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**Numerical Investigation of the Failure of Stiffened Steel Plates Subjected to Near-Field Blast Loads**
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**Abstract**
This paper study the failure of stiffened steel plates subjected to near-filed blast loads using finite element (FE) analysis. Half-symmetry 3D FE models were developed using Abaqus for unstiffened and stiffened steel plates with different stiffeners configurations and sizes were used using solid brick elements. The behaviour of steel plates was modelled using classical plasticity constitutive equation, and the failure of the plates was modelled using ductile damage criterion. The influence of strain rates was considered using the Cowper–Symonds equation. The blast loads were applied using CONWEP function in Abaqus. The FE model of unstiffened plates was verified and validated against experimental data from literature where a good agreement was achieved. The FE model then was extended to incorporate different sizes and configurations of stiffeners. The study observed that stiffened steel plate tends to fail at lower blast pressure. The failure is influenced by the position and arrangement of stiffeners with respect to the size of stiffeners. Two new sub-modes of failure for stiffened steel plates are proposed namely Mode II*s and Mode IIs for partial plate tearing along stiffener and rupture of stiffener, respectively. © 2023, ASM International.

**Author Keywords**
Damage energy; Ductile damage; Finite element; Stiffened steel plate

**Index Keywords**
ABAQUS, Ductile fracture, Dynamic loads, Finite element method, Plates (structural components); Blast loads, Damage energy, Ductile damage, Finite element, Finite element modelling (FEM), Mode II, Near fields, Numerical investigations, Steel plates, Stiffened steel plate; Strain rate

**References**

- Chung Kim Yuen, S., Nurick, G.N., Langdon, G.S., Iyer, Y.
  **Deformation of thin plates subjected to impulsive load: Part III—an update 25 years on**
  (2017) *Int. J. Impact Eng.*, 107, pp. 108-117.
- Jacob, N., Nurick, G.N., Langdon, G.S.
  **The effect of stand-off distance on the failure of fully clamped circular mild steel plates subjected to blast loads**
  (2007) *Eng. Struct.*, 29 (10), pp. 2723-2736.
- Yuen, S.C.K., Nurick, G.N.
  **Experimental and numerical studies on the response of quadrangular stiffened plates. Part I: subjected to uniform blast load**
  (2005) *Int. J. Impact Eng.*, 31 (1), pp. 55-83.
- Langdon, G.S., Yuen, S.C.K., Nurick, G.N.
  **Experimental and numerical studies on the response of quadrangular stiffened plates. Part II: localised blast loading**
  (2005) *Int. J. Impact Eng.*, 31 (1), pp. 85-111.
- Bonorchis, D., Nurick, G.N.
  **The influence of boundary conditions on the loading of rectangular plates subjected to localised blast loading: importance in numerical simulations**
  (2009) *Int. J. Impact Eng.*, 36 (1), pp. 40-52.

- Henchie, T.F., Chung Kim Yuen, S., Nurick, G.N., Ranwaha, N., Balden, V.H.
  **The response of circular plates to repeated uniform blast loads: an experimental and numerical study**
  (2014) *Int. J. Impact Eng.*, 74, pp. 36-45.

- Yuen, S.C.K., Langdon, G.S., Nurick, G.N., Pickering, E.G., Balden, V.H.
  **Response of V-shape plates to localised blast load: experiments and numerical simulation**
  (2012) *Int. J. Impact Eng.*, 46, pp. 97-109.

- Rigby, S.E., Osborne, C., Langdon, G.S., Cooke, S.B., Pope, D.J.
  **Spherical equivalence of cylindrical explosives: effect of charge shape on deflection of blast-loaded plates**
  (2021) *Int. J. Impact Eng.*, 155 (November 2020), p. 103892.

- Razak, N.S.A., Alias, A.
  **The response of steel plates subjected to close-in blast loads**
  (2021) *IOP Conf. Ser. Earth Environ. Sci.*, 682 (1), p. 012036.

- Gan, L., Zong, Z., Lin, J., Chen, Y., Xia, M., Chen, L.
  **Influence of U-shaped stiffeners on the blast-resistance performance of steel plates**
  (2022) *J. Constr. Steel Res.*, 188 (November 2021), p. 107046.

- Kong, X.
  **Corrected method for scaling the dynamic response of stiffened plate subjected to blast load**
  (2021) *Thin-Walled Struct.*, 159 (June 2019), p. 107214.

- Bonorchis, D., Nurick, G.N.
  **The analysis and simulation of welded stiffener plates subjected to localised blast loading**
  (2010) *Int. J. Impact Eng.*, 37 (3), pp. 260-273.

