# Digital Material Libraries: overview and application case

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**Abstract**
Information needs on building materials can be expressed by various stakeholders, both in the field of architectural practice (design and production), as well as in the field of built heritage (restoration, refurbishment, renovation, etc.). Tools are developed to meet these needs. This article will present an overview focused on one of the most common and practical tools in this context, namely digital material libraries. Examples will be discussed and the basic aspects that are essential to know, consider and include when developing such tools will be presented. The early stages of an application case in the context of Algerian architectural heritage will be briefly addressed.

**Keywords:** digital material library, material database, information need, intervention on built heritage

## 1 Introduction

The architectural design, regarding the new projects, and the conservation of the old built environment are two completely different processes, but they can be related in some aspects. On one hand, in addition to their intangible values that can be brought and created or inherited, it is a matter, in both cases, of operating on tangible units, consisting of a set of construction materials, implemented according to specific techniques. On the other hand, multiple needs in information allowing the proper progress of these processes are expressed by the different stakeholders, particularly at the time of the tasks requiring a perfect knowledge of the construction materials and the techniques of their implementation.

To meet these needs, once the documentation produced on these materials and techniques is capitalized and structured, its digitization, dissemination, availability and its practical and immediate accessibility becomes essential. In fact, the use of the digital version of knowledge vulgarization about those aspects is an obvious step, and its necessity has been illustrated by several studies (Over 2005, Kampfová 2010, etc.). However, this response does not seem that widespread in some countries, such as Algeria. Indeed, digital tools to practically manage and access the information about materials and techniques, are almost non-existent.

This work was primarily motivated by the existence of this gap and the importance of thorough knowledge of building materials for an accurate selection during architectural design processes and more particularly intervention on existing buildings. This article aims to provide an overview of one of the most common, rudimentary and practical tools for knowledge vulgarization on building materials, namely digital material libraries, as well as an example of

application in its early stages of development, for the context of the architectural heritage in Algeria.

For better understanding, and in the context of this article, a "material library" will be defined as: a space where a number of physical samples of materials are collected and organized in a thoughtful manner. Physical samples can be displayed in a variety of ways, depending on the space and furniture chosen: on shelves or displays, with drawers or sometimes in bins; hung on vertical panels in the case of small samples; or horizontally on tables or cabinets with large drawers. The samples allow direct physical contact and a concrete and visual appreciation of the sensory values of the materials. Thus, a digital material library would simply be, in a general sense, a virtual space to search, consult and learn about materials.

## 2 Why digital material libraries

In this article, the choice of digital material library is due to several reasons, among others, a first state of the art that allowed to notice the existence of many interesting examples, developed under different contexts, thus facilitating the understanding of their functioning and allowing to suggest ideas and aspects to be evolved and readapted according to the needs and objectives of all those wishing to develop their own digital material libraries. Furthermore, a digital material library remains a practical, often decision-support tool in the processes of architectural design (Hindmarch 2009, Wilkes 2018, etc.) and intervention on built heritage (Frangipane 2010, Kampfová 2010, Napolitano 2019, etc.), allowing to store, organize, disseminate, access, and exploit various materials information in a convenient and instantaneous way. This same choice also emerges from the unavailability of such tools in the Algerian context, as mentioned above, which could have assisted and responded to the information needs expressed by various stakeholders during their interventions on built heritage.

## 3 Working method

This work consisted of a continuous back and forth between two essential components, namely: the literature review and the search for examples of existing digital material libraries. The review of the published literature on the subject of digital material libraries was conducted using several academic research databases such as Scopus, Science Direct, DOAJ, Jstor, Taylor & Francis, Sage Journals, Wiley Online Library, etc., and using keywords mainly in English and occasionally in French. The part concerning the examples of digital material libraries was an online search using keywords and synonyms in both languages around the same theme. This paper will consist, on one side, in presenting illustrative and varied examples, developed under different contexts, and seek to extract the basic aspects to be known, understood and included when developing such tools. On the other, some aspects related to a project of digital material library applied to the Algerian architectural heritage, in progress, will be discussed. The latter is currently in its early stages, consisting of the data collection which will constitute the content of the database.

