MADA: online experimental database for mechanical modelling of existing masonry assemblages

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SUMMARY:
Mechanical modelling is a key step of the seismic assessment of existing masonry constructions. Unrealistic assumptions on masonry properties can lead to unreliable seismic performance predictions, resulting in the lack of safety (if capacity is overestimated) or even useless strengthening interventions (if capacity is underestimated). Therefore, the authors collected experimental data available in the literature to support researchers and practitioners in mechanical modelling of masonry and its constituents. Such data were implemented in MADA (MAsonry DAtabase), an electronic database which can be used in the Internet.
This paper presents the main features of MADA which allows to select experimental data from about 400 electronic files associated with more than 100 research papers and reports. Each file provides detailed information on tests, specimens, and measured/computed data. MADA can be updated over time to improve knowledge on existing masonry assemblages and to promote statistical analysis of experimental data for seismic code revisions.

Keywords: experimental data, masonry, mechanical properties, online database

1. INTRODUCTION

The definition of mechanical properties plays a fundamental role in developing a capacity model of an existing masonry construction. This is often a challenging task either for researchers or practitioners because seismic capacity of masonry constructions is typically very sensitive to modelling assumptions. Unrealistic hypotheses on masonry properties can lead to unreliable seismic performance predictions, resulting in the lack of safety (if capacity is overestimated) or even useless strengthening interventions (if capacity is underestimated). It is also emphasised that mechanical modelling can be even more crucial than computational accuracy of structural analysis methods when only visual inspections, rather than in-situ tests, are carried out on the masonry construction to be assessed. According to Eurocode 8 (CEN 2005a) and the Italian building code (IMIT 2008), a confidence factor should be applied to material properties to account for uncertainty in the knowledge of the structure. Based on such considerations, a high priority level was assigned to the collection of experimental data available in the literature in the frame of the ReLUIS-DPC 2005–2008 project (Manfredi and Dolce 2009). Then the authors preliminarily developed an Italian database called *Database Murature UNINA-DIST*, which was implemented in the official website of University Laboratories Network of Earthquake Engineering (ReLUIS) [URL: http://www.reluis.it/dbuninadist/].

The lack of tools for computer-aided mechanical modelling of masonry motivated the authors to expand that database during the ReLUIS-DPC 2010–2013 project, creating *MADA* (*MAsonry DAtabase*) which is available in the Internet for worldwide online use on ReLUIS website [URL: http://www.reluis.it/index.php?option=com_mada&Itemid=156]. A twofold objective was thus reached: (1) collection of reliable experimental data for structural analysis; (2) development of a dynamic data management system for rapid selection of experimental estimates of masonry properties. Experimental data were derived from research papers, reports, and textbooks (Augenti 2000). MADA

can be updated over time to include the latest experimental results on masonry tested in different countries according to national and international standards. Such a database can also be employed for statistical analysis of masonry properties in order to include reliable ranges within building codes. For instance, some revisions were proposed by Augenti and Parisi (2009) for reference ranges and modification factors of the main mechanical parameters of tuff masonry, which are provided by Annex C8A.2 to the Italian building code commentary (IMIT 2009). The main features of MADA are presented herein providing a few examples for its use. Experimental data on mechanical properties of masonry and its constituents, namely masonry units and mortar, were selected from more than one hundred research papers and reports and were collected in about four hundred electronic files. Each file includes general information on scientific sources where experimental data were published, as well as detailed information on specimens, test type, and measured/computed data. Experimental data can be selected by means of single or multiple keywords in order to define the data sample size and hence the accuracy of the experimental data selection. In the case of masonry testing, MADA allows to identify corresponding tests on masonry units and mortar. Any data set can be gathered by searching for specific papers, materials, test types, or measured/computed parameters. MADA includes five sections (Fig. 1): Home page; Notation; Masonry unit; Mortar; and Masonry. The "Notation" section is crucial for data analysis because it defines symbols, units and description of all parameters included in the database.

Figure 1. MADA homepage

2. SEARCH FOR MASONRY UNIT PROPERTIES

Experimental data on masonry unit properties can be selected through the masonry unit search page shown on the left in MADA homepage. Such properties can be searched by file, title/author of research paper or report, test type (bending, compression, direct/indirect tension), test effect on specimens (destructive, minor destructive, or non destructive tests), measured parameter, and type of masonry unit. Drop-down menus help the user in the definition of each selection parameter, allowing multi-criteria search. The number of available files appears in round parentheses along with each selection parameter and the list of research papers and reports is provided by clicking on the "search"

button. Multi-criteria selection often provides a lower number of results compared to its single-criterion counterpart, but it allows to get more detailed information on specific mechanical properties. Figure 2 shows the selection of a file containing experimental data on tuff stones, based on a single-criterion search by test type. Files can be related to masonry unit specimens (in such a case, the file code is preceded by the symbol "EL") or masonry specimens including the masonry units of interest. The typical masonry unit file is composed by five sections.

