques allow for a narrowing down of promising experiments and subsequently, enable targeted data collection [29–32]. However, the reuse of data is not straightforward, and the general lack of metadata makes data collection challenging and curation essential [4,33,34].

This issue is heightened when machine learning approaches or AI's are used, as training such systems requires larger datasets of high quality due to their statistical nature [35,36]. This implies the automatic processing of data from various sources, which can only be routinely deployed if these sources provide the required data in a common machine-readable format. The comparability of experimental data with calculated theoretical datasets can be improved impressively by using data that has a solid metadata record, as it enables the screening of unfit data, outliers and errors [37].

1.4 Funding requirements

Funding of cement decarbonisation projects in the EU alone has been increasing in the past years from EUR 19.2 million in 2012 to EUR 75.6 million in 2022 [38] to aid in mitigating the climate crisis and driving innovation [39,40]. Due to increased scrutiny on public spending, and the growing push for open science, including the dissemination to the public, governmental funding agencies are adopting stricter rules regarding data management and data publication. In 2019, around a quarter of funding agencies listed in the Sherpa Juliet online database had an open science requirement [41], although this varies widely by country. For example, the European Commission has required a data management plan for all research projects, and evaluates grant proposals based on concrete actions for data management and open science [42]. Common actions include the creation of shared folders, or shared electronic notebooks. However, the lack of consistent strategies means that these actions are often isolated. It should also be noted that the compliance with funding body mandates is not the primary reason cited by researchers as the benefit for sharing research [41].

2 Introduction to the FAIR principles

The FAIR principles [21] provide guidelines for the data-producer to achieve a sustainable data management. It states that the (meta)data should be:

- **F**indable – easily discoverable by humans and computers alike.
- **A**ccessible – retrievable/browsable/downloadable for further use according to the data access policy.
- **I**nteroperable – in a form that can be imported into programs and systems
- **R**eusable – well-described (by metadata) to allow its reuse, and/or integration with other data

The idea has gained significant attention, as following its guideline [21] will enable future developments in digitally based scientific progress, the full extent of which can only be roughly estimated at this point. A clear take-away from these principles is the importance of the metadata collection and storage, which supports all four aspects of the FAIR principles. Therefore, it is the main focus of this TC. An estimate by the European commission in 2018 stated that, across all scientific disciplines, the annual costs of not having FAIR data amount to a minimum of €10.2bn per year. The actual cost is most likely higher [43].

3 Current status of Metadata and Data management

3.1 Current status in the construction materials research field

The current data management situation in the construction materials research community mainly relies on classical concepts, such as publishing of papers in scientific and technical journals. This approach caters the human users who seek to read and comprehend findings to gain useful insights into research subjects and environments.

Raw data from experiments are rarely shared in publications, although diligent authors sometimes provide it as supplementary materials, or in cases of larger datasets, as a link to a data repository (e.g. Zenodo). The typical way of handling the data is reflected in the common data availability statement: “The data that supports the findings of this study are available on request from the corresponding author”.

A statistical evaluation of five well-known journals in the field of cement, concrete and construction research revealed that in the timespan 2020 – 2022, for each 200 citeable journal publications, only one included data in a repository (see Appendix Table 1). Only data in repositories was counted, electronic supplementary materials like excel tables were not counted. The findability of repository files strongly depends on the journal used for publishing and connected repository platforms.

Random samples of the available repository data showed a diverse range of materials, including raw data, code, additional descriptions, photos, diagrams and videos.

The statistical evaluation of published repository data can act as a metric of the progress, and success of this TC. Together with citations of the used tool in publications, it allows RILEM as a stakeholder to track the TCs impact on the scientific community.

3.2 Current status in RILEM

Although each RILEM technical committee (TC) typically publishes its findings in reports and papers, the raw data generated by the TC often remains unpublished. As a result, new TCs often find themselves repeating parts of the experimental work of their predecessors. This TC specifically aims to propose a data and metadata treatment standard in the field of construction material research to address this issue.

In the RILEM Cluster D. *Service Life and Environmental Impact Assessment,* the RILEM TC 315-DCS: Data-driven concrete science [44] is pioneering this work. Modelling approaches and simulation calculations that rely on data for development, calibration and validation have been explored in the past several decades by various RILEM TCs. Some TCs have also put in a massive amount of work to curating databases [45]. In addition to scientific research, many companies in the cement and concrete business have already streamlined their manufacturing processes by utilizing massive data amounts from their own factories in simulation- and machine learning approaches [37,46]. Examples like the creep database [47,48] as well as the ILS-mech [49] and the carbonation database [50] show the common effort of the research community in creating and curating valuable databases.

3.3 Current status in other research fields

Certain fields, such as genetic research in biology, material informatics [34] and bio informatics [51] as well as some large facilities, like synchrotron beamlines [33,52–56], maintain very high standards for the data they produce. These fields typically follow set protocols, using the same instruments and setups repeatedly to generate consistent data. The principles and ideas for handling the data in these fields are often already well-developed, providing valuable examples of how best practices in construction materials research could be implemented [28]. Examples of well curated databases in the fields of geoscience are available for thermodynamic data [57–59]. This work has been extended to cement science, and it enabled sustained progress in the understanding of phase assemblage as materials age, deterioration processes, etc. (e.g. the CEMDATA thermodynamic database for cement phases) [27].

3.4 Current status in construction industry

Building Information Modelling (BIM) is a method that transforms data into information, enabling the digitalization of the construction industry’s value chain throughout the asset lifecycle. Usually it is used for the design and construction phase of buildings and infrastructure. The CEN/TC 442 tailors ICT technologies to fit the specific needs of the construction ecosystem in the BIM context. The scope is aimed to support European construction projects and infrastructure.