## 4 Discussion

### 4.1 Digital material libraries in published literature

The literature review revealed that material libraries, whether physical (as a real space) or digital (as a virtual space), are a very common and widespread concept around the world, which is not the case in Algeria for example, where they remain almost unknown. Moreover, most material libraries have digital access to their collections. Indeed, several studies, notably (Over 2005, Kampfová 2010, Jost 2011), have illustrated the necessity of using digital versions for the spreading and vulgarization of knowledge about building materials. A situation emphasized in particular by the limitation imposed by material libraries, where access to physical collections requires moving and is limited to a specific spatial area (Kampfová & Přikryl 2010).

During the process of architectural design or intervention on ancient buildings, and in order to assist and meet the needs in terms of information, expressed by various stakeholders at the time of choice and selection of materials, many digital tools have been developed and continue to be. Digital material libraries, or material databases are very common and practical examples (Ozao 2007, Scott 2008, Turmel 2016, Perucchetti 2020, etc.).

In the context of scientific research, digital material libraries or material databases can be developed, for specific, sometimes sensitive, domains, such as architectural heritage or old buildings in general. The fragility of the latter requires particular attention to the reliability and quality of information sources to be provided to users on building materials and the used techniques of implementation. This aims for a better knowledge and management of the resources of old materials, for an effective intervention on this type of buildings, in particular at the time of the choice of conservation or replacement methods. Historic stone has been the subject of several studies, such as: PierreSud (Dessandier et al 2013, 2016), historical and technical atlas of Burgundian building stone (Büttner 2011), electronic database of historical stone resources in Italy (Frangipane 2010), electronic database of historical natural stones of the Czech Republic (Kampfová & Přikryl 2010), building stone databases in the UK (Hyslop 2010), etc.

The availability of this type of material is one of the first aspects to consider before intervening. (Turmel 2016) is a representative example of studies that can be carried out for this purpose, often using Geographic Information Systems, allowing to list, identify, locate and inform not only on the provenance of a material but on the material itself. Digital reconstruction is another very common form of conservation of historic buildings. In the same way that tools are developed to assist a physical intervention, they are also developed to provide interdisciplinary data needed to facilitate digital reconstruction (Napolitano 2019). The importance of developing digital tools to address the need for information about materials in general is no longer up for discussion, whether for architectural designers or stakeholders intervening on the valuable building.

### 4.2 Online material libraries

It has been noticed that material libraries, whether physical (as a real space) or digital (as a virtual space), can be designed by institutions with diverse characters, belonging to distinct fields (construction, architecture, archaeology, materials science, engineering, different design disciplines, etc.). and therefore have very different scopes.

Indeed, in the case of online material libraries, the scope can be commercial, allowing to advertise, promote or sell products. This is, for example, the case of Material Lab - Johnson Tiles in London and Heylen Ceramics in Belgium, created and managed by manufacturers or traders. They can also be designed to offer resource and consulting services, as in the case of Innovatheque-FCBA Technological Institute in France. As for those created and managed by architectural offices, such as La MAT in France, the primary goal is to assist both designers and clients during the design process. Digital material libraries can also be designed for educational purposes, and most often, managed by academic institutions, to assist the teaching and learning process, especially for the different design disciplines. This is the case, for example, of the MLAB of the Aarhus School of Architecture, the Materials Gallery of the Colegio Oficial de Arquitectos in Madrid, the Material Research Collaborative of the University of Houston, the Institute of Making of the University College of London, the Materials Lab of the Austin School of Architecture, etc. In addition, the creation of a digital material library can be part of a scientific research project, such as the digital "technotheque" of the "Laboratoire Préhistoire et Technologie" of Paris-Nanterre university.

The content of a digital material library can vary depending either on the character and purposes of the institution managing it, or on the nature of the samples selected and presented, whether it is raw materials or debris of materials/objects, collected most frequently by historical, archaeological, artistic…etc. institutions, like the technotheque mentioned above. It can also be

about building materials or products, such as “ARCHI-MATERIAL”, “Digital environemental hub for global construction products”, “Sweets" for building product and manufacturer source, “BuildSite”, etc. often observed in the case of commercial or building consultancy companies; and sometimes even finished objects, generally found in design institutions, in its different disciplines, such as the material library of “Cité du Design” of Ecole Supérieure d'Art et Design de Saint-Etienne in France.

