The State of the Art on Analytical Investigation of RCC Viaduct Pier Structure due to Air Blast

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Abstract - *Nowadays, the number of terrorist activities increased and it leads to explosions. This shows that the blast loads effect on buildings is a serious matter that should be taken into consideration in the design process. Thus, an attack on the pier structures is just a matter of time. In the modern metros, roads are running on either side of these piers, as the metros are constructed over the roads. Any accident involving a blast can damage the pier structures resulting in serious injuries and even loss of life. Designing the piers to be blast resistant can help in reducing the casualties to a great extent.*

***Key Words*: Blast, Explosions, Detonation, Deflagration**

1.INTRODUCTION

Transportation is an area which requires huge and well-planned infrastructure. The infrastructure required for transportation includes roads, bridges, fly-overs, metros, underpasses etc. Piers are used to elevate many of these structures from the ground level. These piers generally do not have any protection except for a small crash barrier.

The increase in population over the years has led to a rapid increase in the number of accidents that are occurring in various parts of the nation. Also, the number of terrorist activities are climbing up. Due to these reasons blasts, both accidental and planned, are happening in different regions of the nation. The reinforced concrete pier structures do not have any protection against the loads that are generated during a blast. As per the present scenario, the chances of these blasts occurring near the pier of an elevated structure like a fly over or a metro is rather high.

The failure of the piers of the structure can cause the structure to fail and topple over. Thus, the failure of these piers may result in a large number of casualties. By understanding the loads generated during a blast and its effects on the structure, we can design the structure to withstand these loads. However, designing these structures to completely resist the blast forces is a tedious process and may not be economical. Designing these structures so that damages may occur to a certain level, but the total collapse of the structure does not occur is advisable.

2. EXPLOSION AND BLAST PHENOMENON

An explosion could be a fast increase in volume associated unharness of energy in an extreme manner, sometimes accompanied with the generation of high temperatures and therefore the unharness of gases. Explosions will be categorized supported their nature as physical, nuclear and chemical events.

Physical explosion: - Energy is also free from the ruinous failure of a cylinder of a propellent, discharge or perhaps combining of two liquids at totally different temperature.

Nuclear explosion: - Energy is free from the formation of various atomic nuclei by the distribution of the protons and neutrons among the inner acting nuclei.

Chemical explosion: - The rapid oxidation of the fuel elements (carbon and hydrogen atoms) is the main source of energy.

The bursts are mainly classified as air burst, high altitude burst, under water burst, underground burst and surface burst. Blast may be a pressure disturbance caused by the fast unleash of energy. The masses ensuing from a blast area created by the fast growth of the energetic material, making a pressure disturbance or shock wave divergent removed from the explosion supply[Fig-1]. Blast pressure is a lot of properly air pressure, as a result of it's relative to close conditions, instead of associate degree absolute pressure.

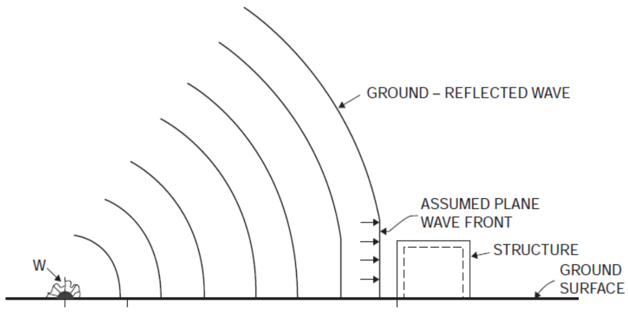

Fig-1 : Propagating blast wave

Expansion of the blast wave causes movement of air particles to outward during the positive phase and inward during the negative phase. The flow of Air particles flow creates a pressure analogous to that caused by wind and pressure produced by this flow is the dynamic pressure. This pressure is lower in magnitude than the shock or pressure wave and imparts a drag load like wind loads on objects in its path.