Nowadays, companies are increasingly adopting digital technologies to improve productivity and reduce risk. BIM has become central to this shift, serving as a digital backbone for design coordination, clash detection, cost estimation and lifecycle asset management. Integration with other technologies (e.g. digital twins, AI-driven project planning, drones for site monitoring and modular construction) is accelerating the move toward more data-driven and efficient project delivery. Moreover, cloud-based platforms and mobile applications are enhancing real-time collaboration across teams, while sustainability requirements are driving the adoption of energy modeling and low-carbon design. There is the approach to create a Material Building Passport that includes information about the used materials. The current state is that it is created by selecting fitting database entries regarding structural components. The materials and composition of the structural components have to be included in the used database beforehand. Usually the entries are well established components and materials that are mass produced for the market. The included materials description is superficial (e.g. there is a distinction between “lightweight concretes” and “normal concrete with reinforcement”) [60,61]. One focus of BIM is to enable automation of processes especially planning processes [62]. At the moment the inclusion of specialized, detailed material data is not in focus although the TC is in contact with members of CEN. There are efforts that already think in this direction that are focussing on digital manufacturing [63]. Nevertheless, the determination of a metadata standard for experimental construction material data and experiments is the first step to allow possible future integration of data in BIM and such possibilities will be part of the exchange with CEN.

As a step-up from BIM the collected data can be integrated during the process of creating a Digital Twin. The data from BIM together with real time monitoring data are used to create digital models with real time behaviour and performance. Digital Twins are a useful tool for the simulation and analysis of physical objects or processes [64,65]. There are huge benefits of using such models for the maintenance and life-cycle assessment of buildings and infrastructure [66,67]. The TC is currently not aware of standardized protocols of material metadata for Digital Twins. Nevertheless, members of the TC SDM currently work with Digital Twins and their input will help to shape the metadata standard in a way that is helpful for the integration of RILEM data into Digital Twins.

4 Data and Metadata – Definitions, approaches and considerations

4.1 Connection of Metadata, Data and FAIR principles

Metadata as per the definition of the NIST is a "Representation of facts, concepts, or instructions in a manner suitable for communication, interpretation, or processing by humans or by automatic means." or a "Collection of values assigned to base measures, derived measures, and/or indicators." [68].

It typically includes "Information describing the characteristics of data including, for example, structural metadata describing data structures (e.g., data format, syntax, and semantics) and descriptive metadata describing data contents (e.g., information security labels)" [69].

This means that while data provides the facts, metadata offers the context. Both, data and metadata serve to attain meaningful and convincing conclusions from research results.

There are many types of metadata. Structural metadata describes the format, syntax and the semantics used to share the data (e.g. the data is stored as C-S-V file). The descriptive metadata provides a meaning to the data, for example the type of experiment (e.g. compressive strength), or the type of material (concrete or mortar) that was tested. The administrative metadata can provide information about the investigators, institutions and funding agencies involved in the creation of the data. Finally, the legal metadata describes the access and reuse conditions to the data (e.g. the copyright). Depending on the data, other categories might be necessary to fulfil the FAIR principles.

The **FAIR** principles are an essential tool in creating sustainable data. In the context of this TC they can be implemented as follows:

- **F**indability can be addressed by a combination of guidance on how to use repositories and the targeted and regulated collection of metadata that allows to search it.
- **A**ccessibility is dependent on organizational needs and rules. A general guide on data storage in repositories is planned to confront this issue.
- **I**nteroperability will be addressed through a general guide on beneficial formats and structures for metadata creation, for data storage, as well as defining a database schema that facilitates translation into existing ontologies.
- **R**eusability strongly depends on the availability of reliable, necessary and sufficient metadata. A key goal of this TC is to create a framework to assist data producers in selecting an appropriate set of metadata.

4.2 Data security and ownership

Although the FAIR principles state that the data should be **A**ccessible, this does not mean that it should be without security and/or the ownership is lost. As each university or research facility has to follow its own guidelines for intellectual property management, there will not be a unique fit-for-all solution. This aligns with the FAIR principles, as long as the metadata is properly collected and stored, searchable by humans and by automatic systems, and that it contains a link to the actual data. However, access to the data can be restricted through authorization or payment. This TC does not aim to store actual data. Instead, a guideline on using existing data storage facilities and creating the data files will be part of the deliverables of the TC. The processes of data storage, encryption, protection and stewardship will remain the responsibility of the data owner, and/or its institution. This approach prevents conflicts over security and ownership while allowing researchers to adhere to the established policies at their institutions.

4.3 Ontologies or database schema?

In information science, an ontology is a definition of how to classify and represent information about a system. In relation to metadata, it concerns both the vocabulary necessary to describe the data and the hierarchy of this description. For example, for a system that could be described by a database in a tabular format, the ontology describes the meaning of each column as well as the potential relationships between each column, e.g. whether two columns can be true. Ontologies are an important tool to categorize data and describe it. There are already some ontologies related to construction materials that have been published or are currently under development [70–72].

The aim of this TC is not to create an ontology but a database schema [73], which is considered more accessible to non-experts. Ontologies focus on meaning and semantic relationships while database schemas focus on the data structure. Ontologies and database schemas are closely related, and our database schema could be translated into an ontology if needed [73,74]. The necessity of ontologies will not be dismissed but adhered as in providing a method of metadata collection that produces an output which later allows a simple integration into existing ontologies. The TC will monitor ongoing work on ontologies and aims to facilitate regular exchanges of information. Insights gained from these exchanges will be incorporated in the TC's work, aiming to create a system that has a low threshold for integration into various ontologies. Once a working concept has been developed, selected ontologies can be annotated or mapped to our schema and notation. This will be attempted at the end of the current TC but may also be addressed in a follow up TC if necessary.

4.4 Reusability of Data – Requirements for the support of material modelling and AI training

As emphasized in the introduction, reusable data is crucial for modelling. Therefore, this TC aims to enable all researchers in the field to manage their data and metadata in a way that facilitates easy re-use by others. The strategy proposed by this TC, with its focus on an easy-to-use concept, may serve as an incentive or catalyst for reusing data from previous studies (including unpublished data, negative results, historical data from labs presented in reports and technical notes in English or other languages) or converting existing databases (like Bazant creep database [48]) into a FAIR-compatible format, to facilitate future re-use. Structured and curated data are essential for AI- modelling, and machine learning clearly has significant applications in materials science and engineering [4,75,76].

