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Performance Enhancement and Simulation Design of Blast Resistant Structure

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Abstract – The rise in the numbers of terrorist incidents, notably in recent years, has demonstrated that the impact of explosive loads on buildings must be taken into account in the design phase. Although this is exceptional, man-made catastrophes are; in particular, blast loads are complex loads, which must be measured as earthquake and wind loads. The purpose of this study is to illustrate the hypotheses of blast resistant buildings, to improve the protection of buildings against explosives, and to establish construction strategies to counteract explosive impact. Firstly, explosives and forms of blasts is briefly described.

Keywords — Blast Explosion, Resistant Structure, SDOF

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I. INTRODUCTION

Last few year the terrorist attacks on structure and human are common around the world so that load of blasting on structure or buildings are serious issues that should consideration of that types of design are required in era. Although these types of attacks are exceptional cases, artificial disasters; blast loads are calculating under fact dynamic loads that need to be calculated just like seismic loads and wind loads. Structural analysis and study has been a field of systematic technical research for more than 65 years. External explosions and goals, such as a bomb explosion within or near a building can trigger catastrophic damage to the internal and external framework of the building, wall disintegration, sputum of large windows, and shutting down of critical life-safety systems. Damages to human lives and injuries to occupants can result from many reasons, including direct blasting-effect, structural damages of collapsing, debris impact, fire, and smoke. The indirect effects can combine to inhibit or prevent timely evacuation, thereby take part into additional casualties. In addition, major catastrophes resulting from gas-chemical explosions result in large dynamic loads, greater than the original design loads of many structures.

If the terrorist attacks become a normal in various countries so strategy for developing the blast resisting structure are required. Conventional structures are not considering the design for the resist blast loads and because the magnitudes of design loads are significantly below than generated by blasting, conventional structures are susceptible to damage from explosions. The civilians building are not able to withstand against the kind of extreme attack that would be happened on World Trade Centre in United State of America. However, owners of diverse building and construction practitioners should take measures to properly recognise possible risks in an unpredictable world to secure tenants and properties. Increasingly, construction managers, developers and engineers are searching at alternatives to possible fires to guarantee the wellbeing of construction staff and precious properties.

Illinois University and other prominent engineering and educational companies. The attacks of 11 September were a set of four co-ordinated jihadist assaults on the morning, Tuesday 11 September 2001, by the Islamic Terrorist Al-Qaida Organization against the United States. In the WTO, 2996 people were killed, wounded, more than 6,000 hospitalised, and the facilities and property were destroyed for at least $10 billion. In the months and years after the bombings, additional persons died of cancer and lung illnesses linked to 9/11. In India, the 2008 attacks in Mumbai (also known as 26/11) have been terrorist groups which occurred in November 2008, when ten Lashkar-e-Taiba members were attacked and shot for four days in Pakistan by the Islamic terrorist organisation based in Pakistan. On Wednesday 26 November, the assaults, with global worldwide criticism, began and lasted on Saturday 29 November 2008. At least 174 people have died and over 300 have been hospitalised, including nine strong assailants. There was eight of the attacks occurred in South Mumbai at Chhatrapati Shivaji Terminus, The Oberoi Trident, The Taj Palace & Tower, Leopold Cafe, Hospital, The Nariman House Jewish community center, the Cinema, and in a lane behind the Times of India building and St. Xavier's College. There was big powerful attack on Mazagaon, in Mumbai's port area, and in a taxi at Vile Parle.

II. REVIEW ON BLAST RESISTANT STRUCTURE

The frequency of explosive detonations is marked by an almost sudden spike from air pressure to peak overpressure. As the front expands pressure against the surrounding pressure, a negative pressure process generally takes place longer than the positive phase as shown in Figure 1.1. Typically in a design the negative step is less important than the positive. Where the incident pressure wave affects a system not identical to the wave's path, the wave reflects and enhances what is known as reflected pressure. The reflected pressure is always greater than the incident pressure at the same distance from the explosion. When a shockwave strikes a surface, it is reflected. Due to the reflection and corresponding momentum change there is a rise in pressure called reflected overpressure on the surface.