Unconfined explosions can occur as an air-burst or a surface burst. In associate degree air burst explosion, the detonation of the explosive happens higher than the bottom level and intermediate amplification of the wave caused by ground reflections happens before the arrival of the initial undulation at a building (Fig-2) because the undulation continues to propagate outward on the bottom surface, a front unremarkably known as a Mach stem is made by the interaction of the initial wave and therefore the mirrored wave.

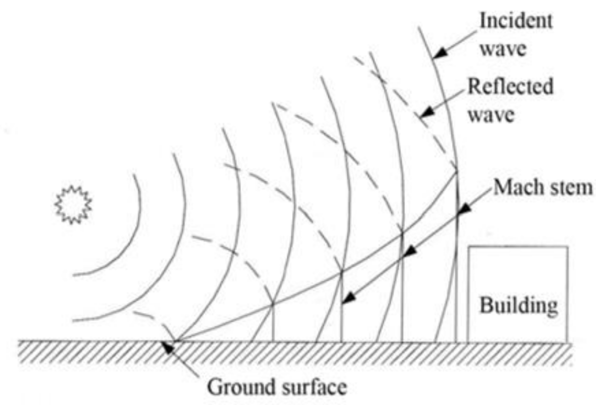

Fig- 2: Air burst with ground reflections

However, a surface burst explosion happens once the detonation happens on the point of or on the bottom surface. The initial blast wave is mirrored and amplified by the bottom surface to provide a mirrored wave(Fig-3). Unlike the air burst, the reflected wave merges with the incident wave at the point of detonation and forms a single wave. In most of cases, terrorist activity occurs in built-up areas of cities, where devices are placed on or very near the ground surface.

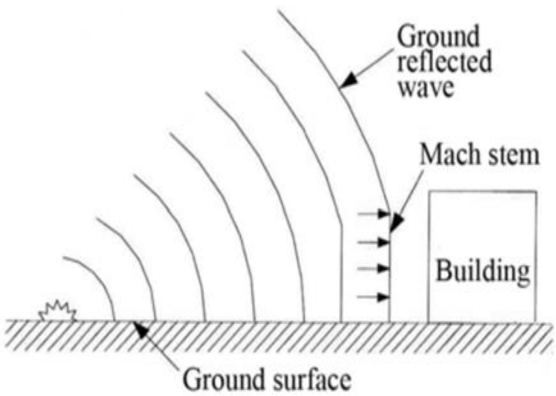

Fig- 3: Surface burst

A blast involving an explosive is an exothermic chemical reaction, usually involving an oxidizer and a fuel. Explosion reactions can be produced by a wide array of materials, some familiar, such as trinitrotoluene (TNT), while others are less well known. The reaction rate is dependent on the chemical and physical properties of the energetic material, reactant proportions and homogeneity, geometry of the material, characteristics of the "container" in which the material resides, method and energy of initiation, and other initial conditions. Use of the TNT (Trinitrotoluene) as a reference for determining the scaled distance, Z, is universal. The first step in quantifying the explosive wave from a supply nonetheless the trinitrotoluene, is to convert the charge mass into constant mass of the TNT. It's performed so the charge mass of explosive is increased by the factor supported the particular energy of the charge and therefore the TNT.

3. BLAST LOADING

The first step within the blast-resistant style of structures is to grasp the way to outline the blast loading. The structures are also subjected to blast loading, that includes blast pressure, ground shock, and fragment impact, notably within the near-range region; whereas, within the far-field region, structures are subjected to solely blast pressure.

In case of nuclear blast, the ensuing undulation produces terribly high blast pressure and huge impulse loading, which ends up in destruction of structures settled at even an oversized distance from the supply. Blast atmospheric pressure is expressed relative to close condition (P0) instead of absolutely the pressure. Blast-induced pressure wave profile created from the perfect detonation, in conjunction with the various loadings in relation with amplitude and frequency that govern the planning of any structural part [Fig-4].