5 Date of creation and current TC status

In 2020, RILEM issued a call to establish a working group to improve the reusability of RILEM data by developing a metadata standard and data storage guidelines. Founded in 2021, the Metadata Management Group initially focused on orientation and defining a potential scope. It soon became apparent that the group would encounter highly heterogeneous datasets and various institutional constraints regarding data storage. Consequently, the group placed an early emphasis on metadata, and planned on designing the data storage guidelines to be flexible and adaptable.

The group thoroughly reviewed existing standards, guidelines, databases, and projects, including FAIR data management principles, the CSMD, relevant ontologies, the Dublin Core Metadata Initiative (DCMI), and ACI guidelines [71–74,77–82]. The group also explored methods to structure material and experimental metadata and tested these approaches through practical use cases.

The group's collective efforts culminated in the proposal of the RILEM TC SDM, which formalized the insights gained during the previous three years of work. The proposal for establishing a new RILEM Technical Committee (TC) on "Scientific Metadata Management of Construction materials" was approved during the TAC meeting held in April 2024. The TC has been assigned to CLUSTER D. As of July 2025, the committee comprises 15 active members and about 30 passive observers representing 13 countries and over 25 institutions or companies. On average, we organize 6 general TC meetings per year.

6 Needs and requirements of the TC's work

6.1 Existing databases

Within the RILEM organization and its network, several databases were created and curated [48,50,83,84], representing some of the most important contributions by RILEM members to the scientific community. However, once the individuals responsible for curating and maintaining these databases step away, their long-term sustainability often becomes uncertain.

In response, the RILEM Technical Activities Committee has requested that all the existing databases associated to RILEM activities be accompanied by a metadata file, ensuring they can be made FAIR compliant in the future.

6.2 Previous approaches

The idea of categorizing data from construction materials research is not new. In the early 2000s, a group of scientists collaborating mainly in ACI but also frequently involved with RILEM, proposed key concepts they deemed essential for the future of their field [79–81]. However, at the time, there was no formalized approach to implementing these ideas in practice or applying them to research data. As this technical letter is written, over 20 years later, advancements in software tools [85–87], modern computing hardware, and affordable cloud storage solutions (e.g. github, gitlab, zenodo…) have made the practical implementation of these concepts feasible. As a result, there is renewed interest in improving data curation for multi-purpose use [5].

6.3 Tool and guideline

The section *Current status in other research fields* has already discussed how different fields approach their data management concepts and needs. Some well-working examples are available, for example, in the genetic field. The difference to these special fields and applications is the variety and diversity of testing methods and the produced data in construction materials research. RILEM's highly interdisciplinary research community — comprising experts from diverse scientific backgrounds — has unique data management needs and requirements that must be carefully considered. The TC's work should serve stakeholders who are working with construction materials e.g. developing and applying new binders like geologists, geochemists, process engineers, material scientists and also end users like civil engineers. The TC aims to provide a solution to record the metadata of various experiments and offers a guideline on how to store the collected raw data.

7 Aim and organization of the Technical Committee

7.1 Aim and idea of the TC – Description of the need for a metadata management tool

The underlying idea of the FAIR principle is apparently simple but in no way easy to implement. The goal of this TC is to empower every scientist in the construction materials research field to collect meaningful metadata and store their data in an accessible manner. To accomplish this task a tool is necessary. It should enable every researcher in this field to collect their metadata easily and comprehensibly. This tool will provide a guided methodology for metadata collection, that follows the FAIR principles. The user should not need any previous knowledge about the FAIR Principle, metadata or programming. Starting with a simple software tool (ideally excel based for easier distribution) and aiming for a more sophisticated solution with a graphical user interface, the researcher should be able to export a computer readable file format of their metadata, that can be attached as an appendix to publications. In a collection, these metadata files will be a strong, easily searchable resource that enables other researchers to filter through metadata and identify appropriate datasets through provided links to the scientific data. This might be a goal of a possible follow-up project or TC.

7.2 List of the planned TC activities

- Create a Tool for metadata collection and reporting file creation for construction materials, starting with cement and concrete related experiments and data. The tool must be comprehensible and easy to use. It will have an output option that gives the user a computer readable formatted metadata file (maybe txt, csv etc.).
- Define the metadata output file format and structure (what is defined where, what is the structure).
- Set up a website with the definitions and structure of the metadata collection tool.
- Collect some use cases.
- Issue a small set of guidelines on where to store actual data, including some possibilities and a discussion about security, including personal data protection. After testing and improvement, it is planned to publish it as a RILEM recommendation.
- Issue a small guideline on how to structure actual data and in what format to store it to facilitate its reuse.
- Create a State-of-the-art article (STAR report) on the concept of metadata management for construction materials, the development and use of the tool and the guideline of actual data storage. Depending on the volume of information, a fitting format will be chosen.
- Correspond with interested committees and organizations E.g.: FIB, ACI 135, ACE TC AICE, CEN, NFDi4ing
- Correspond with interested Data-stewards, departments or connected organizations.
- Educate the scientific community within RILEM about the use of the tool in seminars, webinars, workshops and at conferences. It will also be presented to the young RILEM community. Another goal is to enable university students to familiarize themselves with the concept early in their career, enabling them to use the tool already for their data management in Bachelor and Master thesis.
- Increase (open) data sharing among the concrete research community and enable a much more significant pool of reusable data than currently available.
- Propose recommendations with the goal to teach best practices for data management.

7.3 Organization of the RILEM TC

The Workpackages are linked as depicted in Figure 1.