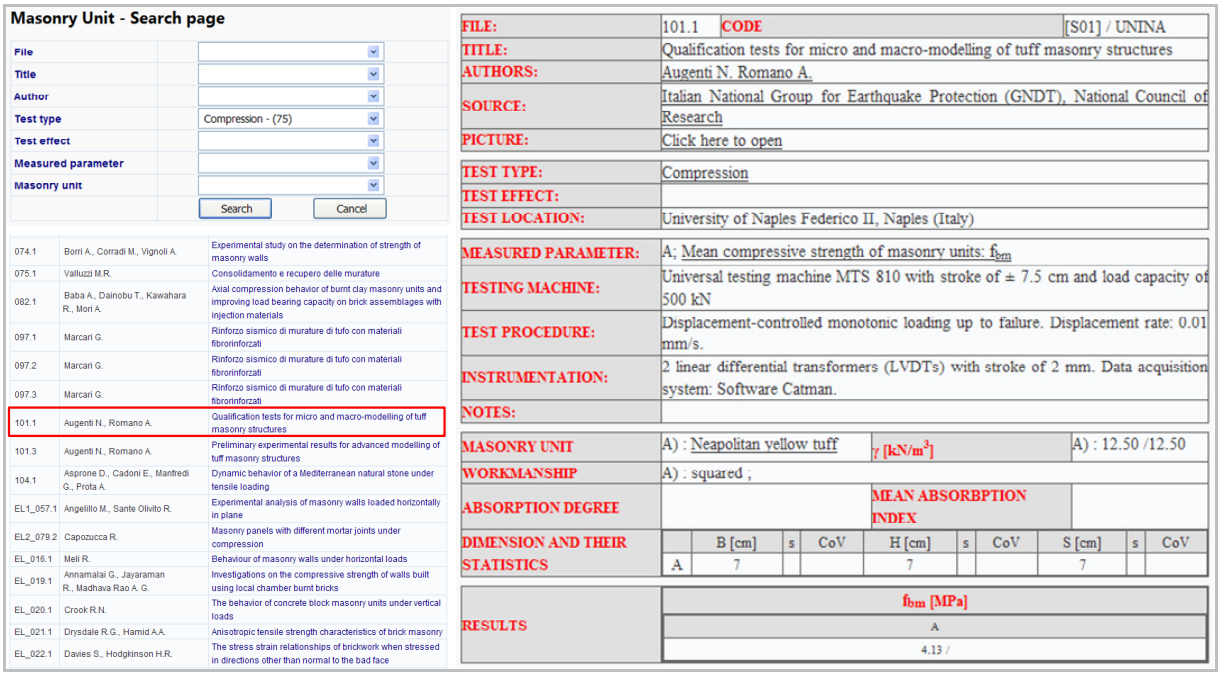

Figure 2. Single criterion-based search for masonry unit properties and file selection

The first file section in the upper part of the screen includes the following general information of the paper or report from which experimental data were collected: file number and code; title; authors; source (e.g., journal, conference proceedings, internal report, research project deliverable); publication year; and pictures representing test setup or specimen. The PDF file of the document and pictures (if available) can be opened to gather further information on the experimental work. The second file section provides general information on the test, namely, specimens, test type and effects, as well as the location of tests. The third file section provides detailed information on parameters measured on one or more specimens, testing machine, test procedure (e.g., monotonic or cyclic loading, force- or displacement-controlled loading, loading rate), instrumentation, and additional notes needed for a better understanding of experimental data. The fourth file section describes specimens in terms of: materials; range of unit weight; workmanship; specimen condition at the time of test; absorption degree; mean absorption index; size and statistics (mean square error and coefficient of variation) of each specimen; experimental results in the form of ranges or single values related to each specimen. Diagrams and equations included in the document are also indicated. It is emphasised that a click on authors, source, test type, or measured parameters allows to open a list of files associated with information being selected.

3. SEARCH FOR MORTAR PROPERTIES

Mortar properties significantly affect the masonry behaviour and their definition is needed for (1) direct implementation in analysis programs, (2) characterization of masonry properties through empirical equations provided by building codes (CEN 2005b, MIT 2008) and literature (Augenti 2000, Tassios 2010), and (3) qualitative reflections on the type of masonry to be studied or modelled which are important especially in the case of historical constructions.

