IECBD 2023

The 1st International Electronic Conference on Buildings

24–26 October 2023 | Online

Numerical calibration of constitutive models for construction materials against blast threat by means of ballistics tests

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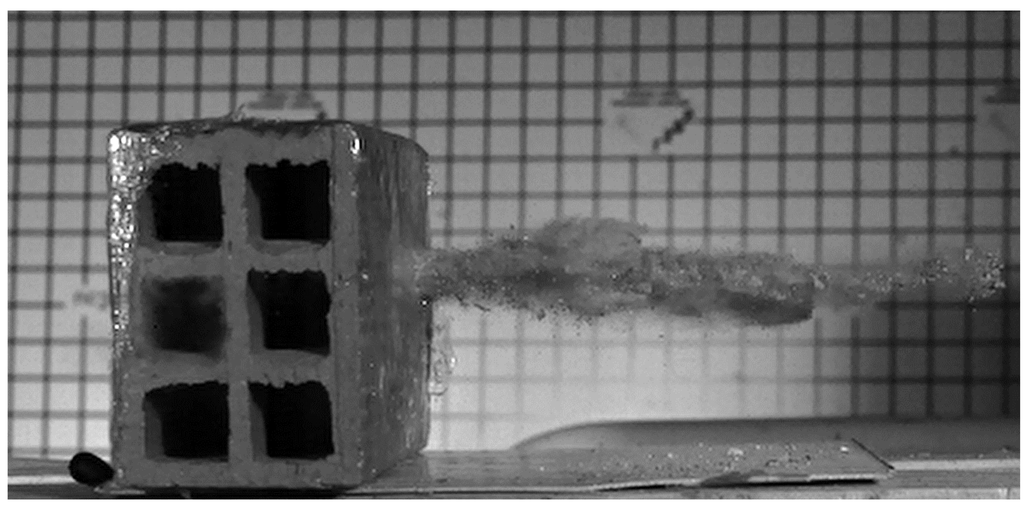
Abstract: *The design of infrastructure protection against ballistic and blast fragment impacts requires a series of costly tests. In this study, the authors propose a methodology based on a practical and economical approach. In this particular case, it is applied to clay and concrete in order to obtain values for the JH2 constitutive model. These parameters will yield more accurate results compared to the direct use of parameters already published in the literature. Furthermore, the results allow the authors to formulate hypotheses that are considered suitable at moderate cost.*

PROBLEM STATEMENT



The explosion behavior depends on the mechanical characteristics of the material. In the case of materials such as clay and concrete, their properties and composition are highly dependent on where and how they are manufactured, amongst other factors.

Therefore, it is necessary to know the characteristics of local building materials in order to understand their blast behavior. As these tests are costly, an economical technique based on ballistic impact is pursued to approximate the parameter values of the JH2 constitutive model [1-8].

JH2 MODEL EQUATIONS

Strength:

$$\sigma^* = \sigma_i^* - D(\sigma_i^* - \sigma_f^*)$$

$$\sigma_i^* = A(P^* + T^*)^N(1 + C\ln\dot{\varepsilon}^*)$$

$$\sigma_f^* = B(P^*)^M(1 + C\ln\dot{\varepsilon}^*)$$

Damage:

$$D = \sum \frac{\Delta\varepsilon_p}{\varepsilon_p^f}$$

$$\varepsilon_p^f = D_1(P^* + T^*)^{D_2}$$

Equation of State (EOS):