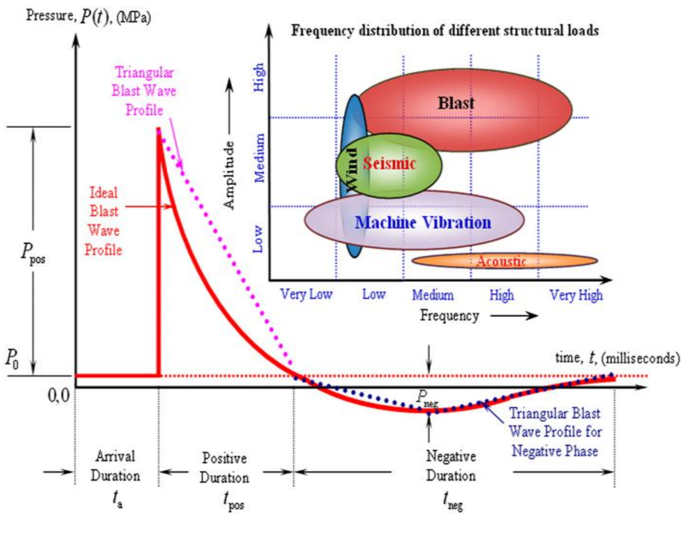

Fig- 4: Blast Wave and Amplitude-Frequency Relations of structural loadings

An ideal shock wave illustration and its characteristics are an operate of the gap of a structure to the centre of the charge, R, and time, t. the height pressure is understood as peak positive atmospheric pressure, P_{pos}. A negative part follows, during which the pressure is under close pressure, called stressed, P_{neg}. The lengths of peak positive atmospheric pressure and stressed area called positive (t_{pos}) and negative (t_{neg}) duration, severally. However, for simplicity within the analysis, a triangular blast load profile is usually applied [Fig-4], neglecting the negative part. For comparatively diluent elements that area versatile, however, the negative part ought to even be modelled.

As a blast wave travels away from the source, the pressure amplitude decreases, and the duration of the blast load increases. Overexpansion at the center of the blast creates a vacuum in the source region and a reversal of gas motion. This negative pressure region expands outward, causing a negative pressure (below ambient), which trails the positive phase. The negative phase pressure is generally lower in magnitude (absolute value) but longer in duration than the positive phase. Generally speaking, positive phase blast loads are more consequential than negative phase loads, the latter of which is often ignored.

4. SOURCES OF BLAST

Blasts involving chemical reactions can be classified by their reaction rates into two primary groups: deflagration and detonations.

A deflagration is an oxidation reaction that propagates at a rate less than the speed of sound in the unreacted material. The corresponding blast wave is often termed a *pressure* wave and has a finite rise time [Fig – 5]. A fast deflagration can create a more sudden rise in pressure.

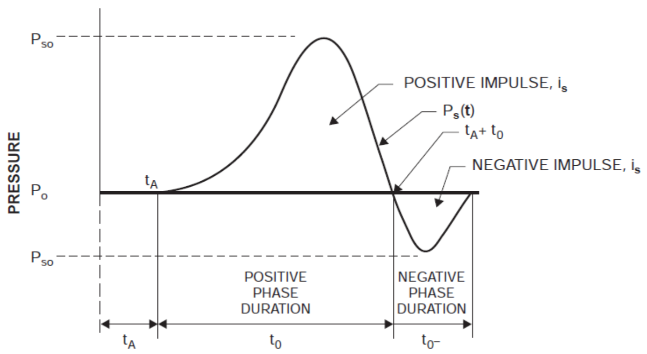

Fig – 5: Pressure wave from deflagration

In a detonation, the reaction front propagates supersonically, sometimes persistently quicker than the speed of sound. This shock wave is termed a blast wave and has an on the spot rise in pressure [Fig -6]. Since pressure is closely concerning reaction rate, detonation pressures are sometimes persistently above combustion pressures.

