DEVELOPMENT OF AN IMPROVED EMPIRICAL FORMULA TO PREDICT THE DEFLECTION OF PLATES UNDER BLAST LOADS

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The world is moving forward with the advances in technology which has had both positive and negative impacts. One such negative impact has been the increment of terrorist attacks on structures around the world. Civil Engineers have focused on blast-resistant structures. Blast-induced loading on structural elements poses a significant challenge in engineering design due to its high-intensity load within an extremely short time duration. The present study aims at studying plate elements and deflection is one of the main criteria that govern the behaviour of plates. Several past studies have aimed to determine the deflection of plates under blast loads, but the accuracy of the results as well as the high experimental costs raises concerns regarding its feasibility. A numerical-based approach such as the Finite Element Method can be computationally expensive. The present study focuses on empirical methods, which have been found to be an effective and efficient method of predicting deflection under blast loads. Several empirical equations developed based on particular sets of experimental data can be found in the literature. But a shortcoming in such equations has been their applicability for any general case. Hence, the present research focused on developing an improved empirical equation to predict the deflection of plates under blast loads by reducing shortcomings identified in the existing equations.

An extensive literature review was conducted to analyse existing empirical formulas and identify the relevant parameters associated with plate deflection. According to past study data, there were three main failure modes. But here, failure mode I (plate deflection) was considered. Plate sizes under uniform load conditions were below 180 mm and under localised load conditions were below 400 mm. Furthermore, charge weights and standoff distances were below 150 g and 100 mm, respectively. Based on past experimental results, the present study provides two improved empirical equations to predict the deflection of square and rectangular plates under blast loads of uniform and localised types. The equation consists of several non-dimensional parameters which take into account factors such as the magnitude of the blast load, blast load impulse, loading type, standoff distance, yield stress, plate dimensions, and materials density. The singular valued decomposition method combines those parameters, and the validation process includes comparing the predicted deflection values with the corresponding measured deflections from experimental data sets available in published literature. According to the validation, all the data points under uniform loads were within the $\pm$10% reliable error percentage range and data points under localised loads were within the $\pm$15% reliable error percentage range. Overall, the proposed improved empirical equations offer a more accurate and practical solution for predicting plate deflection under blast loads, contributing to the advancement of blast-resistant structural design. This will be of use in applications such as blast doors, blast shield-armed vehicles, protective barriers and general blast-resistant structures.

Keywords: Deflection, Plates, Empirical, Non-dimensional parameters, Blast loads

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Main parameters related to deflection of plates under blast loads

- Blast load impulse (I)
- Standoff distance (S)
- Loading type (Uniform or localised)
- Charge weight (T.N.T equivalence)
- Yield stress (σ)
- Plate density (ρ)
- Plate dimensions (B, L, t)
- Charge diameter (R)

Non-dimensional parameters related to plate deflection

Deflection / Thickness	$\frac{\delta}{t}$
Non-dimensional Impulse parameter (Uniform)	$q = \frac{I}{2t^2(BL\rho\sigma)^{1/2}}$
Non-dimensional Impulse parameter (Localised)	$ql = \frac{I(1+ln\,(\frac{LB}{\Pi R^2})}{2t^2(BL\rho\sigma)^{1/2}}$
Slenderness parameter	$\frac{L}{t}$
Aspect ratio	$\frac{L}{B}$

Improved empirical equations-Uniform load type

$$\frac{\boldsymbol{\delta}}{\boldsymbol{t}} = \mathbf{0.0886}(\boldsymbol{\Phi q})^{\mathbf{1.1292}}\left(\frac{\boldsymbol{L}}{\boldsymbol{B}}\right)^{\mathbf{-0.1834}}\left(\frac{\boldsymbol{L}}{\boldsymbol{t}}\right)^{\mathbf{0.3182}}$$

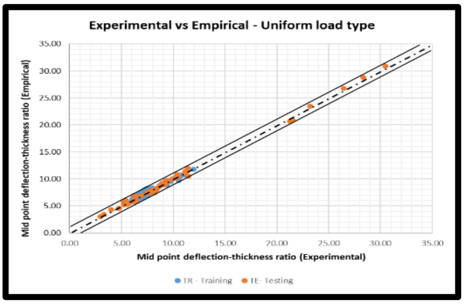
Improved empirical equation-Localised load type

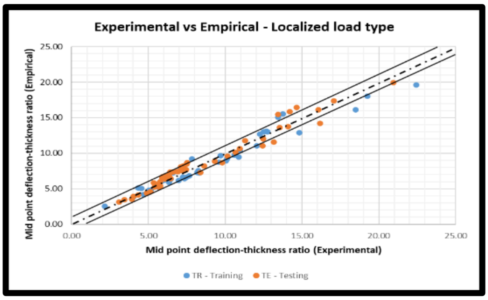
$$\frac{\boldsymbol{\delta}}{\boldsymbol{t}} = \mathbf{0.3588}(\boldsymbol{\Phi ql})^{\mathbf{1.1102}}\left(\frac{\boldsymbol{L}}{\boldsymbol{B}}\right)^{\mathbf{0.1205}}\left(\frac{\boldsymbol{L}}{\boldsymbol{t}}\right)^{\mathbf{-0.0051}}\left(\frac{\boldsymbol{R}}{\boldsymbol{t}}\right)^{\mathbf{-0.025}}$$

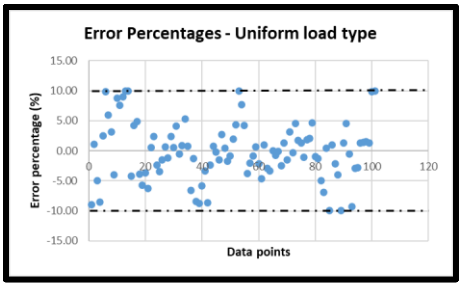
CONCLUSION

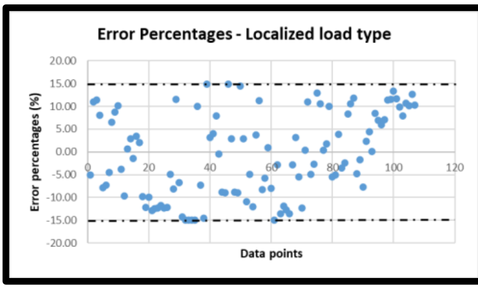
All the data points under uniform loads are in between ±10% error range, and data points under localised loads are between ±15%

VALIDATION









The two solid lines (1±δ/t) are plotted to explain the fitting precision. results show that 100% of the data is within a reliable range

The two solid lines (1.5±δ/t) are plotted to explain the fitting precision. results show that 100% of the data is within a reliable range