

EFFECTS OF INCLINATION ANGLE AND HEIGHT OF BLAST LOAD ON THE DYNAMIC BEHAVIOR OF FLOOR SLABS WITH STIFFENING BEAMS

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Abstract

In order to ascertain how explosive load influences orthotropic slabs with short span stiffeners partially positioned in the x-direction, the purpose of this study is to perform a numerical analysis. The maximum displacement of a floor surface with respect to the force of an explosive load and the angle of inclination. It is feasible to calculate the impact of the angle of inclination and the height of the blast load on the vertical deflection of the slab using the 6th order polynomial blast equation, as long as the local blast load is positioned in the center of the slab. An analysis reveals that the vertical deflection of the slab is affected by the timing of the explosion. Specifically, a more powerful explosion has a diminishing effect on the deflection of the slab. The inclination angle has no major impact on the outcomes of deflection.

Keywords:

Blast load;
Plate;
Stiffeners;
Tilt Angle;
Blast height.

1 Background

The floor slab system utilized in a structure differs according to the intended function of the area, financial constraints, and architectural specifications. The SNI 2847:2019 regulation specifies two types of reinforced concrete floor slab systems: one-way slabs and two-way slabs. Two-way slab systems model the floor load distribution in both orthogonal directions, whereas one-way slab systems presume the load is distributed in a single orthogonal direction (the short direction). This principal differentiation defines two-way slab systems from one-way systems [1]. The implementation of floor beam stiffeners has the potential to reduce bending moments and deflections in a floor slab. Conditional boundaries along the sides of a slab are determined by the type of support. These include partial or elastic fixity, support only, support freely, and total fixity. A grid beam can serve as an approximation for plate modeling due to the similar stress path that plate components follow in comparison to beams.

Accidents in the building industry can lead to explosions or other disruptions that were not included into the planned design. Several circumstances may lead to accidents at electrical substations, including winding failures, abrupt power surges, design errors, insulation oil leaks, and the creation of combustible mixtures [2]. It is necessary for fire walls to be built in order to prevent fire from spreading to adjacent units in the event of an explosion or fire in any kind of electrical transformer. Pre-cast concrete in the shape of a slab covered in a heat-resistant substance makes up the structure, which has to be taller than the transformer and reach a height of at least ten meters [3]. A brief chemical reaction that releases pressure and heat energy in a matter of milliseconds is known as an explosion. Through faster-than-sound wave propagation, the massive explosive pressure created in the air fills the whole air cavity. A blast wave is produced when the air around an explosion is compressed by the tremendous explosion pressure [4]. Every explosion has many characteristics: (a) pressure peaks that are both positive (P_{so}) and negative (N_{dn}); (b) blast periods that are both positive (t_{dp}) and negative (t_{dn}) in length.

The dynamic load on the construction is determined by the model equation input, which impacts the blast load scenario. [5]. The height and angle of the explosion need a consideration of this blast load in relation to the floor slab's dynamic behavior.

To provide thorough information and effectively communicate the desired findings of a research, results visualization and blast load formulation are essential. For a society to be informed, thinking and communicating using data visualization is crucial. In order to comprehend linkages, analyze scientific models, and present data to others, students must employ visualizations, according to science education standards [6], [7]. Additionally, scientific psychology is influenced by visual communication. The Project on Scientific Information Exchange in Psychology has conducted previous investigations that elucidate the mechanisms and progression of information, starting from its generation by the researcher and culminating in its retrieval from a secondary source [8]. Regarding the system's overall operation, the scientists' information-exchange behaviour is the most crucial component. As part of their endeavors to stay informed about contemporary developments, scientists consistently remain vigilant for scientific or technical information that is pertinent to their ongoing or forthcoming endeavors, and actively pursue such data [9], [10]. Graphs and tables are the fastest way to communicate findings.