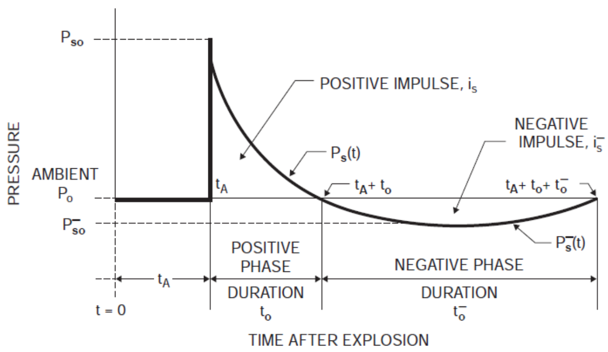

Fig – 6: Shock wave from detonation

Shock waves are aggressive blast waves that travel through air (or another medium) at a speed quicker than the speed of sound. Shock waves are characterized by a right away increase in pressure followed by a speedy decay. Pressure waves are lower amplitude and travel below the speed of sound. Pressure waves are characterized by an additional gradual increase in pressure than a wave, with a decay of pressure abundant slower than a wave. In most cases, shock waves have a larger potential for harm and injury than pressure waves.

A deflagration may be initiated by a soft ignition source such as friction, spark, or open flame Under certain conditions, a deflagration can transition into a detonation. Alternatively, detonations can be directly initiated in an explosive material that exceeds certain minimum geometry constraints if it is impinged upon by a shock source of sufficient strength.

As the shock or pressure wave strikes a wall or different object, a mirrored image happens, increasing the applied pressure on the surface. This mirrored pressure is significantly more than the incident or free-field pressure wave. At the free edges of a mirrored image surface, the separation between the forward traveling incident shock wave and rearward traveling mirrored shock wave creates a concentration, or pressure relief wave. Rarefactions travel inward from the outer edges across the face of the reflection surface. The concentration waves relieve the positive mirrored pressure all the way down to the free-field or side-on pressure and drag pressure. the height mirrored pressure isn't affected, solely the period. The time needed for the concentration waves to utterly relieve the mirrored pressure is termed the clearing time. This clearing time varies across the surface. It ought to be noted that a concentration wave doesn't in a flash clear mirrored pressure; rather, the relief is somewhat gradual and takes longer than the time needed for the vanguard of the concentration to jaunt the center of the mirrored surface. If the clearing time exceeds the positive part shock wave period, clearing doesn't have an effect on the positive parts hundred.

5. BLAST WAVE SCALING LAWS

Blast pressures, load length, impulse, blast wave speed, arrival times, and alternative blast parameters are often bestowed in scaled kind analysis has shown that scaling laws will be applied to explosions, permitting knowledge from one explosion take a look at to be applied to a geometrically similar (larger or smaller) case. Both dimensional and dimensionless scaling are used, and care must be taken with all unit parameters to ensure the scaling is correctly applied for the blast curves being used. In blast analysis, there are many differing methods of scaling blast parameters. By scaling the parameters determined from experimental results of an explosion, the results are generalized and thus can be utilized for the simulation of blasts of varying energy or varying distances. The two most common methods, and the ones used here, are Hopkinson and Sachs blast scaling methods. These are described below.

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5.1 Hopkinson Blast Scaling

Hopkinson blast scaling is based on cube root scaling, formulated by Hopkinson in 1915. Essentially, Hopkinson put forth the idea that if two differing weights of the same explosive, both detonated in similar atmospheric conditions, then at some identical scaled distance, both charges produce similar blast waves. Using this idea, he presented the idea of a dimensional scaled.

$$Z = \frac{R}{W^{\frac{1}{3}}} \text{ or } Z = \frac{R}{E^{\frac{1}{3}}}$$

where R is the distance (range) from the explosive blast center, W is the weight of the charge, and E is the energy of the charge. However, W is usually used only for a weight of standard explosives such as TNT, but energy E is a much more physically realistic parameter.

5.2 Sachs Blast Scaling

Sachs scaling was planned in 1944 as an additional general blast scaling law that is predicated on the blast parameters being distinctive functions of a scaled distance.

$$P = \left(\frac{RP_0^{\frac{1}{3}}}{E^{\frac{1}{3}}}\right)$$

where R is that the distance (range), Po is that the close pressure, and E is that the energy of the burster. Thus, Sachs scaling law states that pressure, time, impulse, and different parameters may be expressed as functions of this scaled distance however assumes that air behaves as an ideal gas and assumes gravity and consistency square measure negligible.

