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UPC BARCELONATECH

Industrial Training Final Report

International Centre for Numerical Methods in Engineering, CIMNE

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Acknowledgement

First of all, I want to thank all the CIMNE workers who have helped me, especially Antonia Larese and Ilaria Iaconeta for all the support they have given me during this internship. Thanks to them I think it has been a very pleasant experience, through which I have acquired multiple knowledge and skills that will be very useful for my future work and professional life.

1. Introduction

To put in situation before starting the Industrial training in CIMNE, I was in the second year of the Master in Numerical Methods in Engineering, in the second semester, although most of the practices I did in summer after finishing that semester. I had completed all the subjects of the Master (corresponding to 75 ECTS) and I still had to do the internship or Industrial Training (15 ECTS) and the Final Project or TFM (30 ECTS) to complete the degree.

I got the internship at CIMNE thanks to the teacher Antonia Larese, since my academic situation was a little complex because I was studying two masters at the same time (Master of Numerical Methods in Engineering and Master of Civil Engineering), I needed to attend classes because I was doing the subjects of the first year of the Master of Civil Engineering. I told Antonia that I would like to do industrial training at the same university to be able to combine it and also because I consider CIMNE to be a reference in computational mechanics.

I believe that these practices have helped me to apply concepts acquired in the master's subjects, as well as to familiarize myself better with the work environment that I can have in the future.

2. Work environment

As we know, the International Centre for Numerical Methods in Engineering (CIMNE) was founded in 1987 on the North Campus of the Polytechnic University of Catalonia under the auspices of UNESCO. This centre is an autonomous research and development centre that currently has more than 200 researchers from more than 50 countries around the world and organizes annual courses, conferences and seminars that keep us present in many cities around the world. In addition, the centre stays in contact with researchers from around the world to allow a constant exchange of knowledge.

My work environment was in an office where several PhD students work, each of which is dedicated to different programs and applications within computational mechanics and the calculation of structures. The development of codes applied to the world of engineering, especially civil engineering.

In this work environment, I worked with Ilaria Iaconeta, she was the one who helped me and taught me what was the code and the method we used: Material Point Method (MPM). Ilaria was always very attentive and has been very kind to me, so I thank her very much for the treatment I received, her help and all the knowledge she has taught me. In addition to Ilaria, Antonia Larese supervised our work and helped us analysing the results and giving us ideas for possible code improvements.

My work during the industrial training was to use the Material Point Method to perform various analyses that we already know, such as the analysis of a compression test in a concrete sample, brazilian test, shear test, etc. After performing the analyses, my job was to observe the results, see how the sample breaks, if it was the expected one, if it happened for the tension it had to be, if the stress-strain curves were correct, etc ... All the analyses were compared with the laboratory and DEM results.

In short, my job was to learn how to use and apply the code on a structure, to learn how the code was structured, to be able to understand and interpret the results, to learn how to modify the code based on interest, to know the different files and to know where everything is and thus be able to modify the code adapting it to each case. At the end of the analysis of the results the purpose was to see if these results were the expected ones, and therefore validate the code.

The MPM code is a code in C ++ language, so the operating system used was Linux. This application of particle mechanics is within Kratos, so, in addition to knowing the material point method, I have also become familiar with the Kratos program in general, which I consider to be very important in the future. Kratos Multiphysics is a framework for building parallel multi-disciplinary simulation software. Modularity, extensibility and HPC are the main objectives. This framework is written in C++ with extensive Python interface and has BSD license.

On the other hand, I also highlight the improvement of knowledge regarding continuum mechanics subject since all the analyses were done using damage models and therefore observing in the final result the damage on the structure (test piece).

3. Acquired experience

3.1. Industrial training experience

Thanks to the realization of these practices I have acquired some knowledge that I did not have before and I have also consolidated much of the knowledge I already knew about the subjects studied in the master. This knowledge prior to the practices was much more theoretical and thanks to the completion of this stay at CIMNE I have been able to apply them and, therefore, see the most practical part. I believe that the practices are a great help and a very interesting initiative, as well as a first contact with the professional life that helps to become familiar with the work environment.

In my place of work, as I have said, there were many PhD students, with a high level of programming and concepts from the world of computational mechanics. I am aware that I have a lot to learn in this field, in the field of programming and numerical methods, thanks to my stay at CIMNE I have been able to observe the great research paths of this entity and the high level of its employees, of the which I feel very grateful to have been able to learn.

As positive aspects I would like to highlight the practical application of the theoretical concepts of the master, but also the application of physics and structural knowledge of the degree to solve problems (when it comes to taking initiative to improve the results). As a weak point I must emphasize the programming in C ++ language, since during the master I did not have much level in this type of programming and at the beginning it was a bit hard to understand how it worked, although if it is achieved it is very useful for new projects.