- Li, Y., Ren, X., Zhao, T., Xiao, D., Liu, K., Fang, D.
  **Dynamic response of stiffened plate under internal blast: experimental and numerical investigation**
  (2021) *Mar. Struct.*, 77 (August 2020), p. 102957.

- Ghani Razaqpur, A., Tolba, A., Contestabile, E.
  **Blast loading response of reinforced concrete panels reinforced with externally bonded GFRP laminates**
  (2007) *Compos. Part B Eng.*, 38 (5-6), pp. 535-546.

- Aune, V., Valsamos, G., Casadei, F., Langseth, M., Børvik, T.
  **Fluid-structure interaction effects during the dynamic response of clamped thin steel plates exposed to blast loading**
  (2020) *Int. J. Mech. Sci.*, 195 (December), p. 2021.

- Curry, R.J., Langdon, G.S.
  **Transient response of steel plates subjected to close proximity explosive detonations in air**
  (2017) *Int. J. Impact Eng.*, 102, pp. 102-116.

- Micallef, K., Fallah, A.S., Curtis, P.T., Louca, L.A.
  **On the dynamic plastic response of steel membranes subjected to localised blast loading**
  (2016) *Int. J. Impact Eng.*, 89, pp. 25-37.

- Mehreganian, N., Louca, L.A., Langdon, G.S., Curry, R.J., Abdul-Karim, N.
  **The response of mild steel and armour steel plates to localised air-blast loading-**

**comparison of numerical modelling techniques**
(2018) *Int. J. Impact Eng.*, 115 (May 2017), pp. 81-93.

- Bohara, R.P., Linforth, S., Ghazlan, A., Nguyen, T., Remennikov, A., Ngo, T.
**Performance of an auxetic honeycomb-core sandwich panel under close-in and far-field detonations of high explosive**
(2021) *Compos. Struct.*, 280 (February 2021), p. 114907.

- Zakrisson, B., Wikman, B., Häggblad, H.-Å.
**Numerical simulations of blast loads and structural deformation from near-field explosions in air**
(2011) *Int. J. Impact Eng.*, 38 (7), pp. 597-612.

- Micallef, K., Fallah, A.S., Pope, D.J., Louca, L.A.
**The dynamic performance of simply-supported rigid-plastic circular steel plates subjected to localised blast loading**
(2012) *Int. J. Mech. Sci.*, 65 (1), pp. 177-191.

- Mehreganian, N., Fallah, A.S., Louca, L.A.
**Plastic dynamic response of simply supported thick square plates subject to localised blast loading**
(2019) *Int. J. Impact Eng.*, 126 (April 2018), pp. 85-100.

- Fallah, A.S., Louca, L.A.
**Pressure-impulse diagrams for elastic plastic hardening and softening single degree of freedom models subjected to blast loading.pdf**
(2007) *Int. J. Impact Eng.*, 34, pp. 823-842.

- Randers-Pehrson, G., Bannister, K.A.
(1997) *Airblast Loading Model for DYNA2D and DYNA3D*,

- Kinnery, G.F., Graham, K.J.
(1985) *Explosive Shocks in Air*,
Springer, Berlin

- Rigby, S.E., Tyas, A., Bennett, T.
**Single-Degree-of-Freedom response of finite targets subjected to blast loading: the influence of clearing**
(2012) *Eng. Struct.*, 45, pp. 396-404.

- Lomazzi, L., Giglio, M., Manes, A.
**Analytical and empirical methods for the characterisation of the permanent transverse displacement of quadrangular metal plates subjected to blast load: comparison of existing methods and development of a novel methodological approach**
(2021) *Int. J. Impact Eng.*, 154 (April), p. 103890.

- Shin, J., Whittaker, A.S., Cormie, D.
**TNT equivalency for overpressure and impulse for detonations of spherical charges of high explosives**
(2015) *Int. J. Prot. Struct.*, 6 (3), pp. 567-579.

- Lin, X., Zhang, Y.X., Hazell, P.J.
**Modelling the response of reinforced concrete panels under blast loading**
(2014) *Mater. Des.*, 56, pp. 620-628.

- Dharmasena, K.P., Wadley, H.N.G., Xue, Z., Hutchinson, J.W.
**Mechanical response of metallic honeycomb sandwich panel structures to high-intensity dynamic loading**
(2008) *Int. J. Impact Eng.*, 35 (9), pp. 1063-1074.

- Spranghers, K., Vasilakos, I., Lecompte, D., Sol, H., Vantomme, J.
**Numerical simulation and experimental validation of the dynamic response of aluminum plates under free air explosions**
(2013) *Int. J. Impact Eng.*, 54, pp. 83-95.