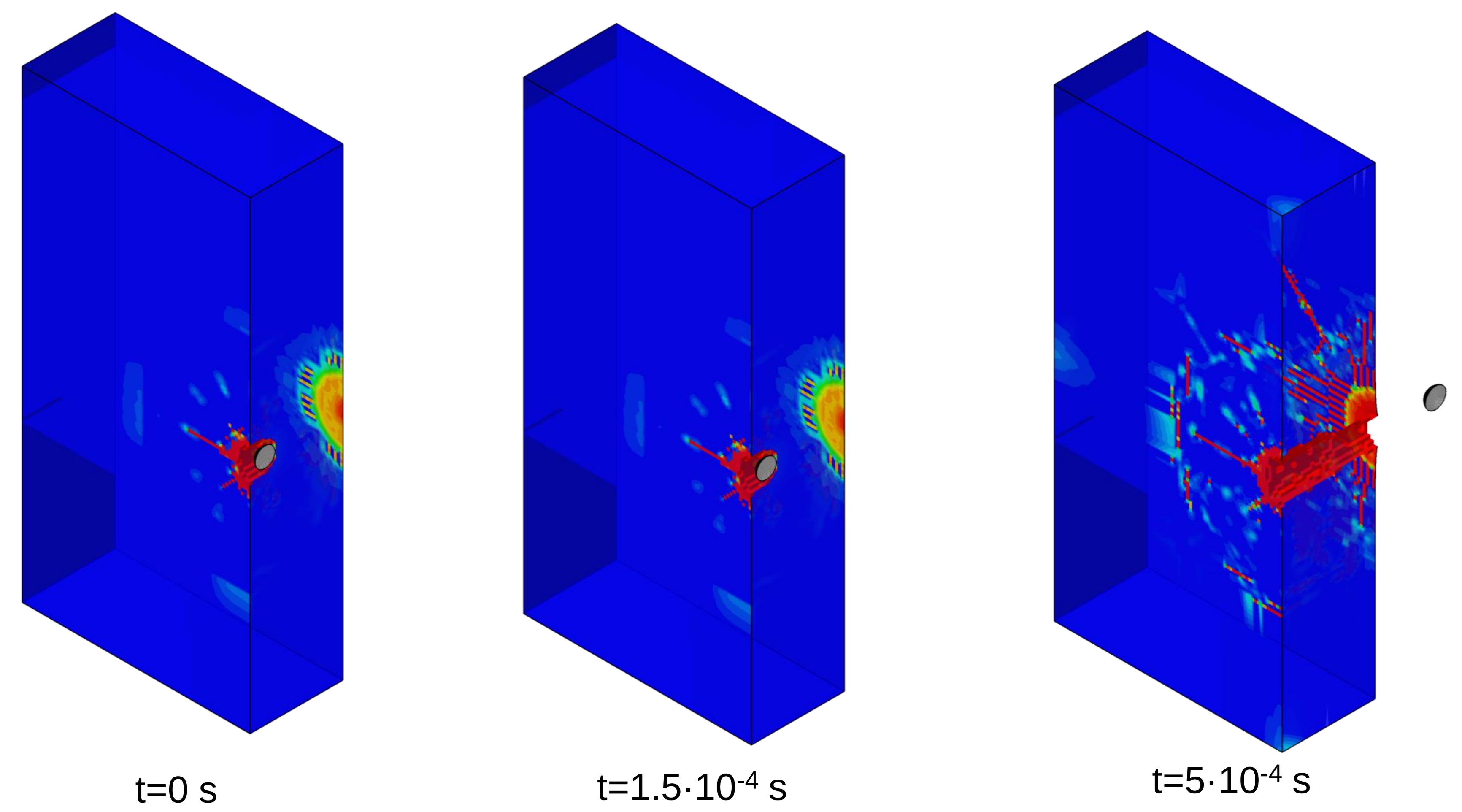
$$P = K_1\mu + K_2\mu^2 + K_3\mu^3$$

$$\mu = \frac{\rho}{\rho_0} - 1$$

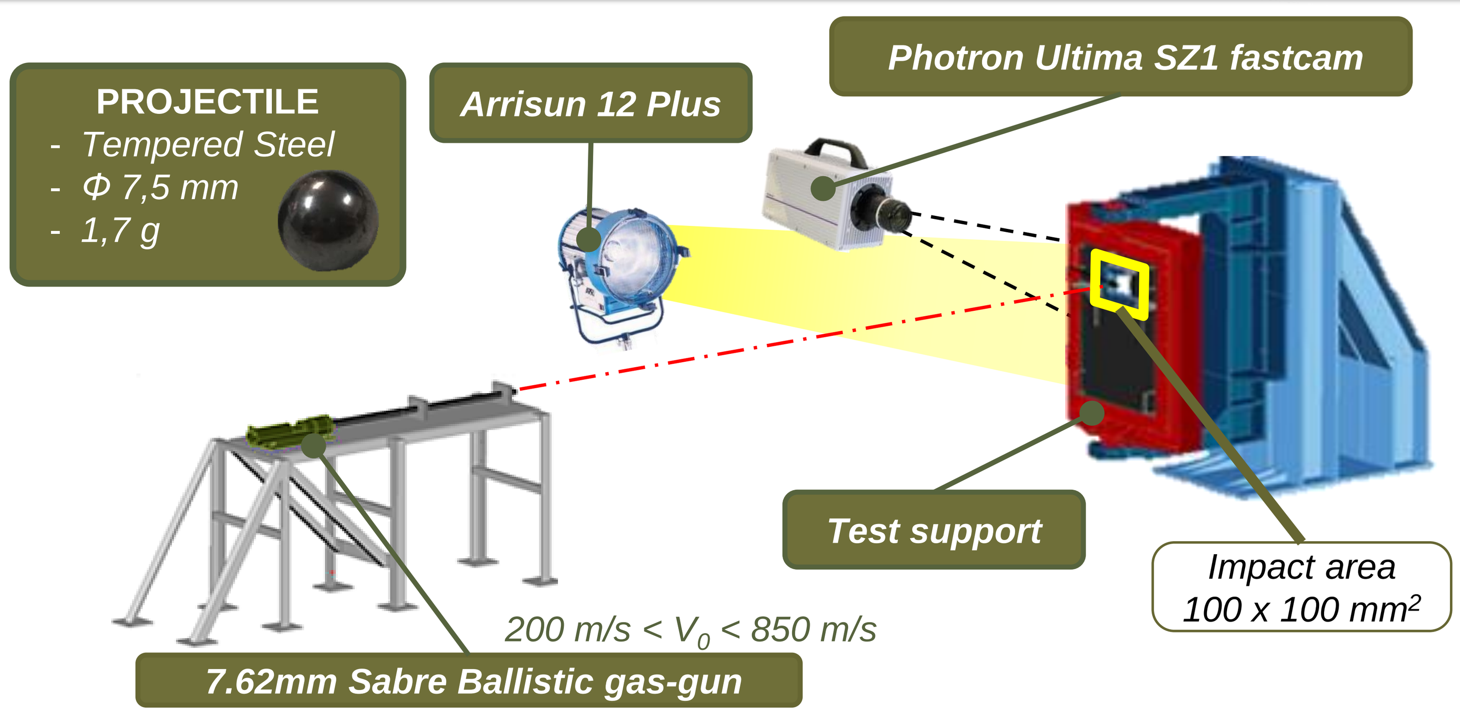
[9,10]