2 Modified Buwono Polynomial Equation

It is imperative to validate the research pertaining to the idealization of the Friedlander equation [11], [12], in light of the numerous studies performed on its modification as an explosive load. Further investigation into the Friedlander equation employing a fourth-order polynomial equation approach is warranted, bearing in mind Reed's 1977 study which employed a polynomial equation approximation to solve the equation. As the simplest mathematical equations or functions, which can be evaluated using only multiplication and addition, this article examines the application of polynomial equations as a method for determining the form of the Friedlander exponential equation. Even more broadly, polynomials can depict nonlinear relationships of the most general kind [13]. Moreover, the utilization of polynomial equations as approximations for exponential equations is justified for two primary reasons: firstly, polynomial equations effectively reduce error; and secondly, they minimize error even when the equation values reach their utmost [14].

This study also corroborates the findings of Buwono's investigation concerning the formulation presented in Modification Modeling of The Friedlander's Blast Wave Equation Using The 6th Order of Polynomial Equation [15], which contrasts with the research's results as depicted in the graph. In one stage, the investigation should be conducted as follows:

$$P(t) = P_r \left(0,00075 \left(\frac{t}{t_d} \right)^6 - 0,0146 \left(\frac{t}{t_d} \right)^5 + 0,1203 \left(\frac{t}{t_d} \right)^4 - 0,5412 \left(\frac{t}{t_d} \right)^3 + 1,4095 \left(\frac{t}{t_d} \right)^2 - 1,9752 \left(\frac{t}{t_d} \right) + 1 \right) \quad 0 \leq t \leq t_d \quad (1)$$

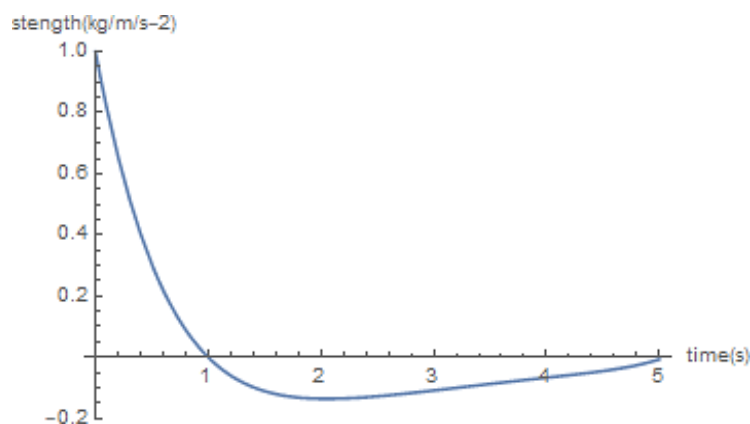


Fig. 1: The 2020 version of Buwono's blast load equation (kg/m/s²) [15].

The constraint of t_d (positive phase duration) is the simultaneous completion of the positive and negative phases of the explosion, as illustrated in Fig. 1 by Buwono's polynomial blast equation. As soon as the positive phase of the explosion load concludes, the load behavior transforms into a negative pressure load. While the duration of this phase is roughly double that of the positive phase, its maximal

amplitude is generally smaller [16]. Once these two phases are completed, the explosion enters a subsequent stage referred to as the free vibration phase, which is also called the no-load phase. The plate is more significantly affected by the impact that occurs during the unconstrained vibration phase or after the explosion [17]. Once these two phases are completed, the explosion advances to the no-load phase, which is also referred to as the unrestricted vibration phase. The plate is more significantly affected by the impact that occurs during the unconstrained vibration phase or after the explosion [18].

3 Blast Load Parameters

Numerous researchers have analyzed the greatest peak explosion pressure, which has led to the development of numerous blast equations. As per the scaling law, these equations incorporate the dimensions of the explosive and the influence of distance on the distinctive configuration of the detonation. With the following equation, Z , which represents a distance scale analysis, is incorporated into the most prevalent scaling law devised by Hopkinson-Cranz.

$$Z = \frac{R}{\sqrt[3]{W}} \quad (2)$$

Under the conditions, $\left[R = \frac{h_0}{\cos \alpha}\right]$ relates the distance (h_0) between the point of impact and the detonation source in terms of the angle formed (α) in units of meters, and W represents the mass of the explosive in kilograms [19].