Hopkinson scaling was shown to be consistent for variable distances however not for variable pressure. Therefore, every take a look at a unique pressure made a unique impulse prediction. This wasn't true with Sachs scaling that made wonderful scaled results that were consistent for every amendment in blast distance and in pressure. Thus, it can be shown that Hopkinson scaling could be a special case of Sachs scaling (i.e., Sachs scaling reduces to Hopkinson scaling once there aren't any atmospherical changes between the explosive take a look at information and also the actual conditions of the specified explosive to that one is predicting for modelling or similar research). Also, as a result of the right gas assumption, shock strengths should be low enough for a vaporish medium to behave as an ideal gas. Therefore, for a few robust shock waves or for distances that square measure notably on the brink of the explosive, this law will not apply.

6. BLAST LOAD CALCULATION

Various relationships and approaches for decisive the incident pressure worth at a selected distance from an explosion. All the projected relationships entail computation of the scaled distance, that depends on the explosive mass and therefore the actual distance from the center of the spherical explosion. Relationships for the height air pressure for spherical blast embrace those of Brode, shown in the below equation. They rely on the magnitude of the explosion. Equations are valid wherever the height air pressure is over ten bars (=1MPa) (near field explosions) and for pressure values between zero.1 bar and one0 bars (0.01MPa-1MPa) (medium and much field explosions). The scaled distance is measured in m/kg$^{1/3}$ and the pressure P_{so} in bars,

$$P_{SO} = \frac{6.7}{Z^3} + 1, \text{for } P_{SO} > 10 \text{ bars}$$

$$P_{SO} = \frac{.975}{Z} + \frac{1.455}{Z^2} + \frac{5.85}{Z^3} - 0.019, \text{for} 0.1 < P_{SO}\ 10 \text{ bars}$$

Another formulation, that's wide used for computing peak air pressure values for ground surface blast has been projected by Newmark and doesn't contain categorization in line with severity of the detonation. this is often given by equation below.

$$P_{SO} = 6784\frac{W}{R^2} + 93\sqrt{\frac{W}{R^3}}$$

where, P_{so} is in bars, W is that the charge mass in metric tons (1000kg) of explosive compound and R is that the distance of the surface from the center of a spherical explosion in m.

Mills have conjointly introduced associate degree expression of the height air pressure in kPa, within which W is expressed in weight unit of explosive compound and also the scaled distance Z is in m/kg1/3 as given in the equation,

$$P_{so} = \frac{1772}{Z^3} - \frac{114}{Z^2} + \frac{108}{Z}$$

Kinney presents a formulation that's supported chemical kind explosions. it's delineated by the equation below and has been used extensively for laptop calculation functions,

$$P_{SO} = P_o \frac{808\left(1 + \left(\frac{Z}{4.5}\right)^2\right)}{\left(\left(1 + \left(\frac{Z}{0.48}\right)^2\right)\left(1 + \left(\frac{Z}{.32}\right)^2\right)\left(1 + \left(\frac{Z}{1.35}\right)^2\right)\right)^{0.5}}$$

where Z in m/kg1/3 is that the scaled distance and Po is that the close pressure.

These area unit a number of the common theories used for the calculation of blast parameters. many different theories are on the market to try to a similar.

7. LITERATURE REVIEW

Due to completely different accidental or intentional events, the behaviour of structural elements subjected to blast loading has been the topic of goodly endeavour in recent years. typical structures aren't styled to resist blast hundreds and the magnitudes of design hundreds are considerably not up to those made by most explosions. typically, typical structures are at risk of harm from explosions. With this in mind, developers, architects and engineers progressively are seeking solutions for potential blast things, to guard building occupants and the structures. There are many studies were distributed on blast resistance in structures. a number of the relevant literature that are in short mentioned below.