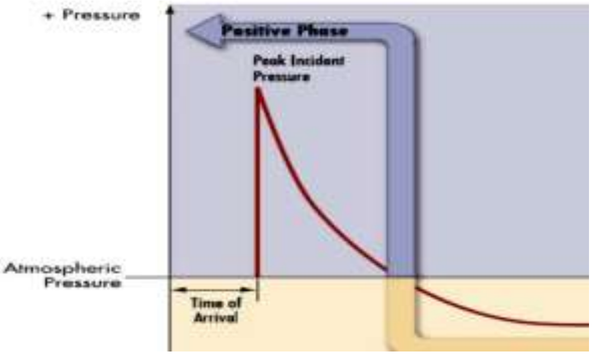

Fig 1: Overpressure-time history indicating sharp initial drop and extended negative phase (FEMA 426, 2003) [9]

Blast Loading and Its Behaviour Shock Waves

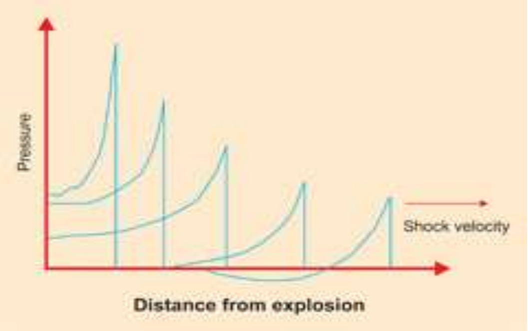

Figure 2: Blast wave propagation [10]

Shock Wave are defined as The rapid enlargement of hot or warm gases resulting from the detonation of an explosive charge gives rise to a compression wave (Figure), that's propagate throughout the air. In practice the shocked wave can considered steep in front of blast shock. This is the period taken to compress uninterrupted air in front of the wave at maximum pressure right after the wave. It can be inferred from Figure 2 that since the explosive source is circular the resultant shock wave becomes spherical, since its surface rises continuously, the energy per unit area decreases continuously. Consequently, the intensity in the front of the wave, called the peak stresses, is decreasing gradually when the shock wave moves away from the charge. The peak pressure is infinitesimal and the wave may be treated as a sound wave at wide distances from the charge. The pressure of the wave falls from the original high value behind the shock wave front. The pressure behind the front of the shock falls some distance from the charge to a lower than the atmosphere and increases to a steady value equivalent to the atmosphere. The portion of the shock wave of higher intensity than that of the environment is considered the positive phase and the part in which the pressure is smaller than it is the negative or the suction step is directly after it.

Through rapid fuel oxidation, the chemical explosion occurs. The vast quantities of real heat and gas produced in this reaction are expanding. Explosive low-end produces nearly static loads. The high explosion of a surrounding medium (chemical and nuclear), such as air or water, contributes to startling medium waves. High pressure gases are published in high temperature ratings.

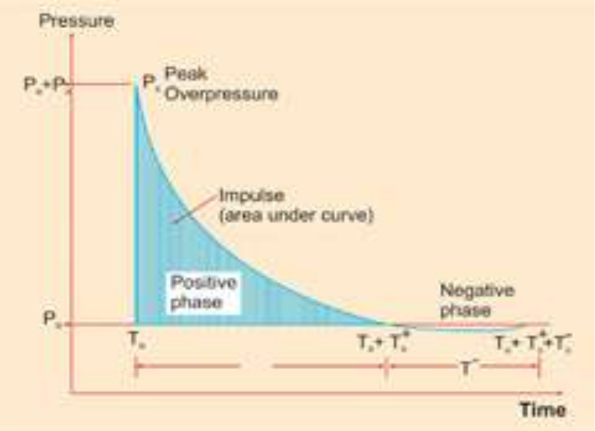

Figure 3: Generalized Blast Pressure History [11]

These gases naturally expand, and the surrounding medium is consequently compressed. The compressed medium, or for the specific case of air, forms a shock front. The shock front travels in a radial direction. The sum of 'overpressure' the front of the shock reduces as explosive gases cool and slow down. The gases emit energy to regulate the air pressure. Owing to the high pressure and mass of the gases, however, further expansion is required to maintain balance. Figure 3 illustrates the basic structure of a pulse shape. The high pressure, the duration, air density behind the shock front, the shock front speed and the blow pressures are essential variables that influence burst pressures.