According to Krauthammer (2008), the explosion parameters that are frequently incorporated into calculations are denoted as TNT (Trinitrotoluene). In order to generalize values, TNT was selected due to its detonation characteristics resembling those of the majority of solid explosives. The equation below, which utilizes the ratio of heat generated during detonation to establish a relationship between the mass of the design selected as the explosive and the equivalent mass of TNT, can be used to calculate the equivalent mass of TNT [20].

$$W_e = W_{exp} \frac{H_{exp}^d}{H_{TNT}^d} \quad (3)$$

Given that W_e represents the equivalent weight of TNT in kilograms (kg), W_{exp} represents the real weight of the explosive in kilograms (kg), H_{exp}^d represents the actual explosive heat of explosion in megajoules per kilogram (MJ/kg), and H_{TNT}^d represents the explosive heat of TNT in megajoules per kilogram (MJ/kg). The heat created by explosives is often described in UFC 3-340-02 Structures to Resist the Effects of Accidental Explosions, which is a frequently referenced table. Table 1 provides a calculation of the thermal energy produced by an explosion. The aforementioned data may be used to compute the weight of TNT that is comparable to equation (4) as stated in reference [21].

Table 1: Explosive name vs heat of blast load [21].

Explosive name	Heat of blast [MJ/kg]
TNT	4.10-4.55
C4	5.86
RDX	5.13-6.19
PETN	6.69
PENTOLITE 50/50	5.86
NITROGLYCERIN	6.30
NITROMETHANE	6.40

The equation developed by Newmark and Hansen is the most often used method to determine the maximum pressure at the peak of an explosion, regardless of the extent of blast damage [22]. It may be stated as follows:

$$P_{so} = 6784 \frac{W}{R^3} + 93 \sqrt{\frac{W}{R^3}} \quad (4)$$

The variable P_{so} represents the pressure in units of bar, W represents the mass of the load in units of metric tons (1000kg) of TNT, and R represents the distance from the explosion source to the location under examination, measured in meters and with regard to the angle produced. In 1984, Kingery and Bulmash provided a detailed description of the mathematical connections between blast parameters. They expressed these relationships using a polynomial equation and measured distances on a logarithmic scale. Fig. 3 is a graphic illustrating the explosion parameters of the positive phase of the blast wave [20].

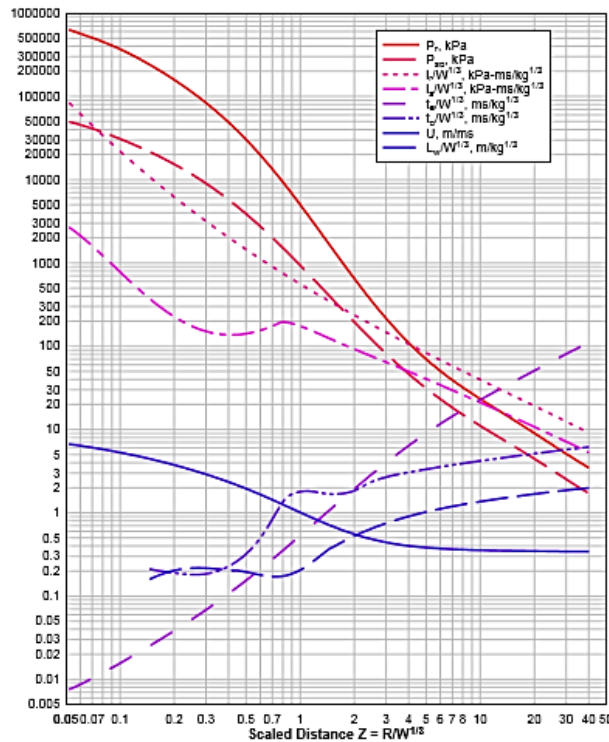


Fig. 2: Parameters describing the positive phase of a spherical shock wave generated by the detonation of TNT in free air [20].

The impact of the blast wave mostly relies on the nature of the explosion and the distance between the explosion source and the target, known as the stand-off distance. The pressure of the explosion wave increases exponentially until it surpasses that of the surrounding atmosphere (positive phase) [23]. Over time, the pressure may decrease to a level lower than the surrounding pressure. The term used to refer to this stage is the negative phase. In this stage, a partial vacuum is created, causing the intake of air. Additionally, it is accompanied by strong suction winds that transport the debris a considerable distance away from the explosion's origin. The positive phase is characterized by a shorter length and greater intensity compared to the negative phase. As the distance between the objects involved in the stand-off rises, the time during which the blast wave's positive phase occurs also increases. This leads to a decrease in the wave's intensity and a longer duration for the shock impulse that accompanies it. The peak overpressure P_+ (in MPa) is a crucial metric for predicting the reflected wave and is influenced by several blast characteristics [24], [25].

