

OBTAINING PHYSICAL PROPERTIES OF A COMPOSITE PLASTER MORTAR THROUGH A CAE ANALYSIS

A. MUSTEA¹ D. L. MANEA¹ Y. A. ORBÁN¹ E. JUMATE¹
R. MUNTEAN²

Abstract: *Continuous improvement of knowledge represents one of the most important requirements in the field of materials engineering when developing new and more efficient materials. The purpose of the present paper is to achieve the physical properties of a reinforced plaster mortar, starting from the individual characteristics of each component material. In order to complete this case study, a CAE software based on Finite Element Method was used. The findings of this simulation are seen as immediately applicable and represent a modern approach on the “lifetime prediction” of the many new designed materials to be found in the market.*

Key words: *simulation; knowledge; fiber reinforced composites; plaster mortar.*

1. Introduction

With a modern society in continuous development, both the industry and the manufacturing technologies of materials in the field of civil engineering (but not only), have received considerable advances. At the same time, investigative methods have become increasingly powerful.

1.1. Theoretical Background

In the past, testing a specimen was done through repeated physical attempts (by using destructive methods), but, nowadays, there are software products that can simulate several types of materials behavior, under different stress conditions.

The research starts from the idea that today's software allows a realistic approach to materials by computing and revealing engineering constants of materials (e.g. composite mortar), including stiffness, Young's modulus, Poisson's ratio, etc. These simulation and modeling techniques help to better understand the overall behavior of the materials, and their practicability is of a real use when performing efficient civil engineering designs.

These solutions are already implemented in industries such as automotive, aerospace, consumer electronics, material suppliers, medical devices and many others [2].

¹ *Technical University of Cluj-Napoca*, str. Memorandumului, nr. 28, Cluj-Napoca, 400114, Romania.

² *Transilvania University of Braşov*, str. Turnului, nr. 5, Braşov, 500152, Romania.

The procedures and the ideas presented in this paper can be considered a novelty in the field of civil engineering due to the approach to building materials as part of the construction industry.

1.2. Research Methodology / Objectives

A composite mortar reinforced with synthetic polypropylene (PP) fibers was chosen for investigation. For this purpose, the FE module of Digimat was used, which is “the state of the art” linear and nonlinear multi-scale material modeling software [6], well-known for its ability to predict and evaluate the lifetime of structures.

The experimental frame includes a routine for defining the microstructure of a synthetic fiber reinforced plastering mortar in order to obtain a valid RVE (representative volume element), computing a solution and achieving results.

It is possible to analyze the particular behavior of a plaster mortar reinforced with synthetic PP fibers, or by extrapolation it is possible to study the behavior of other composite elements.

The results can lead to a more appropriate manufacturing process, ultimately aiming at reducing total costs and increasing production efficiency.

2. Experimental Program

A new mechanical analysis is started using Digimat-FE material modeler and code solver, choosing a 3D type of RVE, as shown in Figure 1, presented below.

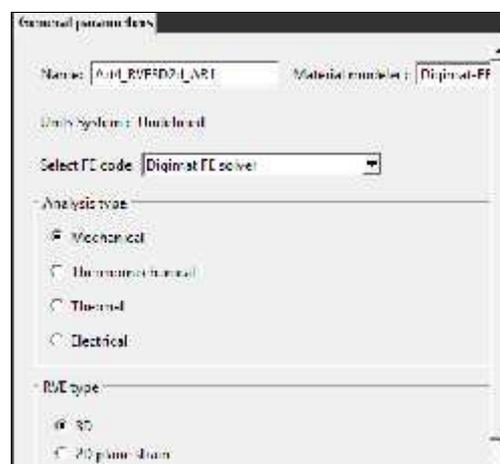


Fig. 1. *General parameters to be set*

In order to introduce a new material, the minimal physical properties, such as Young’s Modulus and Poisson’s ratio, must be provided. It must be taken into account that the software unit system is undefined.

For a plaster mortar (simplified elastic model) these characteristics are considered similar to concrete [1] and can be seen in Figure 2a and 2b.