Dynamic Loadings

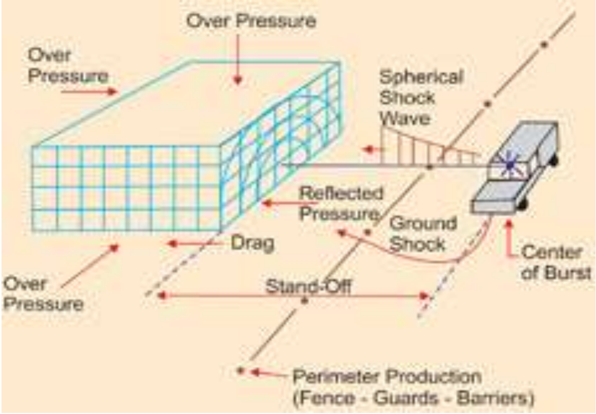

Figure 4: Blast loads on buildings [10]

All the structural member design based maximum resist the external forces and stable under entire period of blast loading. Load bearing structure fully damaged under the blasting braces that weak compared of framed structure. The shock waves strike a surface of the structure when structures would experience the combined loading conditions caused by the incident overpressure, the dynamic and highly transient reflected pressure that develop. Possibility of protection of people in basement when sudden great damage caused because basement slabs are provided objection at time of blast phase.

Effects on Structures

Classification of blast effect listed –primary based and secondary.

1. **Air blast**- The Pressure of air surrounding the structure are increase suddenly by external attack and a wind blasting.

2. **Direct ground shock**: Ground shocks are defined as the explosive that are partially or complete buried below the ground surface (G.L).

3. **Heat**: Heat is not new but the part of explosion and that are only form of explosion. In higher rate of temperature any building material does not perform their function.

4. **Primary fragments**: In explosion process the micro or small particles separated from somethings with high velocity which are the responsible for structural damages that's are also for injury to human and animal around the building.

Classification of blast loading are (figure4) [9]

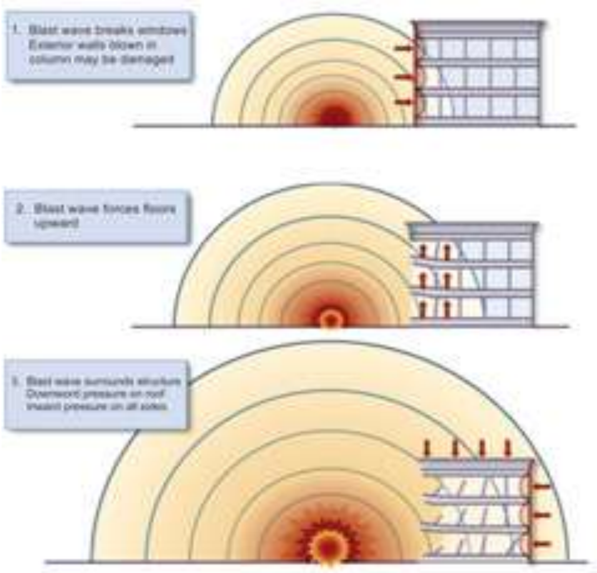

Figure 5: Blast Pressure Effects on a Structure [9]

In the first types of blasting, the consideration the magnitude of blast is high but its far away from structure so the possible damage on structure are relatively small as compared blasting magnitude. Capability of damage of blasting more but the important factor for less damages is distance. The structure is, however, massive enough to resist translation.

Structural Response or Analysis to Blast Loading

Impulsive loads are defined as Short duration loading, the shock load similar the impulsive load. Sometime the wave load or shock load are treated as triangular loading system in base of mathematically. The natural period of vibration and ductility of a structure governs its response to an explosion in the building construction there are different materials used like steel and concrete, the steel are well known example of ductile material and bricks and monolithic glass are example of brittle material. Different material absorbed significant amount of strain energy as per its property, below figure introduced relation between forces v/s times are followed