4 Free Vibration analysis

Understanding the behavior of a structure when subjected to an external force or oscillation is crucial for conducting structural analysis. The natural frequency of a structure, determined under the assumption of no damping or loading, only depends on the beginning circumstances and serves as a numerical representation of the structure's behavior. This is often known as a free vibration analysis. Equations may be used to establish the equations of motion for a damped rectangular orthotropic plate that is stiffened in one direction and subjected to a dynamic load.

$$D_x \left(\frac{\partial^4 w(x,y,t)}{\partial x^4} \right) + 2B \left(\frac{\partial^4 w(x,y,t)}{\partial x^2 \partial y^2} \right) + D_y \left(\frac{\partial^4 w(x,y,t)}{\partial y^4} \right) + \gamma h \left(\frac{\partial w(x,y,t)}{\partial t} \right) + \rho h \left(\frac{\partial^2 w(x,y,t)}{\partial t^2} \right) = p_z(x, y, t) \quad (5)$$

Flexural rigidity of orthotropic plates in the direction perpendicular to the stiffener (D_x): $D_x = \frac{E_{cy}.h^3}{12.(1-v_x.v_y)} + \frac{E_{cx}.bx}{6.a_x} \left((hx - (ex - \frac{h}{2}))^2 . (2.hx + ex + h) - (ex - \frac{h}{2})^2 . (ex + h) \right)$ and then Flexural rigidity of orthotropic plates in the direction parallel to the stiffener (D_y): $D_y = \frac{h^3}{12} \left(\frac{E_{cx}}{1-v_x.v_y} \right)$. Orthotropic plate torsional rigidity (B): $B = \sqrt{D_x . D_y}$. Thickness of orthotropic plate (h), Density of orthotropic plate (ρ), Equivalent viscous damping of orthotropic plates (ξ), Poisson ratio of plate material in the x-axis and y-ordinate direction (v_x & v_y), Modulus of elasticity of concrete in x-axis (E_{cx}) and y-ordinate (E_{cy}) direction, and The z-direction transverse load function that depends on the position (x,y) and time (t) functions ($p_z(x,y,t)$).

4.1 Modified Bolotin method

The plate differential equation with partial fixity boundary conditions may be solved using the modified Bolotin technique, which incorporates the capability to include the influence of high mode. By considering the plate as a basic support on all sides, it is feasible to calculate the eigenvalue for a rectangular plate with partial fixity on all sides. The p coefficient is substituted for the integer index value in the x direction, whereas the q coefficient is employed in the y direction. The actual numbers obtained throughout the resolution of the auxiliary issue are used to ascertain the values of p and q . The eigenvalue equation for the plate's partial fixity boundary condition is represented by equation (7) below.

$$\omega_{pq} = \sqrt{\frac{\pi^4}{\rho h} \left[D_x \left(\frac{p}{a} \right)^4 + 2B \left(\frac{pq}{ab} \right)^2 + D_y \left(\frac{q}{b} \right)^4 \right] + k + G_s \left[\left(\frac{p}{a\pi} \right)^2 + \left(\frac{q}{b\pi} \right)^2 \right]} \quad (7)$$

Where p and q are real numbers obtained from the auxiliary solution in the x and y directions, respectively. shown in the format of a Wolfram Mathematica application.

```
For[i = 1, i ≤ iter, i++,
  For[j = 1, j ≤ iter, j++,
    ω[i, j] =
      Sqrt[
        (
          (π^4 / (ρ * h)) *
          (
            Dx * (p[i, j] / a)^4 +
            2 * B * (p[i, j] * q[i, j] / (a * b))^2 +
            Dy * (q[i, j] / b)^4
          ) +
          k +
          Gs * (
            (p[i, j] / (a * π))^2 +
            (q[i, j] / (b * π))^2
          )
        )
      ];
```