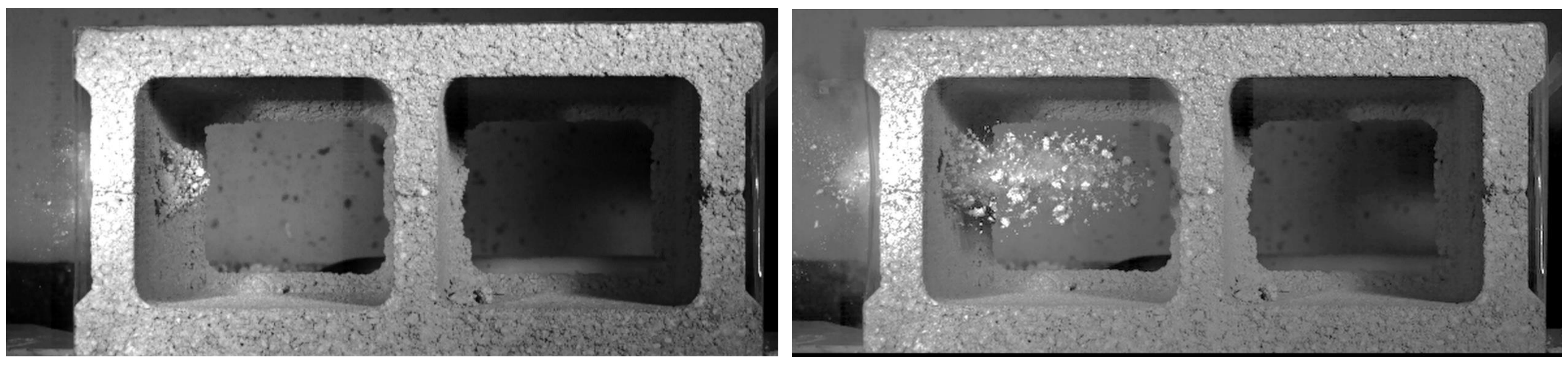
NUMERICAL MODEL

Developed numerical models allow the prediction of residual velocity with enough accuracy to obtain the ballistic curve of the material [11].