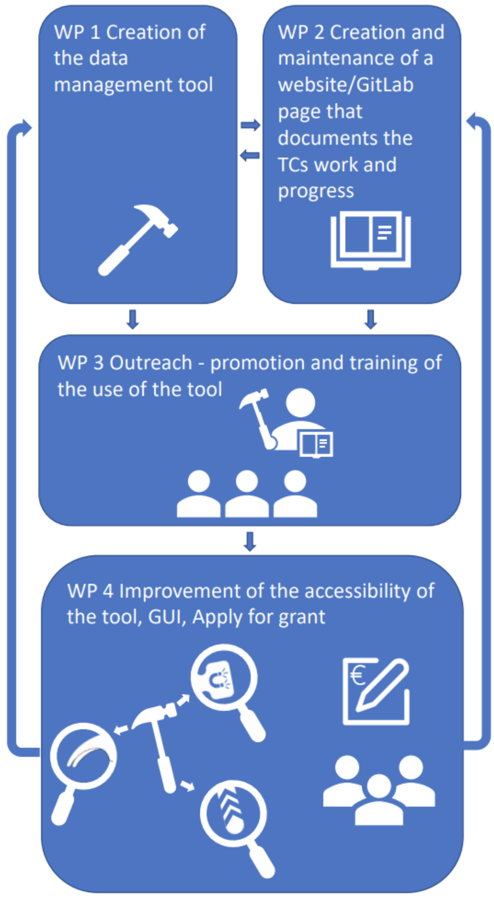

Figure 1. Work packages and their connection within the TC SDM

<u>WP 1: Creation of the data management tool</u>

In an iterative process, the tool will be improved, tested and further improved by using real life examples. The tool is currently in the Pre-Alpha stage as it does not contain all the intended functions yet. It will be tested and improved in the TC environment in an Alpha stage. It will later be offered to selected TCs to test it as a Beta stage. Finally, it should become available to every RILEM member and for public use.

<u>WP 2: Creation and upkeep of a website/GitLab page that documents the TC's work and progress</u>

The TC will keep some documents on the RILEM webpage, but the primary documentation of its work will be hosted on a GitLab page. This platform allows for easy accessibility, as well as efficient tracking and adaptation of changes and versions.

<u>WP 3: Teaching of the use of the tool</u>

To maximize the impact of this TC's work, as many researchers as possible should be encouraged to use it. Guidelines how to do this and how to handle data will be prepared. The work includes training of RILEM members through Workshops while also aiming to teach students at the start of their career how to use the tool. Young researchers with strong data management skills will help sustain the TC's long-term objectives. The WP contains the creation of instructional videos and their online distribution.

WP 4: Improvement of the accessibility of the tool, GUI, Grant application

This work package is optional, as it depends on securing external funding. After the tool has undergone beta testing and initial user feedback has been gathered, further improvements should be made to enhance the user experience. The more intuitive the tool, the more metadata information can be generated and collected. To enable this, the goal of this WP will be the improvement of the original tool by the generation of a Graphical User Interface. It will also be considered if an online version for the tool could be added.

The strategy proposed in the TC could serve as an incentive or catalyst for reusing data from previous studies (including unpublished data, negative results, historical data from labs presented in reports and technical notes or publications in other languages but English), for putting existing databases (like the Bazant creep database [48,83]) in a FAIR compliant format by creating accompanying metadata, etc. generally creating an awareness for the value of data and how to keep it useable.

8 Position of the TC SDM in the RILEM network

The TC aims to serve several parties in the RILEM Network. The primary user group that will be catered by the TC are RILEM members. The TCs deliverables and goals should enable the average RILEM member to establish a mature, FAIR complying data management routine with a minimum of effort. The routine should be universally applicable for all construction material research so that it can be used for publications outside the RILEM network and as an established reference data management concept for funding applications between collaborating RILEM members but also for funding applications in general. The secondary user group will be every researcher in the field that is reliant on accessible and well-organised data.

The availability of properly stored metadata and corresponding raw data will significantly enhance and accelerate modelling approaches, simulation calculations, and AI applications. Consequently, the TC's work will align closely with the goals of the TC 304-ADC interlaboratory study on mechanical and durability properties. However, its impact extends beyond this specific TC, benefiting other TCs that depend on external data for their work packages. The TC SDM and TC 315-DCS share members and collaborate closely to align the relevant material data and properties to be incorporated into the tool. The two TCs also anticipate co-organized initiatives, including training activities, the development of example datasets, and the organization of workshops and shared symposiums.

Authorship statement (CRediT)

Tanja Manninger: Conceptualization, Visualization, Project administration, Writing – Original Draft. **Fabien Georget:** Conceptualization, Visualization, Project administration, Writing – Original Draft. **Ravi Patel:** Conceptualization, Writing – Review & Editing. **Tulio Honorio:** Writing – Review & Editing. **Gilberto Cidreira Keserle:** Writing – Review & Editing. **Roman Wan-Wendner:** Writing – Review & Editing. **Sandra Barbosa Nunes:** Writing – Review & Editing.

References

[1] 2050 long-term strategy - European Commission, (2019). https://climate.ec.europa.eu/eu-action/climate-strategies-targets/2050-long-term-strategy_en (accessed November 18, 2024)

[2] RILEM, GLOBE - Global Consensus on Sustainability in the Built Environment, (n.d.). https://www.rilem.net/globe (accessed November 18, 2024).

[3] RILEM, Net Zero Carbon Buildings | Energy Neutral and Sustainability in Construction and Building Materials, (n.d.). https://www.rilem.net/agenda/net-zero-carbon-buildings-energy-neutral-and-sustainability-in-construction-and-building-materials-1520 (accessed November 18, 2024)

[4] L. Himanen, A. Geurts, A.S. Foster, P. Rinke, Data-Driven Materials Science: Status, Challenges, and Perspectives, Advanced Science 6 (2019) 1900808. https://doi.org/10.1002/advs.201900808

[5] D. Fernández‐Ordóñez, M. Fernández Ruiz, N. Tošić, R. Wan‐Wendner, A. De La Fuente, Rethinking databases: The fib project for a connected data repository, Structural Concrete 24 (2023) 4480-4491. https://doi.org/10.1002/suco.202201023

[6] H. Van Damme, Concrete material science: Past, present, and future innovations, Cement and Concrete Research 112 (2018) 5-24. https://doi.org/10.1016/j.cemconres.2018.05.002

[7] J.W. Bullard, E.J. Garboczi, P.E. Stutzman, P. Feng, A.S. Brand, L. Perry, J. Hagedorn, W. Griffin, J.E. Terrill, Measurement and modeling needs for microstructure and reactivity of next-generation concrete binders, Cement and Concrete Composites 101 (2019) 24-31. https://doi.org/10.1016/j.cemconcomp.2017.06.012