4.1.1 First spatial auxiliary solution

The following is the trial function for the initial spatial auxiliary solution (x direction):

$$W(x, y) = X(x) \sin \left[\frac{q\pi y}{b} \right] \quad (8)$$

The equation for the x-direction position function solution is:

$$X(x) = A_1 e^{i\frac{\mu\pi}{a}x} + A_2 e^{\frac{\pi}{ab}\beta x} + A_3 e^{-i\frac{\mu\pi}{a}x} + A_4 e^{-i\frac{\mu\pi}{a}\beta x} \quad (9)$$

shown in the form of a wolfram mathematica program as follows:

```
X[i, j] = A1[i, j] * Cosh[
  (β i j[i, j] * π * x) / (a * b)
] + A2[i, j] * Sinh[
  (β i j[i, j] * π * x) / (a * b)
] +
  A3[i, j] * Cos[
  (p[i, j] * π * x) / a
] + A4[i, j] * Sin[
  (p[i, j] * π * x) / a
];
```

4.2 Second spatial auxiliary solution

Just like the first auxiliary issue, the solution to the second auxiliary problem may be computed. However, the key distinction is that it can only be computed along the y-axis.

The second spatial auxiliary solution y-direction trial function is as follows:

$$W(x, y) = Y(y) \sin\left[\frac{p\pi x}{a}\right] \quad (10)$$

The equation for the solution of the position function for the Y direction is as follows:

$$Y(y) = B_1 e^{\frac{\pi}{ab} y} + B_2 e^{-\frac{\pi}{ab} y} + B_3 e^{i\frac{q\pi}{b} x} + B_4 e^{-i\frac{q\pi}{b} x} \quad (11)$$

shown in the form of a wolfram mathematica program as follows:

$$\begin{aligned} Y[i, j] = & B1[i, j] * \cosh\left[\frac{\Theta i j[i, j] * \pi * y}{a * b}\right] + B2[i, j] * \sinh\left[\frac{\Theta i j[i, j] * \pi * y}{a * b}\right] + \\ & B3[i, j] * \cos\left[\frac{q[i, j] * \pi * y}{b}\right] + B4[i, j] * \sin\left[\frac{q[i, j] * \pi * y}{b}\right]; \end{aligned}$$

4.3 Total solution of plate motion equation

There are two potential outcomes for the behavior of plates when subjected to dynamic transverse loads: the homogeneous solution, which refers to free vibration, and the particular solution, which pertains to forced vibration. The cumulative plate response is achieved by combining the homogeneous solution with the particular solution, both of which are solved separately. The correlation between two solutions may be expressed as follows: The true overall reaction, taking into consideration the impacts of both free and forced vibrations, is referred to as the whole solution. The sum of the homogeneous solution and the specific solution yields the total solution, which is denoted by the following equation:

$$\begin{aligned} w = & \sum_{p=1}^{\infty} \sum_{q=1}^{\infty} X_{pq}(x) Y_{pq}(y) e^{-\xi \omega_{pq} t} (a_0 \cos(\omega_D t) + b_0 \sin(\omega_D t)) + \\ & \sum_{p=1}^{\infty} \sum_{q=1}^{\infty} X_{pq}(x) Y_{pq}(y) \int_0^t \frac{p(x, y, \tau)}{\rho h Q_{pq}} \int_{x=0}^a X_{pq}(x) dx \int_{y=0}^b Y_{mn}(y) dy \frac{e^{-\xi \omega_{pq}(t-\tau)}}{\omega_D} \sin(\omega_D(t-\tau)) d\tau \end{aligned} \quad (12)$$

shown in the form of a wolfram mathematica program as follows:

```

In[ ]:= For[i = 1, i <= iter, i++,
  For[j = 1, j <= iter, j++,
    Defbfe1[i, j] =
      Xx0[i, j] * Yy0[i, j] *
      \frac{Xx0[i, j] * Yy0[i, j]}{\rho * h * Q[i, j] * \omega_D[i, j]} *
      \left( \int_0^t (e^{-\xi * \omega[i, j] * (t-\tau)} * \sin[\omega_D[i, j] * (t-\tau)] * p01) d\tau \right) //
      Simplify;
    Print["Defbfe1[" , i, ", ", j, "] = ", Defbfe1[i, j]]
  ]
]