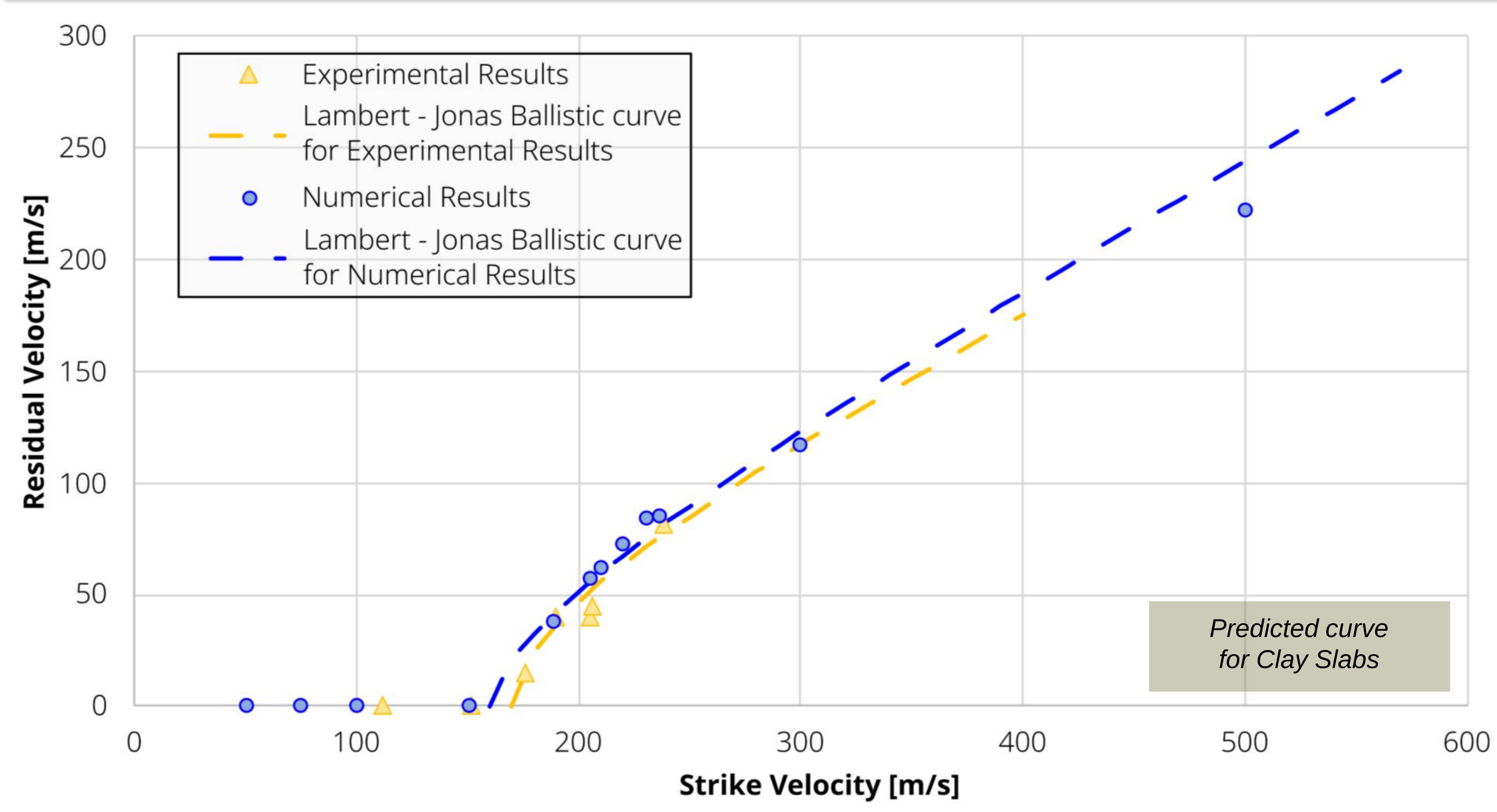


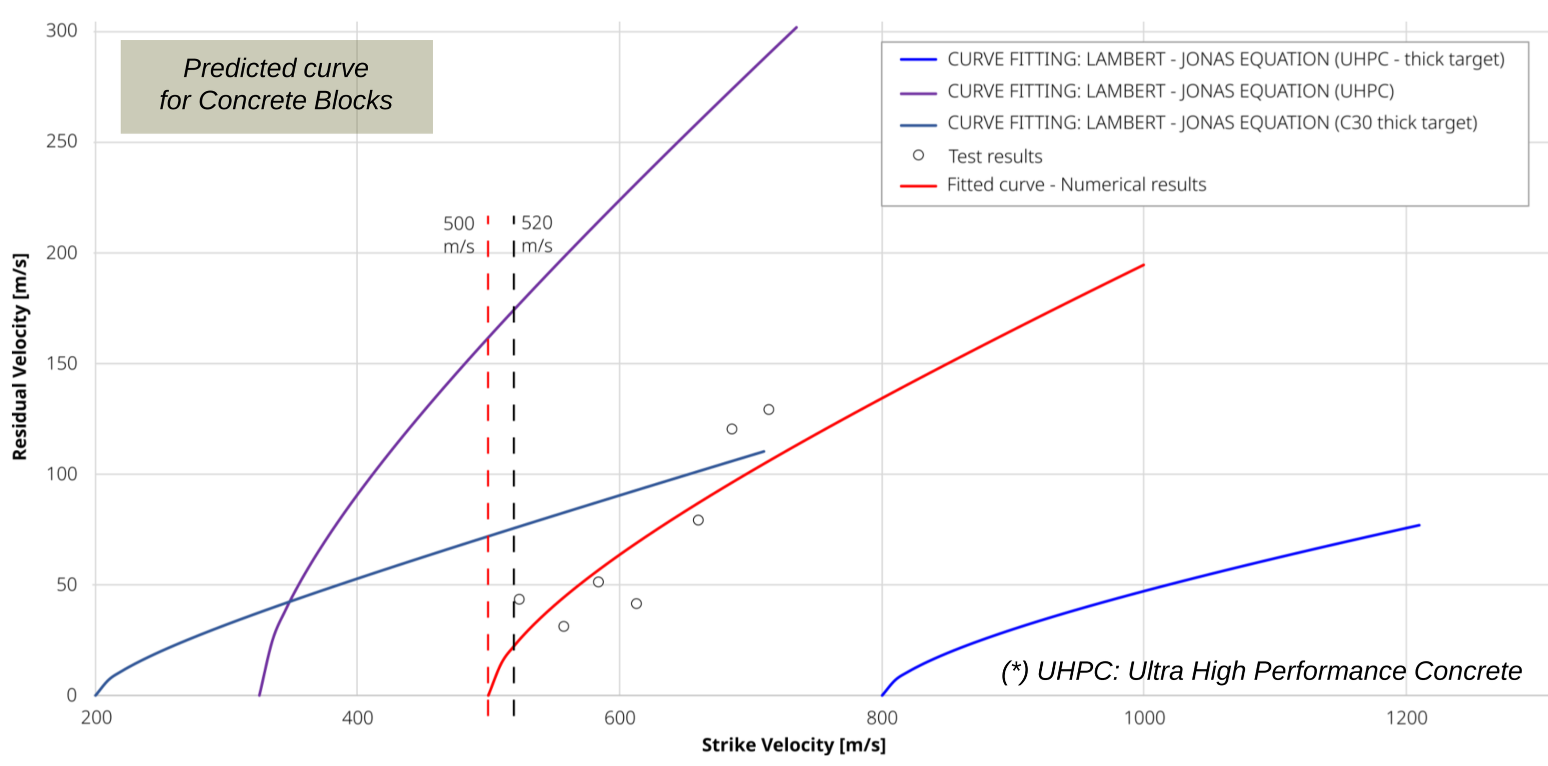
EXPERIMENTAL DEVICE





PREDICTED BALLISTIC CURVES





REFERENCES

[1] G. Görhan and O. Şimşek, "Porous clay bricks manufactured with rice husks," Constr Build Mater, vol. 40, pp. 390–396, Mar. 2013, doi: 10.1016/j.conbuildmat.2012.09.110.