IS 4991-1968, was studied and the terms and notations utilized in blast loadings in Asian nation were studied. the overall characteristics of blast and its effects were thought of. Equations for blast force calculation was studied. Blast hundreds on structures on top of ground were studied specifically. The structural response and period of the structures is given during this IS code. Load mixtures for style is additionally prescribed within the code.

G. C Mays and P. D Smith in 1995, offer a textbook on blast effects on buildings. The supposed purpose of this book is to clarify the idea of the look of structures to resist blast loading then to recommend comparatively easy techniques for increasing the potential of a building to produce protection against explosive effects. The scope of the book is restricted to blast effects that derive from on top of ground, non- nuclear, high- order explosions and the style solely covers structures that contain a degree of plasticity.

Alexander M. Remennikov in 2003, studied the ways for predicting blast effects on buildings. once one building is subjected to blast loading made by the detonation of weapon of mass destruction device. Simplified analytical techniques used for getting conservative estimates of the blast effects on buildings. Numerical techniques together with Lagrangian, Eulerian, Euler- FCT, ALE, and finite component modelling used for correct prediction of blast masses on business and public buildings.

Luccioni et al in 2005, studied the consequences of mesh size on pressure and impulse distribution of blast masses with the help of hydrocodes. A process dynamic analysis victimisation AUTODYN-3D was administrated over the engorged urban surroundings that corresponds to the other rows of buildings of a block, within the same street. The results obtained for various positions of the explosive square measure bestowed and compared.

A.K.M. Anwarul Islam in 2005, investigated the foremost common kinds of concrete bridges on interstate highways and assessed the capacities of the crucial parts. A 2-span 2-lane bridge with sort III AASHTO girders was thought of for modelling. AASHTO Load and Resistance issue style ways were employed in the bridge style. The girders, pier caps and columns were analysed beneath blast loading to see their capacities. This study determined the blast capacities of the AASHTO girders, pier caps and the columns, and the needed stand-off distance of explosion from the columns which will probably shield the bridge from failure. Performance of AASHTO girders, piers, and columns beneath typical blast loading were analysed and documented for future use in blast resistant style of concrete bridges. The model bridge failing beneath typical blast masses applied over and beneath the bridge. The analysis findings all over that the AASHTO girders, pier cap, and columns couldn't resist typical blast masses. the quantity of blast masses, that the individual members will resist before failure, made up our minds. The model bridge columns were capable of resisting typical blast masses, if the explosion happens at a minimum standoff distance.

T. Ngo, et al. in 2007 for his or her study on blast loading and blast effects on structures provides a summary on the analysis and style of structures subjected to blast masses development for understanding the blast masses and dynamic response of assorted structural parts. This study helps for the planning thought against extreme events equivalent to blast, high speed impacts. the analytical investigation conducted at the University of Melbourne on the behaviour of high-strength concrete (HSC) columns subjected to severe blast loadings. The variables thought of were the magnitude of the blast, the concrete strength (40 MPa for traditional strength concrete and eighty MPa for HSC).

Zeynep Koccaz et al in 2008, studied the blast resistant building styles and theories, the sweetening of building security against the consequences of explosives in each beaux arts and structural style method and the style techniques that ought to be administrated. With correct choice of the structural system, neat beam-column connections, structural parts designed adequately, moment frames that transfer sufficient load and high-quality material; it's potential to make a blast resistant building. each single member ought to be designed up-to-date the potential blast loading. For the present structures, retrofitting of the structural parts may well be essential. though these precautions can increase the value of construction, to safeguard special buildings with coup de main risk like embassies, federal buildings or trade centres is unquestionable.

Donald O. Dusenberry et al. in 2010, provided an enchiridion for blast resistant building style. This enchiridion is organized into four elements, style issues, blast phenomena and loadings, system analysis and particularization and blast resistant particularization every addressing a spread of aspects of blast-resistance style. style issues provide a summary of basic principles coping with general issues and the style method, risk analyses, reduction, and shunning criteria that establish acceptable performance, science of materials performance beneath the extraordinary blast surroundings and performance verification for technologies and answer methodologies. Blast phenomena and loadings describes the explosion surroundings, loading functions to be used for blast response analysis, and fragmentation and associated ways for effects analyses. System analysis and style has covers analysis and style issues for structures. Blast-resistant particularization addresses particularization structural parts for resistance.