```

4.4 Moment

The magnitude of the bending moment acting on the edges of a plate with limited rotational flexibility depends on the rotational stiffness of those edges. Equations are used to ascertain the boundary conditions for partial fixity conditions. [11].

$$M_x(x, y) = -D_x \left(\frac{\partial^2 w(x, y)}{\partial x^2} + \nu_y \frac{\partial^2 w(x, y)}{\partial y^2} \right) = k_1 \frac{\partial w(x, y)}{\partial x} \text{ di } x = 0 \text{ dan } x = a \quad (13)$$

$$M_y(x, y) = -D_y \left(\frac{\partial^2 w(x, y)}{\partial y^2} + \nu_x \frac{\partial^2 w(x, y)}{\partial x^2} \right) = k_2 \frac{\partial w(x, y)}{\partial y} \text{ di } y = 0 \text{ dan } y = b \quad (14)$$

4.5 Absolute Maximum Deflection

In the slab during free vibration, the absolute maximum deflection is the largest deflection. Checking if the absolute maximum deflection value still satisfies the analysis's boundary conditions and serviceability standards is necessary.

The deflection that happens complies with the small deflection theory's norms, which is one of the essential presumptions utilized in the process of obtaining the equations of motion of the plate. This presumption has a significant impact on how we articulate the connection between the moment of curvature and the resulting deflection. To validate the values acquired from the study, the deflection values must be reassessed in light of this criteria. Live load and dead load are two different types of loading. Live loads include those caused by earthquakes, wind, and explosions[1]. According to SNI 2847: 2019, plates must meet the maximum permitted instantaneous deflection.

During free vibration of the slab, the absolute maximum deflection corresponds to the biggest deflection. It is essential to verify whether the absolute maximum deflection value still meets the boundary requirements and serviceability criteria of the analysis.

The observed deflection adheres to the principles of the small deflection hypothesis, which is a fundamental assumption used in deriving the equations of motion for the plate. This assumption greatly influences how we express the relationship between the curvature at a given time and the resultant deflection. In order to verify the accuracy of the data obtained from the research, it is necessary to reevaluate the deflection values in accordance with these criteria. Live load and dead load are distinct categories of loading. Live loads include the forces generated by seismic activity, wind, and explosions [1]. The utmost allowable instantaneous deflection for plates is outlined in SNI 2847: 2019.

$$\delta \leq \frac{l}{360} \quad (15)$$

5 Methodology

The following procedures outline the process of establishing the blast load parameters: Determine the specific explosion scenario, the mass of the explosive material denoted as W , and the distance from the center of the explosion to the structure being analyzed represented by R in equation (3). Determine the specific region of the building that will be impacted by the explosion. The component of the plate construction shown in Fig. 4 is used to counteract the explosion's location in this investigation. To determine the highest value of the positive phase's amplitude parameter, P_{so} , represented by the polynomial equation as $P_{r,max}$, a scenario involving an explosion using a specific type of TNT with a magnitude of 5 kg is used in the third stage. Fig. 3 depicts the explosion scenario. The experiment involves detonating 5 kg of TNT, as depicted in Fig. 4, to measure the maximum amplitude parameter of the positive phase, referred to as $P_{r,max}$, in the polynomial equation. The duration of the positive phase, t_0 , is determined by analyzing the computed z values from Fig. 3. The negative phase, t_d , is generated by the use of a 6th-order polynomial equation model.

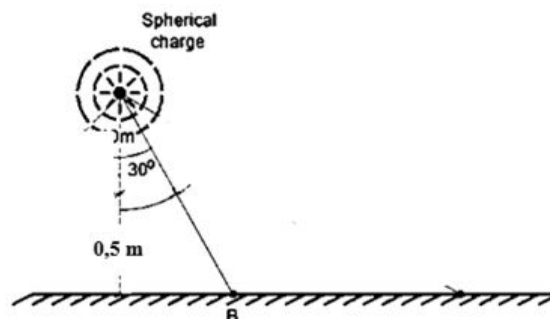


Fig. 4: Distance from the explosion to the location where the observation point was impacted [3].