3.2. Formation

During the practices my work was the realization of different simulations to apply and validate the Material Point Method (MPM) to the calculation of structures. The MPM is a numerical technique used to simulate the behaviour of solids, liquids, gases and any other continuous material. Especially, it is a robust spatial discretization method to simulate multi-phase interactions (solid-gas fluid). In the MPM, a continuous body is described by a series of small Lagrangian elements called "material points". These material points are surrounded by a background mesh that is used only to calculate the gradient terms, such as the deformation gradient. Unlike other mesh-based methods such as the finite element method, the finite volume method or the finite differences method, the MPM is not a mesh-based method and is categorized as a meshless/meshfree or continuous method.

During the development of the practices my objective was to see if the method works for different cases. I carried out different analyses and obtained different results for tests in which the breaking mechanism was known, with the objective of validating the method and the code, as well as identifying the weak points of this.

To verify that the method works and that therefore our implementation in the code is correct, the different results have been compared with the results of DEM, FEM and laboratory. In general, the results we have obtained have been optimal, although there

are certain aspects that need to be improved, for example, that stress distributions are not the most appropriate, for this it would be necessary to continue researching in the MPM and to think about future and possible improvements.

Some of the analyses I have done are: compression test, Brazilian test, shear test ..., in addition, these analyses were carried out in 2D and 3D. It has been shown that the method works, and the code can be used for different applications.

These practices have reinforced my knowledge in areas like structures, materials, also physics and mathematics because we are using mathematical formulation. But above all continuum mechanics since we have used damage models, and without a solid basis of this subject is very difficult to understand the models and the results that are obtained.

I will only show a small part of the results on following lines because the report size is quite limited, although I have a longer report, where more results are shown.

Note: to see the analysis better and how it has been reached, I have a more extensive report explaining everything.

Compression test

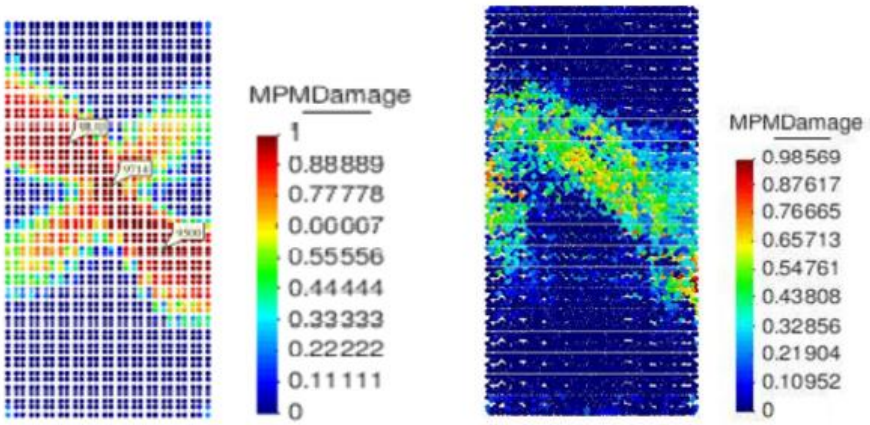
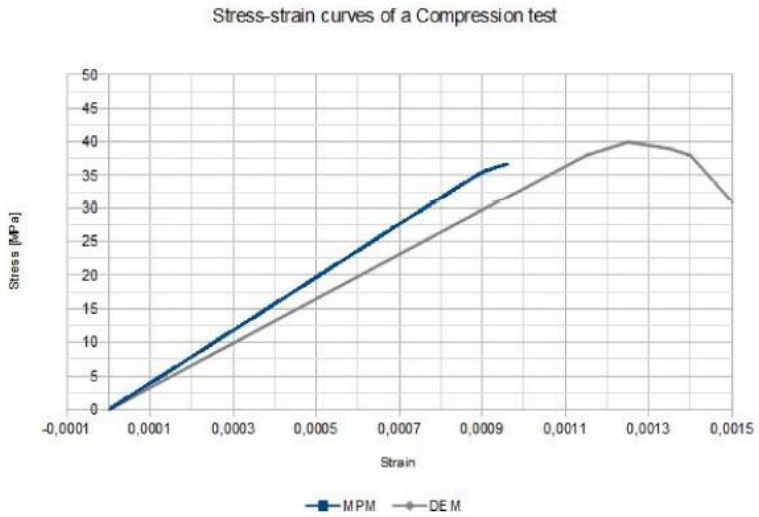


Image 1: Damage distribution of a compression test with Material Point Method, 2D and 3D respectively.



Graph 1: DEM and MPM stress-strain curves in a Compression test.