[8] R. Snellings, P. Suraneni, J. Skibsted, Future and emerging supplementary cementitious materials, Cement and Concrete Research 171 (2023) 107199. https://doi.org/10.1016/j.cemconres.2023.107199

[9] L.L. Sutter, R.D. Hooton, Progress towards sustainability through performance-based standards and specifications, Cement and Concrete Research 174 (2023) 107303. https://doi.org/10.1016/j.cemconres.2023.107303

[10] R. François, A. Castel, T. Vidal, N.-A. Vu, Long term corrosion behavior of reinforced concrete structures in chloride environnement, J. Phys. IV France 136 (2006) 285-293. https://doi.org/10.1051/jp4:2006136029

[11] Long-term performance of reinforced concrete under a de-icing road environment, Cement and Concrete Research 164 (2023) 107039. https://doi.org/10.1016/j.cemconres.2022.107039

[12] J. Schmidt, M.R.G. Marques, S. Botti, M.A.L. Marques, Recent advances and applications of machine learning in solid-state materials science, Npj Comput Mater 5 (2019) 83. https://doi.org/10.1038/s41524-019-0221-0

[13] B. Hanson, S. Stall, J. Cutcher-Gershenfeld, K. Vrouwenvelder, C. Wirz, Y. Rao, G. Peng, Garbage in, garbage out: mitigating risks and maximizing benefits of AI in research, Nature 623 (2023) 28-31. https://doi.org/10.1038/d41586-023-03316-8

[14] N. Oreskes, Trouble in the Fast Lane, Sci Am 330 (2024) 69. https://doi.org/10.1038/scientificamerican0424-69

[15] Modern science: What's changing? - Understanding Science, (2022). https://undsci.berkeley.edu/modern-science-whats-changing/ (accessed August 20, 2024)

[16] E. Kaeser, Fast Science: Die Schattenseiten der schnellen Wissenschaft, Neue Zürcher Zeitung (2022). https://www.nzz.ch/wissenschaft/fast-science-die-schattenseiten-der-schnellen-wissenschaft-ld.1653784 (accessed August 20, 2024)

[17] I. Stengers, Another science is possible: a manifesto for slow science, English edition, Polity, Cambridge, UK, 2018.

[18] R. Shute, Fast Science, Effective Collaboration and the Need for Trust, Curlew Research (2020). https://curlewresearch.com/fast-science-effective-collaboration-trust/ (accessed November 15, 2024).

[19] Normalizing Slow Science - Science & Justice Research Center, (n.d.). https://scijust.ucsc.edu/2021/08/06/normalizing-slow-science/ (accessed November 15, 2024)

[20] U. Frith, Fast Lane to Slow Science, Trends in Cognitive Sciences 24 (2020) 1-2. https://doi.org/10.1016/j.tics.2019.10.007

[21] M.D. Wilkinson, M. Dumontier, Ij.J. Aalbersberg, G. Appleton, M. Axton, A. Baak, N. Blomberg, J.-W. Boiten, L.B. Da Silva Santos, P.E. Bourne, J. Bouwman, A.J. Brookes, T. Clark, M. Crosas, I. Dillo, O. Dumon, S. Edmunds, C.T. Evelo, R. Finkers, A. Gonzalez-Beltran, A.J.G. Gray, P. Groth, C. Goble, J.S. Grethe, J. Heringa, P.A.C. 'T Hoen, R. Hooft, T. Kuhn, R. Kok, J. Kok, S.J. Lusher, M.E. Martone, A. Mons, A.L. Packer, B. Persson, P. Rocca-Serra, M. Roos, R. Van Schaik, S.-A. Sansone, E. Schultes, T. Sengstag, T. Slater, G. Strawn, M.A. Swertz, M. Thompson, J. Van Der Lei, E. Van Mulligen, J. Velterop, A. Waagmeester, P. Wittenburg, K. Wolstencroft, J. Zhao, B. Mons, The FAIR Guiding Principles for scientific data management and stewardship, Sci Data 3 (2016) 160018. https://doi.org/10.1038/sdata.2016.18

[22] C. Kommers, What if science moved faster, not slower?, Meaning Lab (2023). https://codykommers.substack.com/p/what-if-science-moved-faster-not (accessed January 2, 2025)

[23] IBM Research: ushering in the era of accelerated discovery, IBM Research (2021). https://research.ibm.com/blog/what-is-accelerated-discovery (accessed January 2, 2025)

[24] 2050 Carbon Neutrality Roadmap, (n.d.). https://cembureau.eu/library/reports/2050-carbon-neutrality-roadmap/ (accessed August 20, 2024)

[25] H.-M. Ludwig, W. Zhang, Research review of cement clinker chemistry, Cement and Concrete Research 78 (2015) 24-37. https://doi.org/10.1016/j.cemconres.2015.05.018

[26] J.J. Biernacki, J.W. Bullard, G. Sant, K. Brown, F.P. Glasser, S. Jones, T. Ley, R. Livingston, L. Nicoleau, J. Olek, F. Sanchez, R. Shahsavari, P.E. Stutzman, K. Sobolev, T. Prater, Cements in the 21st century: Challenges, perspectives, and opportunities, Journal of the American Ceramic Society 100 (2017) 2746-2773. https://doi.org/10.1111/jace.14948

[27] B. Lothenbach, D.A. Kulik, T. Matschei, M. Balonis, L. Baquerizo, B. Dilnesa, G.D. Miron, R.J. Myers, Cemdata18: A chemical thermodynamic database for hydrated Portland cements and alkali-activated materials, Cement and Concrete Research 115 (2019) 472-506. https://doi.org/10.1016/j.cemconres.2018.04.018

[28] C.R. Groom, F.H. Allen, The Cambridge Structural Database in Retrospect and Prospect, Angew Chem Int Ed 53 (2014) 662-671. https://doi.org/10.1002/anie.201306438

[29] T. Miyakawa, No raw data, no science: another possible source of the reproducibility crisis, Mol Brain 13 (2020) 24. https://doi.org/10.1186/s13041-020-0552-2