6 Numerical result and discussion

The numerical computations include manipulating problem parameters using different values for the number of modes in the x and y directions, denoted as $m = 1, 2, \dots, 5$ and $n = 1, 2, \dots, 5$, while considering the convergence of eigenvalues. The slab has the following parameters: length (a) = 8 m, width (b) = 5 m, and thickness (h) = 0.23 m. A stiffener with dimensions of 30 x 50 cm² is used, where

the height of the stiffener comprises the thickness of the slab. The density of concrete is 2400 kilograms per cubic meter. The plate exhibits orthotropic behavior, meaning that the modulus of elasticity and Poisson's ratio are different in the x and y directions. Specifically, the modulus of elasticity in the x direction (E_{cx}) is 23400 MPa, while in the y direction (E_{cy}) it is 22200 MPa. The Poisson's ratio in the x direction (ν_x) is 0.2, while in the y direction (ν_y) it is 0.15. The rotational stiffness, as referenced in Gibigaye's journal, is denoted by the values of k_1 and k_2 , which are both equal to 1.0×10^6 Nm/rad [14].

Table 2: Modeling the inclination angle and height of a blast load parameter.

Parameter	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
h_0	0.10	0.50	1.00	0.1000	0.5000	1.00
α	0.00	0.00	0.00	30.00	30.00	30.00
R	0.10	0.50	1.00	0.1155	0.5774	1.1547
H_{exp}	5.86	5.86	5.86	5.86	5.86	5.8600
H_{tnt}	4.55	4.55	4.55	4.55	4.55	4.5500
W_{ex}	0.6567	0.6567	0.6567	0.6567	0.6567	0.6567
Z	0.0534	0.2670	0.5340	0.0617	0.3083	0.6166
P_{so}	50000	12000	4000	49500	11800	4000
i_s	6820	1636.8	108.82	6750	1625	108.82
t_{of}	0.2728	0.2728	0.0544	0.2727	0.2754	0.0544
t_{dp}	0.2173	0.1521	0.0608	0.2173	0.1182	0.0608
t_{total}	1.0865	0.7605	0.3042	1.0865	0.5911	0.3042
t_{dn}	0.8692	0.6084	0.2434	0.8692	0.4729	0.2434

This research investigates the behavior and dynamic response of a specific model of a concrete floor slab of 5 x 8 meters with a thickness of 0.23 meters. The slab includes one stiffening beam and is exposed to a local explosion load equivalent to 5 kilograms of TNT. The modeling is categorized according to the inclination angle and height of the blast load in the following manner: 1) Model 1 has an inclination angle of 0 degrees and a height of 0.1 m. 2) Model 2 has an inclination angle of 0 degrees and a height of 0.5 m. 3) Model 3 has an inclination angle of 0 degrees and a height of 1.0 m. 4) Model 4 has an inclination angle of 30 degrees and a height of 0.1 m. 5) Model 5 has an inclination angle of 30 degrees and a height of 0.5 m. 6) Model 6 has an inclination angle of 30 degrees and a height of 0.1 m.

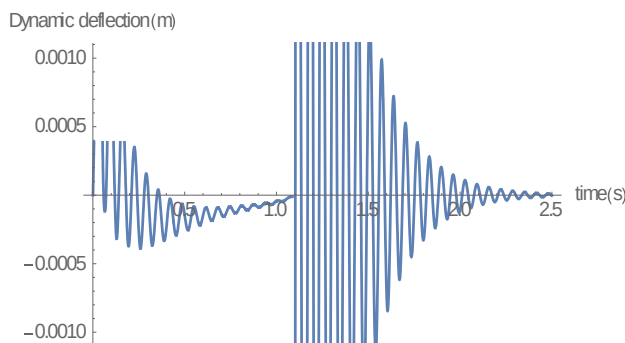


Fig. 5: Cumulative of Dynamic Deflection.