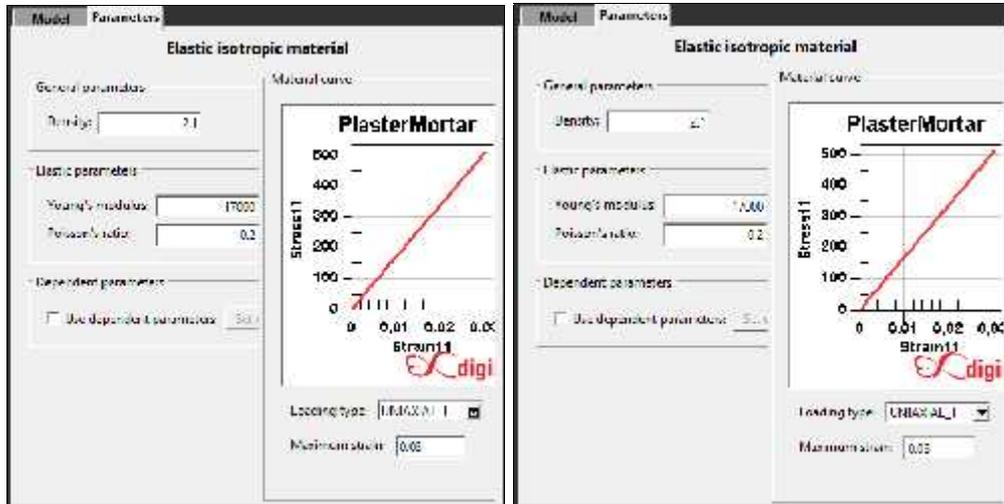


Fig. 2. a) Plaster mortar properties and b) polypropylene fibers properties

After PP fibers were stated as an independent material, the next step is to establish the components of the composite microstructure, which are the “Matrix” consisting of “PlasterMortar” material, respectively the “Fibers” consisting of “PPfibers”.

As parameters, the VF (Volume Fraction) of phase “Fibers” is calculated as being equal to 0.0010977 and the number of inclusion is set to 10.

Also, the inclusion shape is stated to “Cylinder”, which provides a shorter processing time for geometry and mesh generation (compared to ellipsoid shape for example). AR (Aspect Ratio) is set to 60 in order to obtain cylindrical (not spherical) inclusion shape.

For the same computational reason, the orientation of the inclusion was set to “Random 2D”.

After setting the type “Single layer analysis” and the size “User defined” (0.25;0.25;0.25) of the RVE, its geometry can be generated (Figure 3).

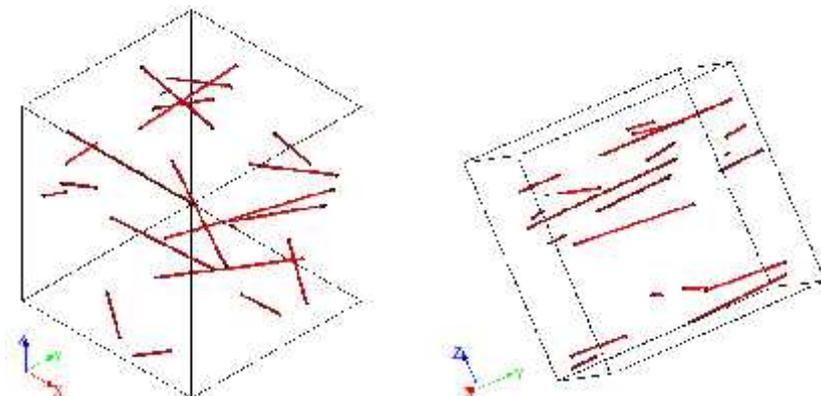


Fig. 3. The generated 3D RVE, with a 2D plane disposal of the inclusions

However, the mesh cannot be generated until the loadings are created.

In the “*Mechanical loadings*” tab, the BC (Boundary Conditions) type is set to “*Dirichlet (displacement)*”, while the loading source is left “*Digimat*”. A “*Biaxial1_2*” load will be applied to this volume element.

Although, depending on the loading direction (strain component), the peak value can change in a varied load range, this time it is left default (0.03).

In this simulation, a simplified model was preferred, reducing the RVE compared to the suggested size and reducing the number of fibers to 10 pieces, also setting the mesh type to “*Tetra*” (Figure 4) with “*User defined*” element definition (max:0.040; min:0.025; CC:off), the calculation time being directly proportional with these variables.

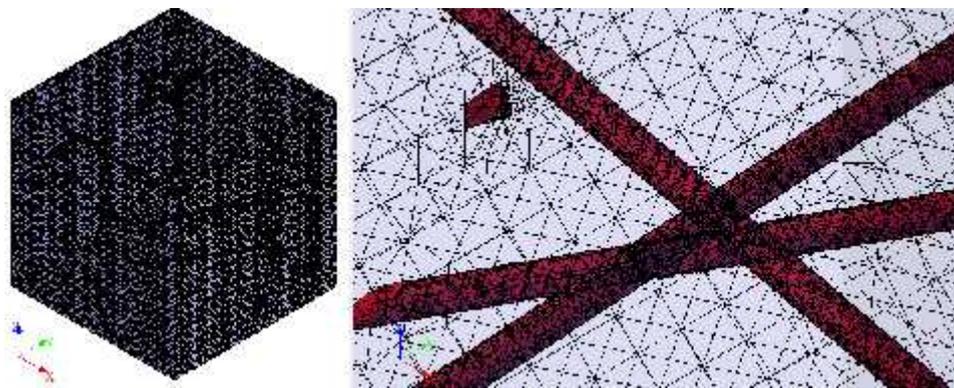


Fig. 4. A mesh preview of both the matrix and the fibers

3. Results and Discussions

The first significant result that can be noticed right after the meshing process is done and the FE (Finite Element) solver analysis job completes, is that the efforts distribution can be visualized. To follow this, a few characteristic diagrams are presented in Figure 5 a), b) and c).