Therefore, these digital tools can be referred to by different names using the terms: materials or products and digital library, databases or collection, etc. It should be noted that in the context of this article, the expression "digital material library" will be used to designate all possible variants of forms and names that these last ones can take.

## 4.3 Aspects related to digital material libraries

### 4.3.1 FAIR principles and data management of digital materials libraries

The value of scientific data, especially that generated in the course of academic research, requires to be conserved and shared. The information produced during the design, creation or exploitation of digital material libraries are no exception. In order to achieve this, it is important to meet certain criteria and principles, including, as an example, the FAIR (Findability, Accessibility, Interoperability, and Reusability) principles for scientific data management (Wilkinson et al. 2016). Note that FAIR, as their name implies, is a set of principles and not a standard, they do, however, help facilitate systematic data reuse and sharing.

The data must first and foremost be easily found, which generally implies the implementation of online databases, which is the case for all the examples mentioned above. The metadata describing them must be rich, meaningful and identifiable in a unique and constant way, hence the need to choose illustrative categories/families according to which the content of the database will be organized and indexed.

Practical and instantaneous access to the data must then be possible, usually to the general public and therefore in open access, which is the case for the vast majority of the examples discussed; or it may be restricted, either from a certain level of information, or totally limited to certain categories of public, notably through a membership request, as is the case for MATERIAL CONNEXION.

A third extremely important aspect of the FAIR principles is data interoperability, which is recommended by the ISO, notably ISO 23387, which is one way to ensure this. Further research is needed to address this issue in the examples of digital material libraries cited above. Nevertheless, interoperability can be assured in various ways, some of which are discussed in the following.

As a matter of fact, each of these digital material libraries has been created in a particular context to respond to specific problems, goals and needs. The digital material library applied to the Algerian architectural heritage, which is part of our research, is no exception. The effort provided throughout the production, collection, processing, organization, and dissemination of data on the selected materials remains consistent. In order to avoid repeating these efforts, and consequently saving invaluable time, the interoperability of both the data and the computer systems used becomes at this stage an essential criterion to ensure.

In this regard, particular attention must be paid to the terminology to use, as well as to the way in which connections between all the data and metadata are made. This implies, particularly in the case of digital material libraries, the importance of the contribution of experts in the field of construction and built heritage during the different steps of the conception and creation of this type of specific databases. The data must obviously be stored in an open, machine-readable and understandable formats, using formal and common languages, so that the metadata can be exchanged and combined with other data, in the short and long term. This approach will allow the connection, sharing and collaboration of the different stakeholders, despite their different fields of expertise and visions, involved in the decision making related more particularly to the aspect of materials and products in the field of construction or, in our case, of the intervention on the built heritage in Algeria.

The introduction of BIM can be considered as one of the main solutions in this matter, especially through the open file format IFC (Industry Foundation Classes), which ensures interoperability between different software, and which has become an international standard, used for the exchange and sharing of data in the construction field. Regarding the cultural heritage domain, ongoing research (Diara & Rinaudo 2020) are aiming to propose experimental IFC to be implemented in HBIM. Concerning the development of HBIM, especially in the Algerian context, where the use of digital tools in the field of architectural heritage (for the capitalization of knowledge, preservation of know-how, management, etc.) still few steps behind, the creation of a digital material library applied to the built heritage may have a very significant impact in this direction.

All the data collected, produced, shared and exploited during the process of designing, creating and using digital material libraries, like any other database, must be reusable, in the long term, in the most optimal way. This is possible through the use of a variety of attributes for their description, that are specific and relevant to the construction or built heritage field and to the specific objectives set beforehand, in order to meet the needs of the users. In addition, in most of the examples cited, documentation and resources are made available for download for probable citation or reuse.

#### 4.3.2 Forms of digital access

The search and digital access to the content of the material libraries can be done either online or offline, and can take different forms, which can be organized into 3 main categories.