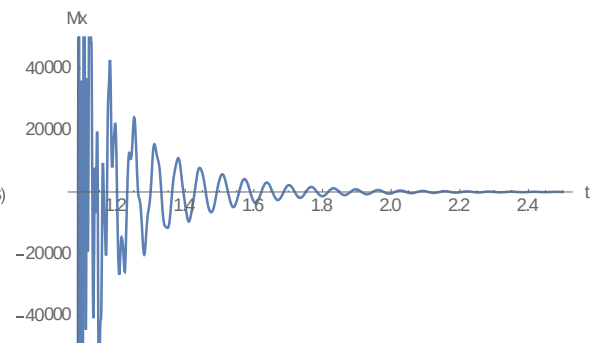


Fig. 6: Absolute moment in the x-direction.

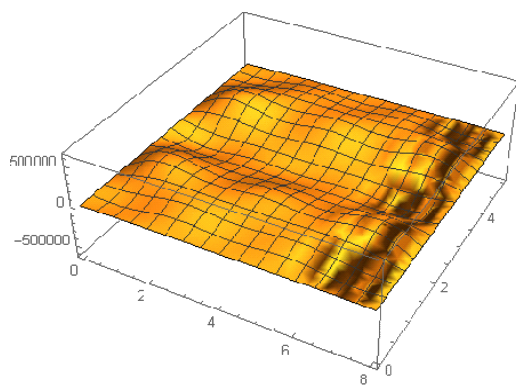


Fig. 7: Total Maximum Moment Pattern.

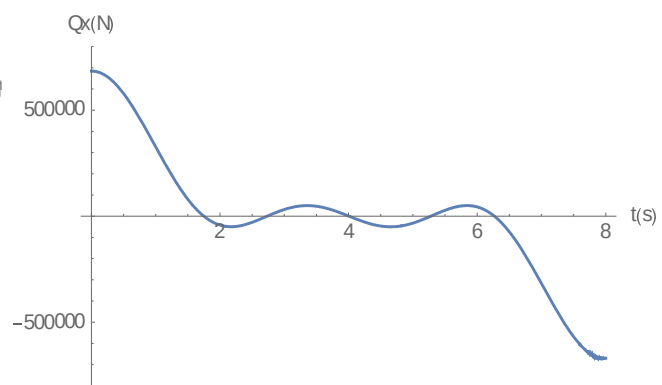


Fig. 8: Maximum shear force.

Table 3: Results of deflection, magnitude of moment, and magnitude of shear for models 1 - 6.

Parameter	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Inclination angle	0	0	0	30	30	30
Height	0.1 m	0.5 m	1 m	0.1 m	0.5 m	1 m
Defl. Tot af	0.01030 cm	0.00590 cm	0.0190 cm	0.02128 cm	0.00242 cm	0.0021 cm
Moment [kNm]	325921	95274.7	134200	639858	173376	171865
Shear	712818	195761	147135	763409	436944	366434

According to the specifications in SNI 2847: 2019, the deflection requirement is that δ should be less than or equal to $l/360$ [1], where l is equal to 8 meters. Therefore, the maximum deflection value is calculated to be $\delta = 0.022$ meters. The table displays a maximum deflection of 0.02128, which transpires subsequent to the starting condition. These findings indicate that the plate is still susceptible to bending caused by the dynamic load of a 5 kg TNT explosion, with the most significant effect seen in model 4. The explosion occurs at position 0.1 m, which is the lowest point for Model 4. The explosion angle is 30 degrees.

7 Conclusion

The study yielded the discovery that the blast load may be calculated by using a modified version of Buwono's 6th order polynomial equation. The Buwono equation was used to analyze the dynamic response of orthotropic floor slabs. The slabs had a thickness of 23 cm and were reinforced with stiffeners measuring $30 \times 50 \text{ cm}^2$. These stiffeners were designed to fulfill the deflection criteria specified in the SNI 2847: 2019 standard. The biggest deflection happens during the initial condition when free vibration takes place and is comparable to the maximum moment that occurs. The moment reaches its peak in the midpoint of the span, whereas shear is concentrated along the sides of the plate with some degree of limitation. The angle of inclination of the blast source does not exert a substantial influence in comparison to the height of the blast source. The table and visual graph depict the endeavors to expedite the comprehension of the research solution's objective outcomes.

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