Mortar properties can be selected from files related to masonry specimens or specifically addressing mortar specimens (in such a case, the file code is preceded by the symbol "M"). The procedure used to select experimental data on mortar properties is depicted in Figure 3. The search page allows to perform data selection by file, title/author of research paper or report, test type (see Sect. 2), test effect on specimens, measured parameter, and mortar type. Also in this case, drop-down menus help the user in the definition of each selection parameter, allowing multi-criteria search. The number of available files appears in round parentheses along with each selection parameter and the list of research papers and reports is provided by clicking on the "search" button. The typical mortar file is composed by five sections. The first, second, third and fifth file sections are equal to those presented in Sect. 2 for masonry unit files, whereas the fourth section provides information on type and composition (by weight or volume) of mortar specimens, in addition to the range of unit weight. Notes on mortar curing and experimental diagrams are also provided, if available.

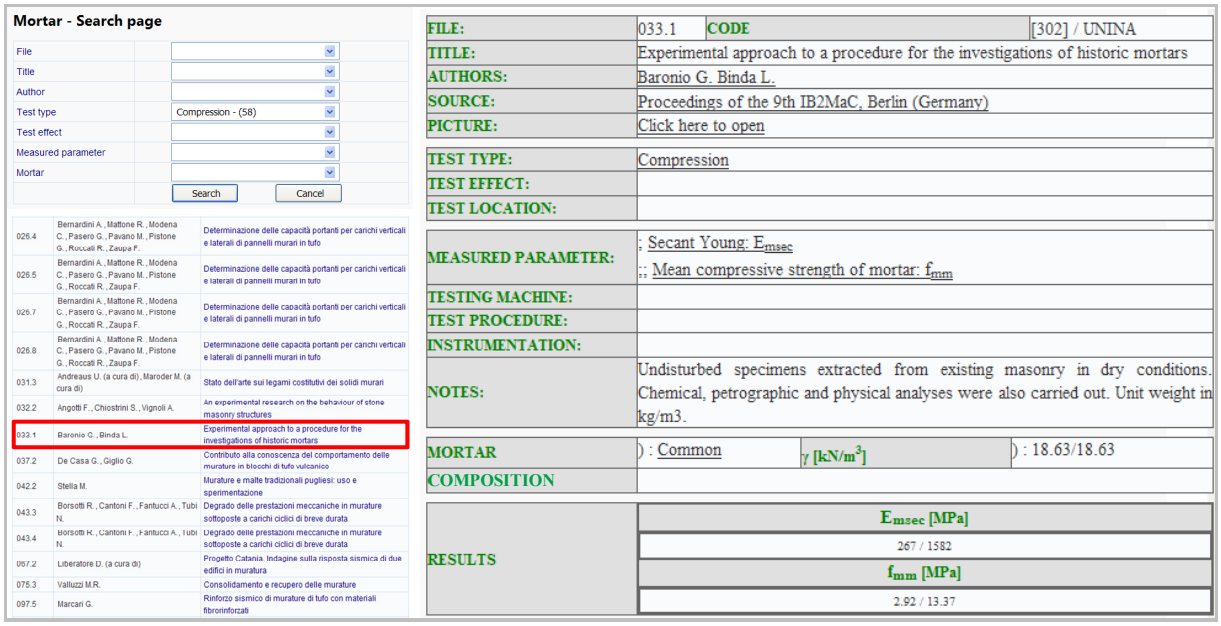

Figure 3. Single criterion-based search for mortar properties and file selection

4. SEARCH FOR MASONRY PROPERTIES

The section related to experimental data selection of masonry properties is certainly the most valuable tool in MADA. Masonry properties are always needed for structural analysis of masonry constructions with the exception of nonlinear finite element (FE) analysis based on micro-modelling approach (Lourenço 1996). In the latter case, the modeller is interested in mechanical properties of masonry units (e.g., bricks, blocks, stones) and mortar which are to be separately modelled. Conversely, masonry is treated as a unique homogeneous material in both macro-element methods (Augenti 2000, Parisi 2010) and macro-modelling FE approaches.

Figure 4 outlines the procedure for experimental data selection of masonry properties. The search page allows to gather data by file, title/author of research paper or report, masonry assemblage (e.g., 2-leaf or rubble masonry), specimen type (i.e., column, prism, panel, core, couplet, triplet), masonry bond, masonry unit, mortar type, test type (i.e., bending, bond, concentric/eccentric/diagonal compression, compression and shear, direct tension, fatigue, Sheppard, splitting, shaking table) parameter measured on masonry units, and parameter measured on the whole masonry specimens. Both single-criterion and multi-criteria data selections can be carried out to gather data at different aggregation levels. MADA provides a list of files including masonry properties after the "search" button is clicked. Then the user can select the file of interest, which is composed by six, rather than five, sections. Both the first and second file sections providing general information on source and testing are identical to those of files

on masonry units and mortar. The third file section includes the type, size and statistics of masonry assemblage, whereas the fourth file section provides type, size and statistics of masonry units, as well as tests and results on masonry unit specimens, if available. The fifth file section gives information on type and composition of mortar, as well as tests and results on mortar specimens if available. Finally, experimental results on masonry specimens are provided in the last file section where assemblages of masonry units and mortar are also reported.