[30] S.H.B. Wijekoon, N. Sathiparan, D.N. Subramaniam, Optimisation of pervious concrete performance by varying aggregate shape, size, aggregate-to-cement ratio, and compaction effort by using the Taguchi method, International Journal of Pavement Engineering 25 (2024) 2380523. https://doi.org/10.1080/10298436.2024.2380523

[31] The optimal experiment? Influence of solution strategies on model-based optimal experimental design, Computers & Chemical Engineering 187 (2024) 108746. https://doi.org/10.1016/j.compchemeng.2024.108746

[32] M.A. DeRousseau, J.R. Kasprzyk, W.V. Srubar, Computational design optimization of concrete mixtures: A review, Cement and Concrete Research 109 (2018) 42-53. https://doi.org/10.1016/j.cemconres.2018.04.007

[33] H.A. Piwowar, Who Shares? Who Doesn't? Factors Associated with Openly Archiving Raw Research Data, PLOS ONE 6 (2011) e18657. https://doi.org/10.1371/journal.pone.0018657

[34] L.M. Ghiringhelli, C. Baldauf, T. Bereau, S. Brockhauser, C. Carbogno, J. Chamanara, S. Cozzini, S. Curtarolo, C. Draxl, S. Dwaraknath, Á. Fekete, J. Kermode, C.T. Koch, M. Kühbach, A.N. Ladines, P. Lambrix, M.-O. Himmer, S.V. Levchenko, M. Oliveira, A. Michalchuk, R.E. Miller, B. Onat, P. Pavone, G. Pizzi, B. Regler, G.-M. Rignanese, J. Schaarschmidt, M. Scheidgen, A. Schneidewind, T. Sheveleva, C. Su, D. Usvyat, O. Valsson, C. Wöll, M. Scheffler, Shared metadata for data-centric materials science, Sci Data 10 (2023) 626. https://doi.org/10.1038/s41597-023-02501-8

[35] T. Linjordet, K. Balog, Impact of Training Dataset Size on Neural Answer Selection Models, (2019). http://arxiv.org/abs/1901.10496 (accessed August 12, 2024)

[36] Big Data in the construction industry: A review of present status, opportunities, and future trends, Advanced Engineering Informatics 30 (2016) 500-521. https://doi.org/10.1016/j.aei.2016.07.001

[37] T. Armstrong, S. Ziegler, O. Kanders, B. Henrich, A. Tepe, Cemtech Live Webinar on optimising cement production with digitalisation, 04.03.2024, (2024).

[38] European Commission. Joint Research Centre., Decarbonisation options for the cement industry., Publications Office, LU, 2023. https://data.europa.eu/doi/10.2760/174037 (accessed January 2, 2025)

[39] Horizon Europe - Performance - European Commission, (n.d.). https://commission.europa.eu/strategy-and-policy/eu-budget/performance-and-reporting/programme-performance-statements/horizon-europe-performance_en (accessed August 12, 2024)

[40] Supporting climate action through the EU budget - European Commission, (n.d.). https://climate.ec.europa.eu/eu-action/eu-funding-climate-action/supporting-climate-action-through-eu-budget_en (accessed August 12, 2024)

[41] Facts and Figures for open research data - European Commission, (n.d.). https://research-and-innovation.ec.europa.eu/strategy/strategy-2020-2024/our-digital-future/open-science/open-science-monitor/facts-and-figures-open-research-data_en (accessed November 14, 2024)

[42] Open science - European Commission, (n.d.) https://rea.ec.europa.eu/open-science_en (accessed November 14, 2024)

[43] European Commission. Directorate General for Research and Innovation., PwC EU Services., Cost-benefit analysis for FAIR research data: cost of not having FAIR research data., Publications Office, LU, 2018. https://data.europa.eu/doi/10.2777/02999 (accessed January 2, 2025)

[44] RILEM, RILEM Active TCs, (n.d.). https://www.rilem.net/activetcs (accessed April 10, 2024)

[45] RILEM, RILEM Tools, (n.d.). https://www.rilem.net/tools (accessed April 10, 2024)

[46] R. Tong, T. Sui, L. Feng, L. Lin, The digitization work of cement plant in China, Cement and Concrete Research 173 (2023) 107266. https://doi.org/10.1016/j.cemconres.2023.107266

[47] V. Šmilauer, L. Dohnalová, M. Jirásek, J. Sanahuja, R. Wan-Wendner, Z. Bažant, Creep and Shrinkage Database of Laboratory Data, (2023). https://doi.org/10.5281/zenodo.8150177.

[48] Z.P. Baˇzant, S. Baweja, Creep and Shrinkage Prediction Model for Analysis and Design of Concrete Structures: Model B3, (n.d.).

[49] F. Bos, A. Robens-Radermacher, S. Muthukrishnan, J. Versteegen, R. Wolfs, M. Santhanam, C. Menna, V. Mechtcherine, Database of the RILEM TC 304-ADC interlaboratory study on mechanical properties of 3D printed concrete (ILS-mech), (2024). https://doi.org/10.5281/zenodo.12200570.

[50] A. Vollpracht, G.J.G. Gluth, B. Rogiers, I.D. Uwanuakwa, Q.T. Phung, Y.V. Zaccardi, C. Thiel, H. Vanoutrive, J.M. Etcheverry, E. Gruyaert, S. Kamali-Bernard, A. Kanellopoulos, Z. Zhao, I.M. Martins, S. Rathnarajan, N. De Belie, Report of RILEM TC 281-CCC: Insights into factors affecting the carbonation rate of concrete with SCMs revealed from data mining and machine learning approaches, (2024). https://doi.org/10.21203/rs.3.rs-4169492/v1

[51] EMBL-EBI, Minimum information standards | Bioinformatics for the terrified, (n.d.). https://www.ebi.ac.uk/training/online/courses/bioinformatics-terrified/what-makes-a-good-bioinformatics-database/minimum-information-standards/ (accessed June 24, 2024)

[52] E. Stamnas, A. Lammert, V. Winkelmann, U. Lang, The HD(CP)2 Data Archive for Atmospheric Measurement Data, IJGI 5 (2016) 124. https://doi.org/10.3390/ijgi5070124

[53] S. Poirier, A. Buteau, B. Gagey, P. Martinez, C. Maréchal, M. Mederbel, M. Ounsy, P. Pierrot, J.M. Rochat, Experimental Data Storage Management in NeXus Format at Synchrotron SOLEIL, Data and Information Management (n.d.).