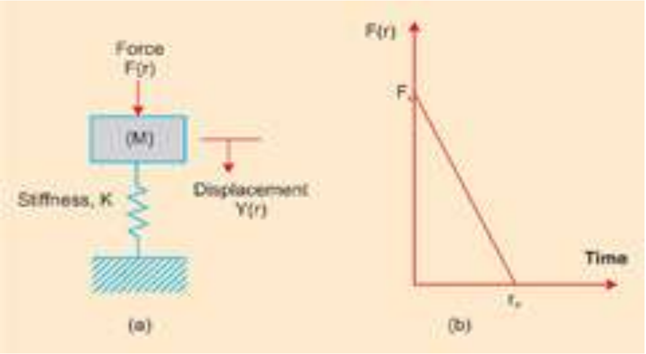

Figure 6: (a) SDOF system (b) Blast loading [8]

(a) Determination of blast properties (b) Determination of the natural response period of the structure (c) Comparisons between natural response period and positive phase of blast. The following can be described on the basis of (c) above:

i. The positive duration of blast pressure is less impulse response defined as the positive phase of the structure's vibration period. In this scenario, the system would mostly become deformed after the explosive charge has decreased.

ii. In almost statics, relative to the positive step length of the exposure pressure the normal time of vibration is smaller. In this scenario, the explosives distort the structure when the load is already in operation.

In case of dynamic pressure, the value of positive phase duration and natural period of vibration are close in structures deformation in structure are determined by solving the equation of motion in structural Equation of motion for a undamped forced system is given by

$MY(t) + KY(t) = F$ ………………(a)

Force which is given by

$F(t) = F_0 (1 - T / t_d)$ …………………. (b)

In equation initial condition for triangular pulse is

$Yo = 0$ and $Vo = 0$

The total displacement of an un-damped SDOF system is given by [6].

$Y(t) = Y_0 \cos\omega t + (V0/\omega)\sin\omega t + 1/m\omega\int^t_0 F(t)\sin\omega(t-T)\,dt$ - - - - - (c)

Displacement

$Y(t) = Fm/K(1-\cos\omega t) + Fm/ktd((\sin\omega t/\omega) - t)$ - - - - -(d)

Velocity

$\acute{Y}(t) = dy/dt = Fm/K[\omega\sin\omega t + 1/td(\cos\omega t - 1)]$ - - - - - - -(e)

In which ω is the natural circular frequency of vibration of the structure and T is the natural period of vibration of the structure which is given by equation

$\omega = 2\pi/T\ \sqrt{}=K/M$ - - - - - - - - - - - -(f)

The maximum response is defined by the maximum dynamic deflection Y_m which occurs at time tm. The maximum dynamic deflection Y_m can be evaluated by setting dy/dt in Equation (c) equal to zero, i.e. when the structural velocity is zero. The dynamic load factor, DLF, is defined as the ratio of the maximum dynamic deflection Y_m to the static deflection Y_{st} which would have resulted from the static application of the peak load F_m, which is shown as follows:

$DLF = Y_m / Y_{st}$ - - - - - - - - - - - - - - (g)

$DLF = 1/(2\pi td/T)\{\sin 2\pi(t/T) - \sin 2\pi(t/T - td/T)\} - \cos 2\pi\, t/T$ - - - - - -(h)

The dynamic load factor of blast loading is given by equation (h) to be considered in evaluating the correctness of evaluating the dynamic stresses.

The available methods for prediction of exposure to systems of buildings are:

- Empirical (or analytical) methods
- Semi-empirical methods
- Numerical methods.

Empirical methods mainly apply to experimental data. The complexity of the underlying experimental database restricts several of these methods. With the explosion occurrence being even more close field the precision of all scientific calculations diminishes. Half-empirical approaches are focused on generalised physical phenomenon models. The goal is to simplify the modelling of the underlying physical processes. These approaches depend on detailed details and case studies. Generally speaking, the statistical precision is higher than observational approaches. Numerical methods are based on mathematical equations which explain the fundamental laws of physics governing the problem. These principles include conservation of mass, momentum, and energy. In addition, the physical behavior of materials is described by constitutive relationships. These models are commonly termed computational fluid dynamics (CFD) models.

III. PROPOSED WORK

Simulation of blast effect on building construction

In this section try to cover the model of finite element for RC framed in MATLAB software and detail study of various element of structure. A brief information of properties of ductile material and brittle material and stress stain curve for steel and concrete. Discussion of Codal provision for blast resistant construction (IS-13920), then introduce the MATLAB Software base analysis on Structure.