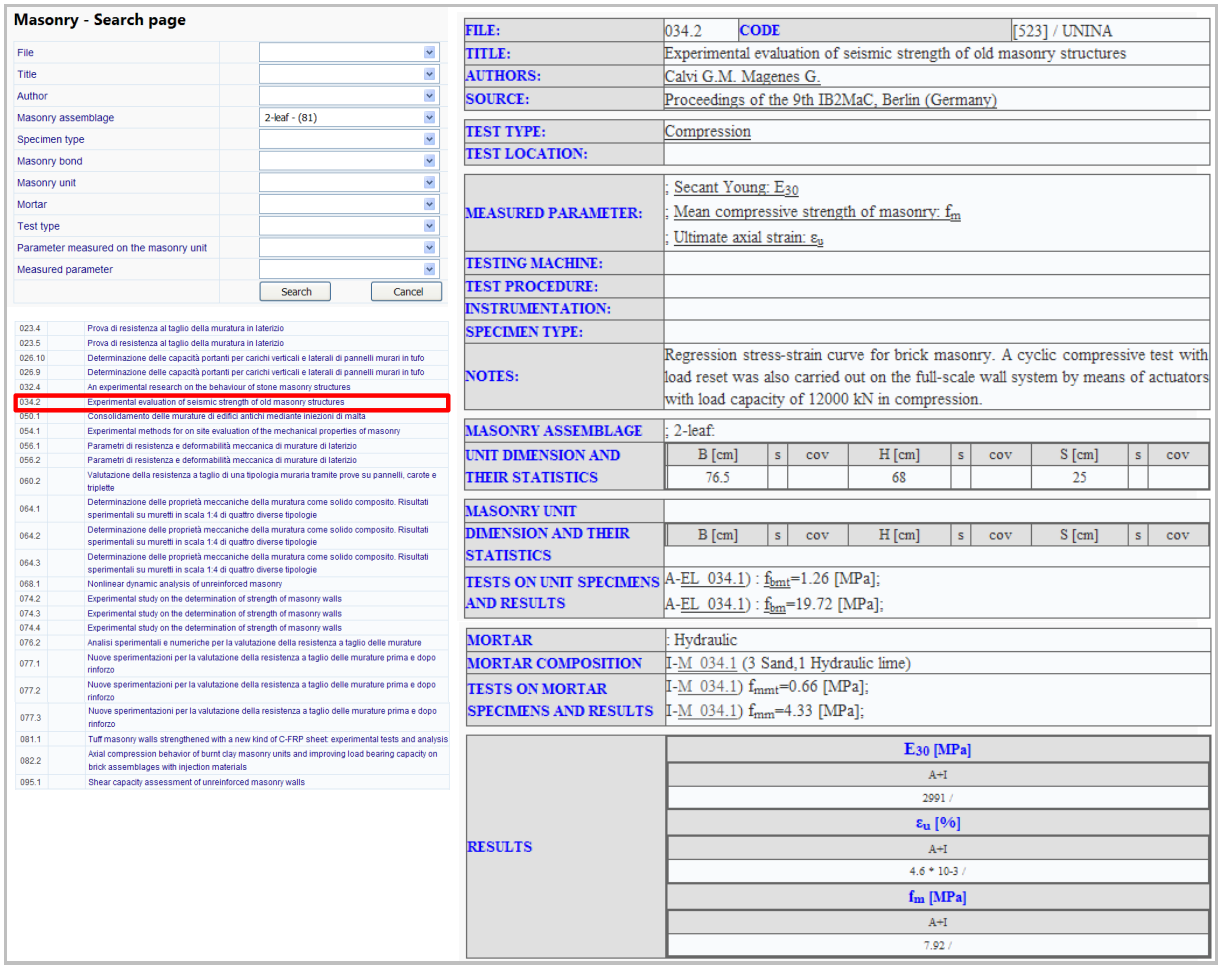

Figure 4. Single criterion-based search for masonry properties and file selection

5. CONCLUSIONS

An online archive named MADA (MAsonry DAtabase) has been presented in this paper in response to both research and practice needs. This tool provides valuable experimental data for mechanical modelling of masonry assemblages and their constituents, namely, masonry units and mortar. Data available in the literature were gathered from more than one hundred research papers and reports and were collected in about four hundred files. The organization of each file including detailed information on tests, specimens, and measured/computed data, has been discussed. MADA will be updated over time to improve knowledge on existing masonry assemblages and to promote statistical analysis of experimental data for seismic code revisions.

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