Connected material libraries, in which the connection is made through electronic chips or QR codes inserted in the physical samples, to be scanned with a mobile device or a tablet, allow automatic and instant access to the digital format of the information about them. This is the case, for example, with "matériauthèques Campus" of the start-up ARCHI-MATERIAL in France. Through the instant access to the data, this approach saves a considerable amount of time but is only possible with in-situ presence. This does not prevent the fact that it can be possible to access the material database independently of the physical samples.

Material libraries that are not connected to the physical samples, but whose digital version of the collection can be accessed in different ways: website (E-commerce, search engine, etc.), a private database, specific to the institution managing it, such as the Material Lab of Pratt Institute, or a database shared between several institutions.

And finally, material libraries existing only in digital version, accessible from the same previous possibilities, for example: MATERIAL DISTRICT, and to which, in some cases, different institutions can subscribe. This is also often the case of material databases developed for scientific research purposes.

#### 4.3.3 Research modes

Access to the content of a digital material library can be done through different search modes. These are often predefined headings, which can be selected by simple click, or by checking several of them at the same time in certain cases. This is the example of Material Lab at the School of Architecture of the University of Texas at Austin, or the Material Research Collaborative of University of Houston. Searching by text entry or keywords is one of the most common modes. Furthermore, in digital material libraries, the use of images is very common, as in the example of the MLAB of the Aarhus School of Architecture or Material Lab of Pratt Institute, etc. Images can be used as a search mode, where the different headings are represented in graphic or photographic form; as a search result; or both at the same time. Indeed, the image is the most appropriate way to represent a physical object (in our case materials), this allows the user to quickly spot the product or material he is looking for. In many cases of digital material libraries, several search modes are combined as in Material District, Raumprobe in Stuttgart, etc. This allows to filter the data according to several levels and reach relevant search results.

#### 4.3.4 Content organization

Depending on the nature of the digital material library, its aims and specialization, and the information needs of its targeted public, the organization or indexing of the content of the database related to the material samples is most often done by material family/composition (

ceramic, composite, hybrid, glass, metal, natural, polymer, wood, stone, plastic, mineral, textile, paper, etc.); or by use/application (shell, foundation, structure, interior or exterior cladding, floor or wall cladding, envelope, roofing, insulation, finishing, joinery, etc.). There are several other aspects according to which materials can be organized such as the manufacturing process (casting, molding, filling, finishing, surfacing, assembling, bonding, deforming, machining, rapid prototyping, etc.); the state/nature (binder, solid, liquid, gas, rigid, aerated, etc.); appearance aspects (gloss, translucency, texture, weight, colors, etc.); form (aggregate, bar, angle, fiber, plate/board, etc.); origin and provenance, etc. In most cases, several forms of organization and criteria are combined offering a larger research options.

#### 4.3.5 Search results

A digital material library allows to store important amounts of information, which is sometimes impossible to provide directly/physically to the users, who can express various needs relating to information about different aspects of materials. To meet these needs, it is important in a first level to provide general information allowing the identification of the material (Name, family, description, etc.) with notably illustrations (graphic or photographic representations) as well as technical data (composition, various properties, etc.).

The nature of the remaining information and the level of detail to be provided may vary according to the character of the institution managing the digital material library and the context in which it was developed. In addition to the aspects mentioned above, those with a commercial scope will tend to provide information on the fields of application (the current uses/suitability, projects that have used it, etc.), and data concerning the origin and provenance of the material, as well as the prices, and contact details of manufacturers, often throughout external links, allowing direct access to the website of the product or manufacturer.

Data on manufacturing processes, installation techniques, maintenance, etc. are important for theoretical learning and teaching, as well as for practical and professional purposes. Users of certain design disciplines (Architects, interior designers, etc.) may be particularly interested in aesthetic and appearance aspects (shape, dimensions, size, weight, colors, textures, etc.).

When the material allows us to orient the design and production practices for a positive impact on the health and the environment, the ecological, environmental and sanitary data concerning it are reported according to various aspects. They can indicate if the resource is renewable or finite, if the material can be re-used or if it is recyclable. The data may include any labels and certifications awarded to the materials (Health Product Declaration, Environmental Product Declaration, Cradle to Cradle, etc.).