STRUCTURAL NONLINEARITY

Now in the World terrorist attacks are common for all the countries of world so that importance of nonlinear analysis of reinforced concrete structure are required. In this study are carried out up to perfectly failure of structure and study of possible damages and safety aspect, there are finding of its property are responsible for deformation. The theory of nonlinear analysis depends upon the types of load on material so selection of loads are important ,the Various analysis based on computer programming and software based analysis of reinforced concrete structure the application load for structure are consider as per standard that's the limitation of analysis. In the fields sometimes accidental loads are more than design load. Individual property of reinforcement and concrete are different, and property of reinforced concrete are varied, the differ nature in cracking, inelasticity and relative property in sense of strength. For detail analysis of the nonlinearity of material the model development of cracked and untracked concrete the gives the load for all stages, in this types of study the model making for its are so difficult.

The major sources, which are responsible for the nonlinear behaviour of reinforced concrete, are: -

1. Appear cracks in concrete

2. Plastic behaviour of the reinforcement and of the Compression concrete

3. The property of concrete which depend on time like creep, shrinkage, temperature, and History of load.

NONLINEARITIES IN REINFORCED CEMENT CONCRETE

The reinforced concrete has complex mixing proportion of ingredient so behaviour of RCC are not taking under linear behaviour, than the strength of structure are changing year by year. The improvement is design philosophy the working stress method become old and the space of it's taken by plastic load method and ultimate strength method. The Reinforced concrete having two types of nonlinearity like material and geometrical. For higher level of deformation in R.C.C both are responsible.

GEOMETRIC NONLINEARITY

The bunch of small deformation and nature of materials are elastic under the loading is the base of Linear structural analysis. The procedure of analysis is based on the initial under formed shape of the structure. As the increase of applied loads, assumption factors are no longer accurate, because of that deformation may causes significantly changes in the structural shapes.

MATERIAL NONLINEARITY

The Reinforced concrete have combination of concrete and steel, both material are different in behaviour, than reinforcement is ductile material so it is strong in ductility or tension than concrete is rich in compression and it's under the brittle material. The relationship of tensile stress strain diagram for concrete represent almost linear in beginning then in compression its shows nonlinear. The tensile stress strain relation for steel is nonlinear from begging. The combination of both give nonlinear behaviour.

STRESS-STRAIN CURVES OF CONCRETE

In figure the stress strain curve for various grade of concrete under standard uniaxial compression test. There are showing the linearity and nonlinearity of various grade of concrete, initial phase of loading in various grade of concrete the occurred linearity. The nonlinearity in graph entered when stress level reaches up to one third of its maximum. The optimum pressure in the concrete is around 0.002, the tension is reduced and the substance straining rises above the maximum. The pressure at failure is between 0,003 and 0,005 with the normal variety of concrete strengths. Internal cracks in mortar and mass concrete are formed when stress level reaches at 90-95 percentage of the maximum. Expansion of concrete is laterally, and Visibility of longitudinal cracks when the lateral strain (due to poison's effect) exceeds the limiting tensile strain of concrete 0.0001.

In figure the curve of stress strain for the lightweight and normal weight of concrete.respectively.in each figure there are presentation of strength of concrete only. In figure the values of higher strength of concrete represented by higher curves. Then changes in curvature when apply of loading is changed. The testing speed and density of concrete are affected on shape of stress and strain curve, but analysis of each figure concluded that, character of all curves are mutual characterize they all are undergoes in same loading in same stage. Below are different aspects of the concrete tension stain curve:

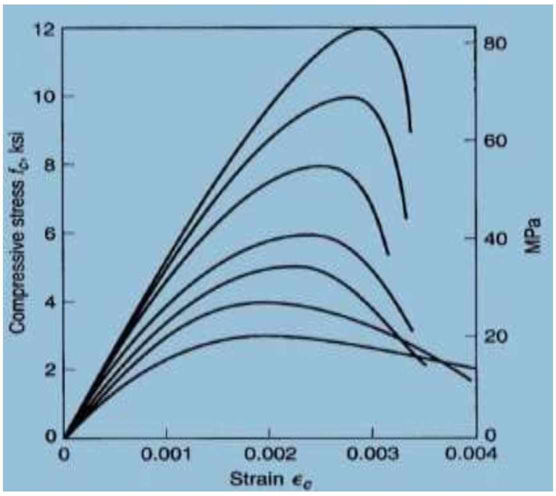

Fig. 7: Set of Stress Strain Curve for Normal Density Concrete

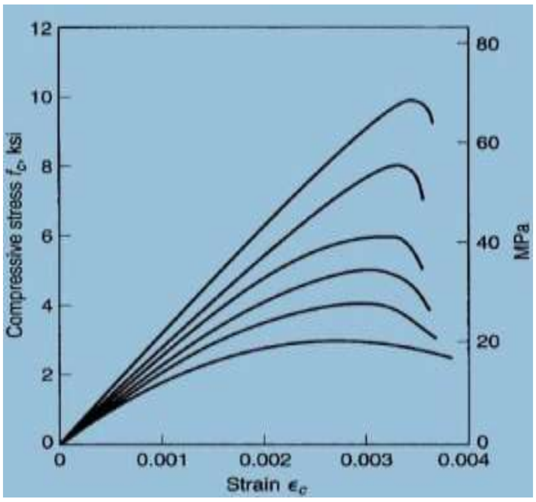

Fig.8: Stress Strain Curve for Lightweight Concrete

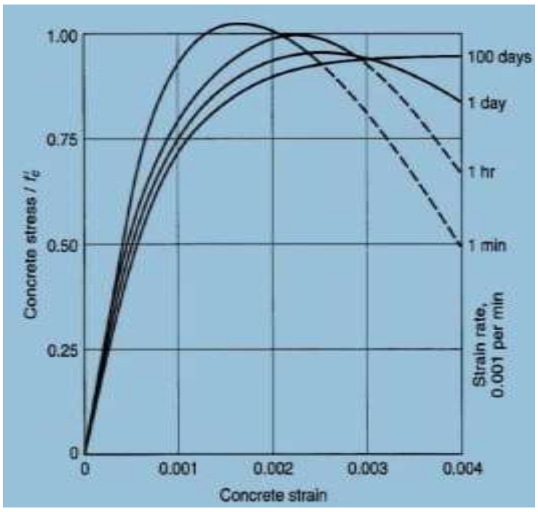

Fig. 9: Stress Strain Curve of Concrete Varies Based on Speed of Testing

1. Straight or Elastic Portion

In initial stage of loading the line is straight observed on graph (figure-7 and figure-8), the law of limit of proportionality follows (the value of stress is directly proportional to strain).The stage of loading the initial stage also known as elastic limit in which after removal of load material gain its original state. The concrete elastic range values continue up to 0.45fc. Modulus of elasticity of concrete find out from the strain stress curve of elastic part. The modulus of elasticity represents the strength of material. Values and important equation of elasticity are providing in ACI code.

2. Peak Point or Maximum Compress Stress Point

Starting appear of elastic behaviour (Nonlinear) of concrete when load is exceed, Then further increase of applied load the curves of stress- strain becomes horizontal, its horizontal position up to maximum load. The maximum stress value observed at compressive strain ranges from 0.002 to 0.003 for the lightweight concrete in normal condition. However, for lightweight concrete, the maximum stress reached at strain ranges from 0.003 to 0. 0035. The larger length of curve represents for higher result of strain. ACI codes for normal weight concrete, ACI specified that value of strain 0.003 is maximum value of strain that value used in concrete for design purpose of structural element. In Europe the value of concrete assumed 0.0035 assumed by European countries codes.

3. Descending Portion

After analysis of stress strain curves of various grade all the curves indicates its descending trends when load is maximum, it's also depends on method of testing.

STRESS-STRAIN CURVE OF STEEL

The steel is ductile material which is subjected under high value of stress and showed plastic behaviour. In initially the acts under elastic material and furthers increase of loading its goes under plastic behaviour i.e. when external load is applied material goes for deformation and after removal of load its gain its original position. Typical uniaxial stress-strain curves are as shown in Figure 10 for various grades of steel.