[54] N. Anderson, G. Hodge, A. Japzon, Harnessing NASA Goddard's Grey Literature: The Power of a Repository Framework, Pub Res Q 23 (2007) 58-64. https://doi.org/10.1007/s12109-007-9006-2

[55] G.R. Meyer, S. Androulakis, P.J. Bertling, A.M. Buckle, W.J. Goscinski, D. Groenewegen, C. Hines, A. Kannan, S. McGowan, S.M. Quenette, J. Rigby, P. Splawa-Neyman, J.M. Wettenhall, M. University, The Australian Store. Synchrotron Data Management Service for Macromolecular Crystallography, Data Management (2015).

[56] A. Vondrous, T. Jejkal, D. Ressmann, W. Mexner, R. Stotzka, Beamline data management at ANKA, (2014). https://doi.org/10.5445/IR/220098469.

[57] T.J. Wolery, Calculation of Chemical Equilibrium Between Aqueous Solution and Minerals: The EQ3/6 Software Package, (1979). https://doi.org/10.2172/6451946

[58] J.W. Johnson, E.H. Oelkers, H.C. Helgeson, SUPCRT92: A software package for calculating the standard molal thermodynamic properties of minerals, gases, aqueous species, and reactions from 1 to 5000 bar and 0 to 1000°C, Computers & Geosciences 18 (1992) 899-947. https://doi.org/10.1016/0098-3004(92)90029-Q

[59] T. Thoenen, W. Hummel, U. Berner, E. Curti, The PSI/Nagra Chemical Thermodynamic Database 12/07, Paul Scherrer Institut, Villigen PSI, Switzerland, Paul Scherrer Institut, Villigen PSI, Switzerland, 2014. https://www.psi.ch/sites/default/files/import/les/DatabaseEN/PSI-Bericht%252014-04_final_druckerei.pdf (accessed November 14, 2024)

[60] I. Kovacic, M. Honic, H. Rechberger, L. Oberwinter, K. Lengauer, A. Hagenauer, J. Glöggler, K. Meier, Prozess-Design für den "Building Information Modeling" (BIM) basierten, materiellen Gebäudepass BIMaterial, Bundesministerium für Verkehr, Innovation und Technologie (BMVIT), Wien, 2019. https://nachhaltigwirtschaften.at/resources/sdz_pdf/schriftenreihe-2019-8-bimaterial.pdf.

[61] IBO Passivhaus Bauteilkatalog, (n.d.). https://www.baubook.at/phbtk/ (accessed July 16, 2025)

[62] A. Paolini, S. Kollmannsberger, E. Rank, Additive manufacturing in construction: A review on processes, applications, and digital planning methods, Additive Manufacturing 30 (2019) 100894. https://doi.org/10.1016/j.addma.2019.100894

[63] M. Slepicka, S. Vilgertshofer, A. Borrmann, Fabrication information modeling: interfacing building information modeling with digital fabrication, Constr Robot 6 (2022) 87-99. https://doi.org/10.1007/s41693-022-00075-2

[64] M. Deng, C.C. Menassa, V.R. Kamat, From BIM to digital twins: a systematic review of the evolution of intelligent building representations in the AEC-FM industry, ITcon 26 (2021) 58-83. https://doi.org/10.36680/j.itcon.2021.005

[65] A.R. Radzi, N.F. Azmi, S.N. Kamaruzzaman, R.A. Rahman, E. Papadonikolaki, Relationship between digital twin and building information modeling: a systematic review and future directions, Construction Innovation 24 (2023) 811-829. https://doi.org/10.1108/CI-07-2022-0183

[66] D.A. Arcones, M. Weiser, F. Koutsourelakis, J.F. Unger, A Bayesian Framework for Simulation ‐ based Digital Twins of Bridges, Ce Papers 6 (2023) 734-740. https://doi.org/10.1002/cepa.2177

[67] S.R. Kalidindi, M. Buzzy, B.L. Boyce, R. Dingreville, Digital Twins for Materials, Front. Mater. 9 (2022). https://doi.org/10.3389/fmats.2022.818535

[68] R. Ross, M. Winstead, M. McEvilley, Engineering trustworthy secure systems, National Institute of Standards and Technology (U.S.), Gaithersburg, MD, 2022. https://doi.org/10.6028/NIST.SP.800-160v1r1

[69] C.S. Johnson, M.L. Badger, D.A. Waltermire, J. Snyder, C. Skorupka, Guide to Cyber Threat Information Sharing, National Institute of Standards and Technology, 2016. https://doi.org/10.6028/NIST.SP.800-150

[70] H. Du, V. Dimitrova, D. Magee, R. Stirling, G. Curioni, H. Reeves, B. Clarke, A. Cohn, An Ontology of Soil Properties and Processes, in: P. Groth, E. Simperl, A. Gray, M. Sabou, M. Krötzsch, F. Lecue, F. Flöck, Y. Gil (Eds.), The Semantic Web - ISWC 2016, Springer International Publishing, Cham, 2016: pp. 30-37. https://doi.org/10.1007/978-3-319-46547-0_4

[71] A.-H. Hamdan, M. Bonduel, R.J. Scherer, An ontological model for the representation of damage to constructions, (n.d.).

[72] S. Hou, H. Li, Y. Rezgui, Ontology-based approach for structural design considering low embodied energy and carbon, Energy and Buildings 102 (2015) 75-90. https://doi.org/10.1016/j.enbuild.2015.04.051

[73] M. Uschold, Ontology and database schema: What's the difference?, Applied Ontology 10 (2015) 243-258. https://doi.org/10.3233/AO-150158

[74] N. Konstantinou, D.-E. Spanos, N. Mitrou, Ontology and Database Mapping: A Survey of Current Implementations and Future Directions., Journal of Web Engineering (JWE) 7 (2008) 1-24.