Hrvoje Draganić et al in 2012, determined the blast load on structures. They studied the varied kinds of explosion and located out completely different loading classes. They studied the structure explosion interaction. They additionally acquired a technique for scheming the blast loading on structure. Their study was conducted on concrete buildings. However, sure aspects of their study will be employed in this thesis. Loading was outlined as a record of pressure over time (pressure-time history). identical will be applied for piers.

Parag Mahajan et al in 2014, created studies to predict the blast masses and its impacts on buildings. numerous cases arising within the event of a blast is taken into account. numerous parameters effecting the blast were studied. They were even compared with seismic masses. The structural response was analysed, and numerous failure mode were additionally realized.

Mohammed Alias Yusof et al in 2014, done a simulation of concrete blast wall subjected to air blast loading. The simulation was done victimisation Autodyn. the consequences of detonations employing a relatively lower charge mass to a comparatively medium quantity of charge mass is bestowed during this paper. The paper provides the consequences of the varied charge lots on a blast wall. This information will facilitate in choosing a charge weight to suit the matter of the thesis.

Aditya Kumar Singh et al in 2014, studied the various kinds of blast loading and their effects on concrete structures. the varied kinds of blast masses and completely different models potential square measure delineated during this paper.

Yazan Qasrawi et al in 2015, studied the impact of blast and impact loadings on concrete stuffed FRP tubes by creating use of numerical models. The analysis was done victimization ANSYS Autodyn. They were able to apply the blast hundreds onto these columns and reach the conclusion that FRP has improved stiffness creating it a promising material in blast resistant application. the assorted components utilized in modelling is laid out in the paper, which might be wont to model the matter of this thesis in finite part package packages.

Aswin Vijay and Dr. K Subha in 2017, studied impact of longitudinal reinforcements in concrete piers subjected to blast loading. during this study a RCC column is modelled and analyzed. The analysis is finished in 2 ways. First one, by fixing the charge weight used for making the explosion and by varied the standoff distance of the explosion. within the second technique, the standoff distance is unbroken fastened and also the charge weight inflicting the explosion is varied. because the standoff distance will increase higher than a specific worth, the deformations created is that the same for the assorted reinforcement percentages. The deformations and stresses created within the pier increase with the rise to blame weight for the assorted share reinforcements, once the increasing charge weights thought of.

8. CONCLUSION

Explosions is categorized on the premise of their nature as physical, nuclear and chemical events. The fast oxidization of the fuel components (carbon and chemical element atoms) is that the main supply of energy in chemical explosion.

An explosion happens once a cloth undergoes a fast reaction. once associate degree explosion happens, the frothy product of the reaction area unit generated at a high temperatures and pressure. These gases expand suddenly into the environment and a shock wave is created. Since the gases area unit moving, they end in the movement of close air additionally. The injury caused by associate degree explosion could be a result of the passage of compressed gas. Blast waves propagate at terribly high speeds and gets mirrored after they meet objects. because the shock wave expands aloof from the supply of the explosion and its intensity diminishes alongside its impact on the objects around.

Deflagration and detonation is that the 2 primary teams of chemical reactions. In burning the waves propagates lower than the speed of sound and it's referred to as pressure wave. In detonation waves propagates over and over quicker than sound speed and it's referred to as shock waves.

Blast parameters area unit oftentimes expressed in scaled type. root scaling is that the most typical one. American Revolutionary leader and Sachs scaling area unit used for the scaling. There area unit varied approaches for the calculation of the explosion parameters. Brode', theory, Newmark's equation, Mill's theory and Kinney' and Abraham's equations area unit some common theories used for the calculation of blast parameters. many alternative theories also are out there to try and do an equivalent.

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