[2] C. B. Emrullahoglu Abi, "Effect of borogypsum on brick properties," Constr Build Mater, vol. 59, pp. 195–203, May 2014, doi: 10.1016/j.conbuildmat.2014.02.012.

[3] O. Gencel, "Characteristics of fired clay bricks with pumice additive," Energy Build, vol. 102, pp. 217–224, Sep. 2015, doi: 10.1016/j.enbuild.2015.05.031.

[4] L. Pérez-Villarejo, S. Martínez-Martínez, B. Carrasco-Hurtado, D. Eliche-Quesada, C. Ureña-Nieto, and P. J. Sánchez-Soto, "Valorization and inertization of galvanic sludge waste in clay bricks," Appl Clay Sci, vol. 105–106, pp. 89–99, Mar. 2015, doi: 10.1016/j.clay.2014.12.022.

[5] N. Phonphuak, S. Kanyakam, and P. Chindaprasirt, "Utilization of waste glass to enhance physical–mechanical properties of fired clay brick," J Clean Prod, vol. 112, pp. 3057–3062, Jan. 2016, doi: 10.1016/j.jclepro.2015.10.084.

[6] M. Sutcu, S. Ozturk, E. Yalamac, and O. Gencel, "Effect of olive mill waste addition on the properties of porous fired clay bricks using Taguchi method," J Environ Manage, vol. 181, pp. 185–192, Oct. 2016, doi: 10.1016/j.jenvman.2016.06.023.

[7] C. Bories, L. Aouba, E. Vedrenne, and G. Vilarem, "Fired clay bricks using agricultural biomass wastes: Study and characterization," Constr Build Mater, vol. 91, pp. 158–163, Aug. 2015, doi: 10.1016/j.conbuildmat.2015.05.006.

[8] M. Sutcu, H. Alptekin, E. Erdogmus, Y. Er, and O. Gencel, "Characteristics of fired clay bricks with waste marble powder addition as building materials," Constr Build Mater, vol. 82, pp. 1–8, May 2015, doi: 10.1016/j.conbuildmat.2015.02.055.

[9] G. R. Johnson and T. J. Holmquist, "An improved computational constitutive model for brittle materials," in AIP Conference Proceedings, AIP, 1994, pp. 981–984. doi: 10.1063/1.46199.

[10] C. E. Anderson and T. J. Holmquist, "Computational Modeling of Failure for Hypervelocity Impacts into Glass Targets," Procedia Eng, vol. 58, pp. 194–203, 2013, doi: 10.1016/j.proeng.2013.05.023.

[11] M. Polanco-Loria, O. S. Hopperstad, T. Børvik, and T. Berstad, "Numerical predictions of ballistic limits for concrete slabs using a modified version of the HJC concrete model," Int J Impact Eng, vol. 35, no. 5, pp. 290–303, May 2008, doi: 10.1016/j.ijimpeng.2007.03.001.

CONCLUSIONS AND ACKNOWLEDGEMENTS

- The ballistic curve of two materials commonly used in construction has been experimentally analysed and obtained.
- The ballistic curve has been obtained numerically for a selection of common construction materials using the values of the JH2 constitutive model published in the literature.
- The appropriate parameters have been adjusted, beginning with the known parameters, to obtain a curve similar to the experimental one.
- The ballistic curves of concrete and clay obtained using numerical models have been compared with the experimental curve corresponding to the material under study in each case.
- The model predicts the ballistic limit with sufficient accuracy and at a low cost to use the parameters obtained in explosion models.

The authors would like to acknowledge the partial funding received from the Spanish Ministry of Science and Innovation through project PID2020-118946RB-I00, which has allowed the development of this research.