- Nelson, S.M., O'Toole, B.J.
**Computational analysis of blast loaded composite cylinders**
(2018) *Int. J. Impact Eng.*, 119 (April), pp. 26-39.

- Rigby, S.E.
**Observations from preliminary experiments on spatial and temporal pressure measurements from near-field free air explosions**
(2015) *Int. J. Prot. Struct.*, 6 (2), pp. 175-190.

- Yuen, S.C.K., Butler, A., Bornstein, H., Cholet, A.
**The influence of orientation of blast loading on quadrangular plates**
(2018) *Thin-Walled Struct.*, 131 (April), pp. 827-837.

- Razak, N.S.A., Alias, A., Mohsan, N.M., Masjuki, S.A.
**The influence of Cowper–Symonds coefficients on the response of stiffened steel plates subjected to close-in blast loads**
(2022) *Key Eng. Mater.*, 912, pp. 171-184.

- Jia, S., Tan, Q., Ye, J., Zhu, Z., Jiang, Z.
**Experiments on dynamic mechanical properties of austenitic stainless steel S30408 and S31608**
(2021) *J. Constr. Steel Res.*, 179, p. 106556.

- Zhang, C., Tan, P.J., Yuan, Y.
**Confined blast loading of steel plates with and without pre-formed holes**
(2022) *Int. J. Impact Eng.*, 163 (December 2021), p. 104183.

- Hsu, S.S., Jones, N.
**Quasi-static and dynamic axial crushing of thin-walled circular stainless steel, mild steel and aluminium alloy tubes**
(2004) *Int. J. Crashworthiness*, 9 (2), pp. 195-217.

- Jones, N., Jones, C.
**Inelastic failure of fully clamped beams and circular plates under impact loading**
(2002) *Proc. Inst. Mech. Eng. Part C J. Mech. Eng. Sci.*, 216 (2), pp. 133-149.

- Yu, J., Jones, N.
**Further experimental investigations on the failure of clamped beams under impact loads**
(1991) *Int. J. Solids Struct.*, 27 (9), pp. 1113-1137.

- Li, F., Yuan, H., Liu, H.
**Implementation of metal ductile damage criteria in Abaqus FEA**
(1906) *J. Phys. Conf. Ser.*, 1, p. 2021.

- Li, M., Zong, Z., Liu, L., Lou, F.
**Experimental and numerical study on damage mechanism of CFDST bridge columns subjected to contact explosion**
(2018) *Eng. Struct.*, 159 (January), pp. 265-276.

- Bao, Y.
**Dependence of ductile crack formation in tensile tests on stress triaxiality, stress and strain ratios**
(2005) *Eng. Fract. Mech.*, 72 (4), pp. 505-522.

- Iqbal, M.A., Senthil, K., Bhargava, P., Gupta, N.K.
**The characterization and ballistic evaluation of mild steel**
(2015) *Int. J. Impact Eng.*, 78, pp. 98-113.

- Das, A., Chowdhury, T., Tarafder, S.
**Ductile fracture micro-mechanisms of high strength low alloy steels**
(2014) *Mater. Des.*, 54, pp. 100-1009.

- Liu, X., Yan, S., Rasmussen, K.J.R., Deierlein, G.G.
**Verification of void growth-based exponential damage function for ductile crack initiation over the full range of stress triaxialities**
(2022) *Eng. Fract. Mech.*, 269 (January), p. 108571.

- Trajkovski, J., Kunc, R., Perenda, J., Prebil, I.
**Minimum mesh design criteria for blast wave development and structural response: MMALE method**
(2014) *Lat. Am. J. Solids Struct.*, 11 (11), pp. 1999-2017.

- Nassr, A.A., Razaqpur, A.G., Tait, M.J., Campidelli, M., Foo, S.
**Experimental performance of steel beams under blast loading**
(2012) *J. Perform. Constr. Facil.*, 26, pp. 600-619.

- Xiao, W., Andrae, M., Gebbeken, N.
**Air blast TNT equivalence concept for blast-resistant design**
(2020) *Int. J. Mech. Sci.*,

- Bogosian, D., Yokota, M., Rigby, S.
**TNT equivalence of C-4 and PE4: A review of traditional sources and recent data, in 24th Int**
(2016) *Symp. Mil. Asp. Blast Shock (MABS*, 24, pp. 1-15.

- Markose, A., Rao, C.L.
**Failure analysis of V-shaped plates under blast loading**
(2017) *Procedia Eng.*, 173, pp. 519-525.


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