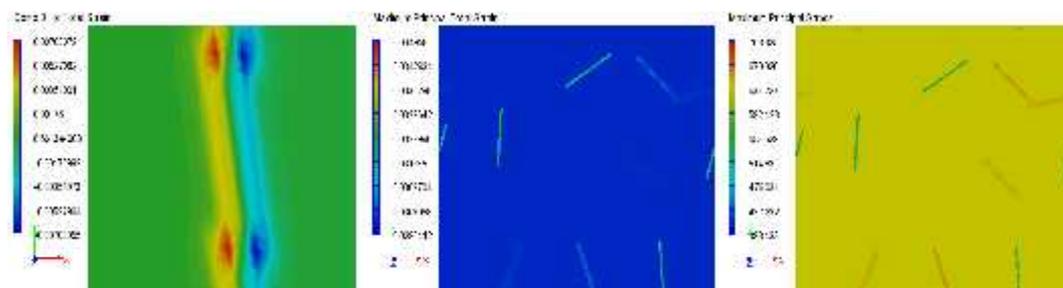


Fig. 5. a) Strain distribution along the fiber b) Maximum strain and c) Maximum stress

On the other hand, in order to achieve the engineering constants, the file “*analysis_name.dat*” must be imported in the MF (Mean-Field homogenization) module of Digimat software, and a quick calculation needs to be carried, as indicated in Figure 6 below.

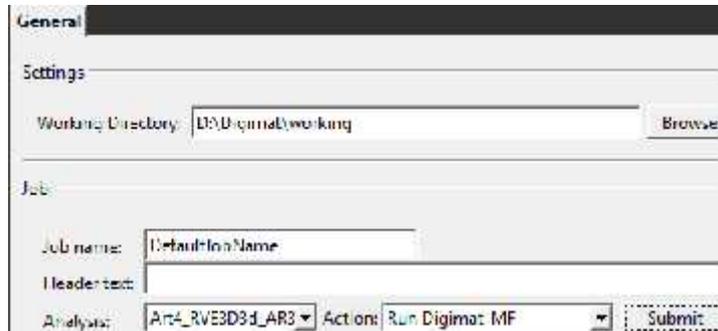


Fig. 6. Running an analyze in Digimat MF in order to obtain the solution

An “.eng” file is then generated, through which the sought values are revealed. Stiffness results are shown in Table 1, namely the in-plane / out-of-plane Young’s modulus, in-plane / transverse Poisson’s ratio, together with the global density of the composite, as provided by Digimat MF.

<i>Stiffness values</i>		Table 1
Crt. no.	Engineering constants	Value
1	In-plane Young’s modulus	16982
2	Out-of-plane Young’s modulus	16978
3	In-plane Poisson’s ratio	0.20021
4	Transverse Poisson’s ratio	0.20035
5	In-plane shear modulus	7074.4
6	Transverse shear modulus	7072.2
7	Global density	2.0987

4. Conclusions

This research paper shares practical knowledge concerning the properties of the less tested polypropylene (PP) Fiber Reinforced Composite Mortars [3], [4].

The 3D mapping shows that the stress is concentrated around the fibers, which is correct, given the friction force with the matrix that occurs while “*the sample*” is subjected to loading.

The graphical presentation of data processed is useful not only for other input variations of this particular material, but for future research in general.

All the above-mentioned variables that influence the computing time and the generation of geometry or mesh, are particularly important and must be handled with care.

For example, a more complicated geometric shape will have many more nodes (which are difficult to mesh and to deal with), resulting in a long calculation period, that is not desirable in this case (or in most cases).

The results of the experimental frame have graphically highlighted the so called “*weak areas*” of a specific pattern. Revealing these areas among with other physical properties,

they can be easily considered and handled properly during the design process of a composite.

An accurate solution can be obtained only after experimental gain of the physical constants submitted in the analysis, otherwise accepting that any small variation of the input values can lead to erroneous results [5].

The original contributions of this research concern the identification of some very important material coefficients that are required during the design process in order to provide faster and accurate results, based on an improved technology. It was also wanted a brief walkthrough the steps to be followed for modeling a 3D RVE of a composite, to observe the random layout of the fibers and to discuss the parameters that influence computing time and mesh / geometry generation in order to optimize it.

The findings of the tests are useful, because through the precise modeling method a new material adapted to the requirements of the current market is developed, improving knowledge both in Computer Aided Design and composite materials domain.

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