

MODELLING BLAST RESPONSE OF REINFORCED CONCRETE STRUCTURES WITH COUPLED SMOOTHED PARTICLE HYDRODYNAMICS (SPH) AND ARBITRARY LAGRANGIAN–EULERIAN APPROACH (ALE)

D.M.L.S. Dissanayaka, P.L.N. Fernando *

Department of Civil Engineering, University of Moratuwa, Moratuwa

Reinforced concrete (RC) structures are widely used in civil infrastructure due to their durability and load-bearing capacity, yet they remain highly vulnerable to blast loads from accidental or deliberate explosions. Such extreme loading can cause severe damage or collapse, posing significant risks to critical facilities and human safety. Accurate numerical simulation of blast effects is therefore essential for understanding failure mechanisms and developing blast-resistant designs. However, conventional methods face major challenges. Lagrangian approaches suffer from severe mesh distortion under large deformations, while Eulerian methods often have difficulty representing structural behaviour. To overcome these limitations and improve the accuracy of the Smoothed Particle Hydrodynamics method, this study develops a coupled approach combining SPH and Arbitrary Lagrangian–Eulerian (ALE) methods, implemented using the advanced finite element code LS-DYNA. The SPH method, being mesh-free, is well suited for modelling large deformations and fragmentation of the explosive charge, while the surrounding air domain is modelled with ALE to efficiently capture shockwave propagation. The analysis focuses on a reinforced concrete slab of 1000 mm × 1000 mm × 40 mm, represented using solid Lagrangian elements with the Riedel–Hiermaier–Thoma (RHT) concrete material model to capture nonlinear, rate-dependent, and damage behaviour. A quarter-symmetric model was used to reduce computational demand while maintaining accuracy. A two-stage validation process was adopted. Both stages considered a 400 mm standoff distance, while the TNT charge weight was varied to represent different damage levels. In the first stage, a non-damage scenario using 0.2 kg of TNT, corresponding to a scaled distance of 0.68 m/kg^{1/3}, was used to fine-tune the material and blast modelling parameters related to the proposed approach. In the second stage, a higher charge of 0.31 kg TNT, corresponding to a scaled distance of 0.59 m/kg^{1/3}, was applied under the same configuration to reproduce cracking and local failure of the slab. A mesh convergence and parametric sensitivity study was conducted to examine the influence of SPH particle spacing, ALE mesh resolution, and key numerical parameters such as the time scale factor (TSSFAC), the constant applied to the smoothing length of the particles (CSLH), and the scale factor for soft constraint forces (SOFSC). Validation was performed against published experimental data, and further comparisons were made among other blast modelling approaches such as Load Blast Enhanced (LBE), ALE, coupled LBE–ALE, and the proposed SPH–ALE techniques. The SPH–ALE approach exhibited the lowest deviation, with an error of 1.7 % in maximum deflection for the non-damage scenario and approximately 6 % deviation in spall radius for the cracking analysis, indicating excellent agreement with experimental results and improved numerical stability. In conclusion, this study presents a validated SPH–ALE-based simulation framework that successfully captures both non-damage and cracking responses of blast-loaded reinforced concrete slabs. The proposed method enhances predictive capability and provides a reliable numerical tool for blast analysis, contributing to the advancement of protective design and safety assessment of critical infrastructure.

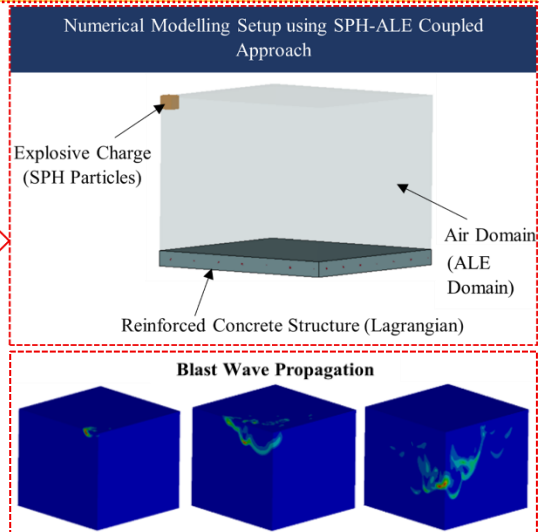
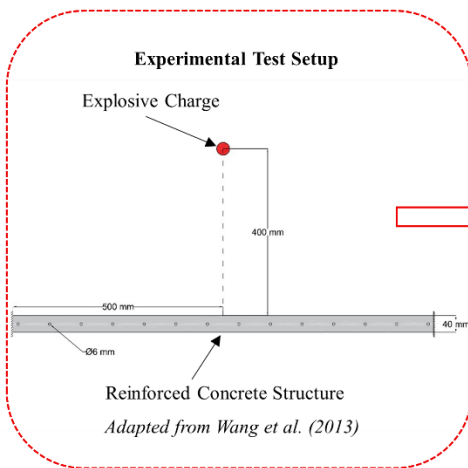
Keywords: ALE method, Concrete structures, Near-field blasts, SPH method

* Correspondence: lakshithaf@uom.lk

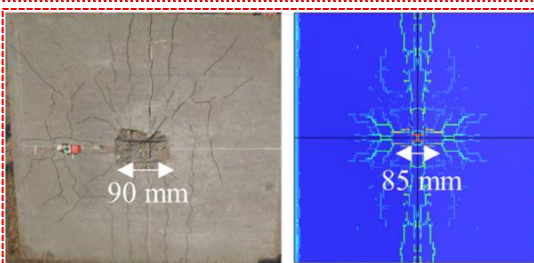
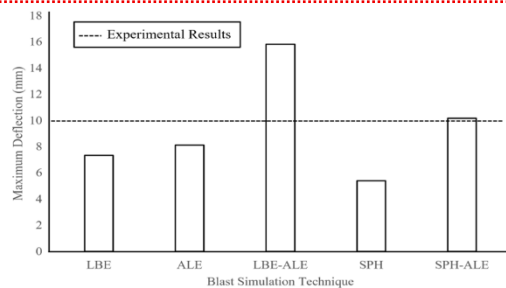
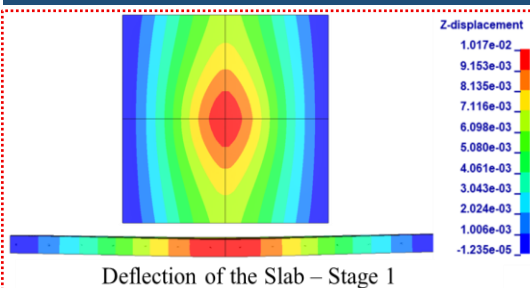
NUMERICAL MODELLING OF CLOSED-IN BLAST EFFECTS ON REINFORCED CONCRETE STRUCTURES USING AN SPH-ALE COUPLING APPROACH

Numerical Modelling

- The **accuracy** of the **Smoothed Particle Hydrodynamics (SPH)** method tends to **decrease** with **increasing standoff distance**.
- The SPH Method is coupled with Arbitrary Lagrangian-Eulerian (ALE) method to improve the accuracy.



Validation of the Numerical Results



Conclusion

SPH-ALE coupling improves accuracy of SPH method for closed-in blast simulations by capturing both detonation physics (SPH) and air-structure interaction (ALE).