In order to ensure one of the FAIR principles related to data reuse, a documentation is made available in some cases in the form of references, bibliographic resources or videos, and sometimes downloadable material/product or technical sheets in PDF format, etc. A citation option (of the product, the information about it or the website containing this information) is sometimes possible. The user can request for more information when needed.

## 5 Application case in the Algerian context

### 5.1 The relevance of a digital material library in the local context

A perfect knowledge of the different aspects related to materials and construction techniques of the architectural heritage is a prerequisite for any intervention process on the latter, especially at the stage of choosing a suitable material or an appropriate treatment method. In this regard, a digital material library applied to the context of the Algerian built heritage is being developed in the ongoing scientific research which is estimated to contribute significantly to meet the information needs expressed by different profiles during interventions on this type of building.

In the local context, this knowledge is necessary, first of all, during the stage of the multidisciplinary analysis and study and the preparation of the expertise report, which are among the phases of the intervention process recommended by the REHABIMED method. Another practice could possibly benefit from the contribution in information that a digital material library applied to heritage could offer. It is, in this case, the archaeology of the building, which allows the recognition of the tools and constructive techniques of implementation, a better knowledge of the

materials and their characteristics, the pathologies of deterioration and the possible techniques of treatment. In addition, one of the canonical parts of the architectural monography is the architectural description and analysis of the building, where, in particular, a description of materials and structures, and therefore a perfect knowledge of them is necessary. It is also important to note that, during the constitution of classification files of the cultural properties as historical monuments (a determining step in the process of patrimonialization), a perfect knowledge of the property to be classified is a decisive aspect, and this induces notably a thorough knowledge of its materials and techniques of implementation.

These examples are among many other processes and decisive moments during which it is important to have answers on when, why, where and how to use materials and techniques in the particular context of Algerian architectural heritage. The digital material library that is being developed in this context aims to be a practical tool contributing to meet these needs.

### 5.2 Aspects to consider for the application case

In addition to the aspects discussed above (section 4.3), the elaboration of a material library applied to the Algerian architectural heritage requires the consideration of certain particularities related to this context. First of all, the organization of the inputs concerning the materials, must be done according to different levels of information related to the materials, from the general to the particular. It will be necessary to use, on one hand, common categories, by family, by application, etc., on the other hand, certain aspects can be proposed to meet the needs of the field, where the organization by geographical region, by historical period or by constructive typology would be relevant possibilities. The taxonomy forming the structure of the database will be developed based on published literature sources. The use of a controlled vocabulary is a prerequisite, such as the Architectural Descriptive System, ICOMOS glossaries, ATT, etc.

For the research results, the information to be included must cover different aspects and must allow the identification of the material (by text and visualization); its different uses, whether by product (plaster, brick, tile, etc.) or by location in the building (load-bearing wall, floor, roofing, etc.); the techniques of implementation and construction principles (casting, formwork, type of installation, layout, dimensions, quantity and dosage, etc.); its technical aspects, composition, performances and weaknesses and different properties (hardness, porosity, density, resistance to the action of water, thermal insulation, etc.), the pathologies related to both the material and the technique of implementation adopted; and finally, the possible techniques of treatment or strengthening.

## 6 Conclusion

Despite their simple use and basic appearance, digital material libraries remain true sources of information, which are much more than a simple compilation of data. Their development requires a perfect knowledge of the domain they are dealing with, and more particularly during the first phases of design of the conceptual scheme of their database concerning the content to be included and its logical structuring. This article remains a brief version of one of the initial steps of a study concerning the development of a digital material library applied to the materials used in built heritage in Algeria, aiming at assisting and answering the information needs of the various stakeholders during restoration and rehabilitation operations. The project is in its early stages, which makes the research presented in this paper a necessary passage that allows for a better understanding of the basic principles of these digital tools operation, thus allowing to direct certain choices and decisions at the time of the development of our digital material library, while operating readjustments according to a specific context. Once the database has been implemented, it is expected that it will provide a continuously upgraded resource for future conservation and restoration projects.

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