[75] R. Boiger, B. Xi, G.-D. Miron, M. Bonvin, J.L. Provis, S.V. Churakov, N.I. Prasianakis, Machine learning-accelerated discovery of green cement recipes, Mater Struct 58 (2025). https://doi.org/10.1617/s11527-025-02684-z

[76] X. Jiang, D. Xue, Y. Bai, W.Y. Wang, J. Liu, M. Yang, Y. Su, AI4Materials: Transforming the landscape of materials science and enigneering, Review of Materials Research 1 (2025) 100010. https://doi.org/10.1016/j.revmat.2025.100010

[77] M.D. Wilkinson, M. Dumontier, Ij.J. Aalbersberg, G. Appleton, M. Axton, A. Baak, N. Blomberg, J.-W. Boiten, L.B. da Silva Santos, P.E. Bourne, J. Bouwman, A.J. Brookes, T. Clark, M. Crosas, I. Dillo, O. Dumon, S. Edmunds, C.T. Evelo, R. Finkers, A. Gonzalez-Beltran, A.J.G. Gray, P. Groth, C. Goble, J.S. Grethe, J. Heringa, P.A.C. 't Hoen, R. Hooft, T. Kuhn, R. Kok, J. Kok, S.J. Lusher, M.E. Martone, A. Mons, A.L. Packer, B. Persson, P. Rocca-Serra, M. Roos, R. van Schaik, S.-A. Sansone, E. Schultes, T. Sengstag, T. Slater, G. Strawn, M.A. Swertz, M. Thompson, J. van der Lei, E. van Mulligen, J. Velterop, A. Waagmeester, P. Wittenburg, K. Wolstencroft, J. Zhao, B. Mons, The FAIR Guiding Principles for scientific data management and stewardship, Sci Data 3 (2016) 160018. https://doi.org/10.1038/sdata.2016.18

[78] DCMI Metadata Terms, (n.d.). https://www.dublincore.org/specifications/dublin-core/dcmi-terms/ (accessed April 10, 2024)

[79] H. Farzam, G. Bollin, B.J. Erlin, F.K. Gibbe, R.L. Henry, M.B. Hogan, E.P. Holub, R.H. Howe, H.L. Isabelle, L.J. Kaetzel, T.S. Khan, J.R. Libby, M.D. Luther, J. Marin, B. Mather, A.G. Meseguer, R.C. Mielenz, Jr. Austin H. Morgan, T. Rutenbeck, Cement and Concrete Terminology, American Concrete Institute, 2005.

[80] 126.3R-99 Guide to Recommended Format for Concrete in Materials Property Database, (n.d.).

[81] C.B. Oland, C.F. Ferraris, CONCRETE MATERIALS DATABASE, Concrete International (2000).

[82] B. Matthews, CSMD: the Core Scientific Metadata Model, (n.d.). https://icatproject-contrib.github.io/CSMD/csmd-4.0.html (accessed April 10, 2024).

[83] Concrete Creep and Shrinkage - Department of Civil Engineering and Natural Hazards - BOKU, University Website (n.d.). https://boku.ac.at/en/baunat/cd-labor/downloads/kriechen-und-schwinden (accessed August 20, 2024)

[84] RILEM TC 223-MSC Data warehouse, (n.d.). https://rilem223dwh.isqweb.it/ (accessed August 20, 2024)

[85] C. Barillari, D.S.M. Ottoz, J.M. Fuentes-Serna, C. Ramakrishnan, B. Rinn, F. Rudolf, openBIS ELN-LIMS: an open-source database for academic laboratories, Bioinformatics 32 (2016) 638-640. https://doi.org/10.1093/bioinformatics/btv606

[86] A. Bauch, I. Adamczyk, P. Buczek, F.-J. Elmer, K. Enimanev, P. Glyzewski, M. Kohler, T. Pylak, A. Quandt, C. Ramakrishnan, C. Beisel, L. Malmström, R. Aebersold, B. Rinn, openBIS: a flexible framework for managing and analyzing complex data in biology research, BMC Bioinformatics 12 (2011) 468. https://doi.org/10.1186/1471-2105-12-468

[87] N. Carpi, A. Minges, M. Piel, eLabFTW: An open source laboratory notebook for research labs, JOSS 2 (2017) 146. https://doi.org/10.21105/joss.00146

Appendix

Table 1. Repository data numbers in five relevant Journals in the construction materials sector.

Journal*	Publisher	Total amount of articles with linked repositories	Total amount of articles with linked repositories 2015-now	average publications with repository link per year since 2015	average repository publications per year 2020 - 2022	average repository publication per 100 publications (2020 - 2022)	average repository publication per 100 publications (2020 - 2022) minus estimated review papers (25 %)	75 % Citeable papers per year (average 2020-2022, excluding a 25 % estimate of all papers as review papers)	Citeable papers per year (average 2020-2022)	Citeable papers 2020-2022	Year										
											2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
Cement and Concrete research	Elsevier	17	17	2.1	3.3	1.3	1.7	198.3	264	793		0	0	0	4	3	3	5	2	0	
Construction and Building Materials	Elsevier	71	71	8.9	10.7	0.3	0.4	2805.0	3740	11220		2	4	3	8	17	16	12	4	5	
Materials and Structures	Springer	0	0	0.0	0.0	0.0	0.0	146.5	195	586		0	0	0	0	0	0	0	0	0	0
Cement and Concrete Composites	Elsevier	6	6	0.8	0.0	0.0	0.0	281.0	375	1124		0	0	0	3	3	0	0	0		0
Building and Environment	Elsevier	48	48	6.0	7.0	0.8	1.0	676.8	902	2707		0	0	0	0	15	0	17	4	6	6
*only data in repositories was counted, electronic supplementary materials like excel tables were not counted																					
Materials and Structures papers with ESMs (Electronic Supplementary Materials) attached as files											1	0	2	2	2	3	2	1	1	0	0
Average		28.4	28.4	3.55		0.46	0.62		1095	3286		0.4	0.8	0.6	3	7.6	3.8	6.8	2	2.2	1.2