Brazilian test

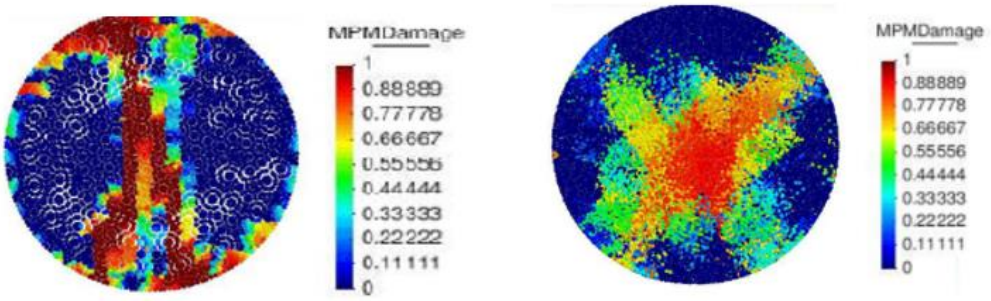
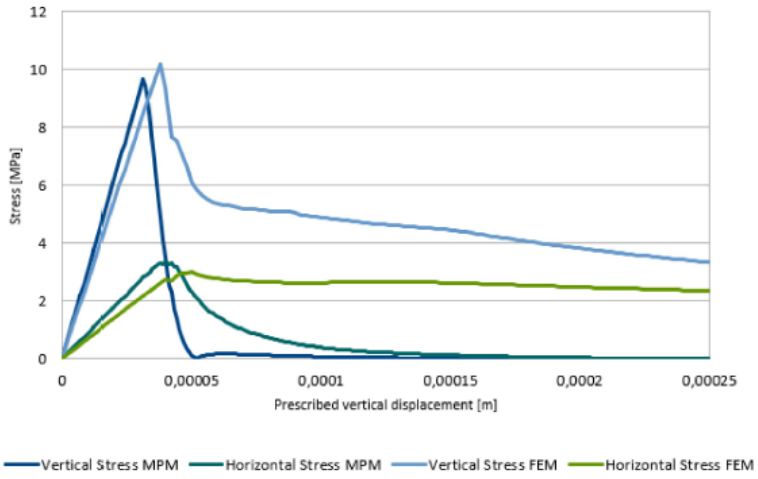


Image 2: Damage distribution of a brazilian test with Material Point Method, 2D and 3D respectively.



Graph 2: Comparison between the evolution of the MPM and FEM stress in function of the sample deformation (displacement).

Shear test

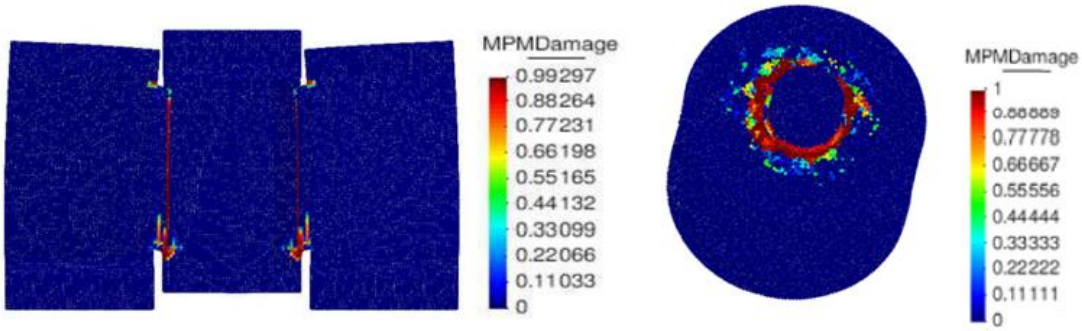


Image 3: Damage distribution of a shear test with Material Point Method, 2D and 3D respectively.

4. Conclusions

As a conclusion, I believe that the realization of the industrial training in a company has been very profitable, for several of the points mentioned above. This stay in a company teaches you the type of work you can do in the future, teaches you to apply theoretical knowledge to the practical part, on the other hand, I think that learning to work with a group of people where you can ask your doubts and concerns with more colleagues is also a very important and favourable point since you learn from others.

I believe that I have fulfilled the initial objectives, now I know much better the code and the different files, I know how to modify them to adapt them to the different models and thanks to the tests carried out the Material Point Method can be positively validated.

It would be very interesting to continue investigating the possible applications and improvements of this method. As a future work, I would like to comment that a UP formulation could be implemented to improve the calculation of stresses, that is, a formulation that takes into account both displacements and pressures. It could also be interesting to use the IMPM (Improved Material Point Method) although this case has limitations regarding the boundary conditions, it could be interesting investigate how to improve imposition of this conditions. On the other hand, and already trying to look for more lines of future research the use of Submerged Boundary Method could also be useful or use an arbitrary order of the IMPM to combine methods of meshfree particles with finite elements.

Therefore, as a conclusion I am very happy and grateful with all the work done and with everything I have learned, and I would like to continue working on this line in the future.