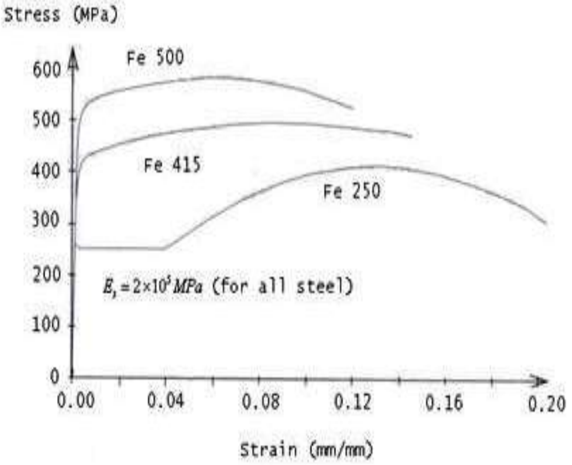

Figure 10 Uniaxial Stress-Strain curves of different steels

As per IS codes the value of Modulus of elasticity of steel (*S E*) is assumed 2 ×105 *N* / *mm*2 (IS-456). Further increase of loading the material goes in yield point. Than the further increasing of loading the material reaches up to the breaking point or at failure point .in that types of behaviour introduced two different possibility of stress strain relationship with two slopes one is tangential modulus (ET).After the point of yielding the slope could be greater equal or less than zero.

IV. SIMULATION RESULTS

Matlab Model of Blast Resistant Building Structure

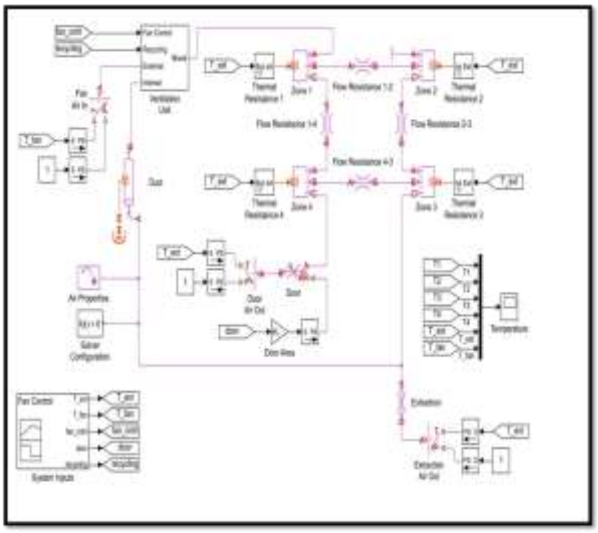

Fig.11- Main System of Building Design for blast resistant structure

In this Matlab Simulation we have design the Matlab model for Building structure for blast resistant effect and the proposed control system will provides temperature, heat and ventilation controlling for reducing the blast effect produced due to blast effect in commercial, home, and other building design structures.

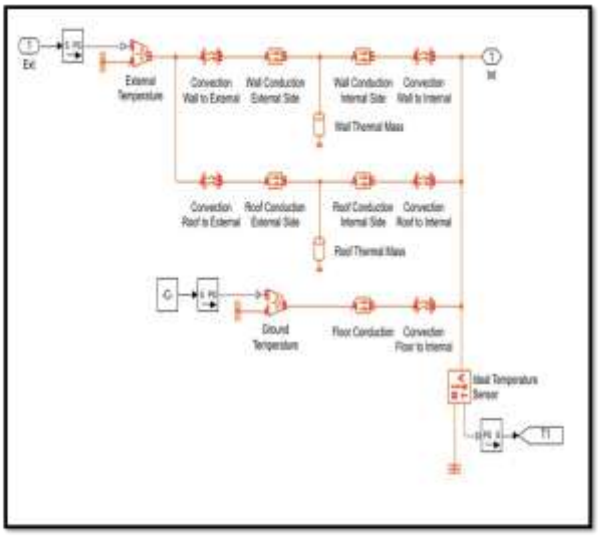

Fig.12- Thermal Effect control subsystem

The control subsystem of fig.12 shows the Thermal effect controlling for any blast effect mitigation or reduced the temperature effect in building design structures, the all block design of Building are shown in this subsystem.

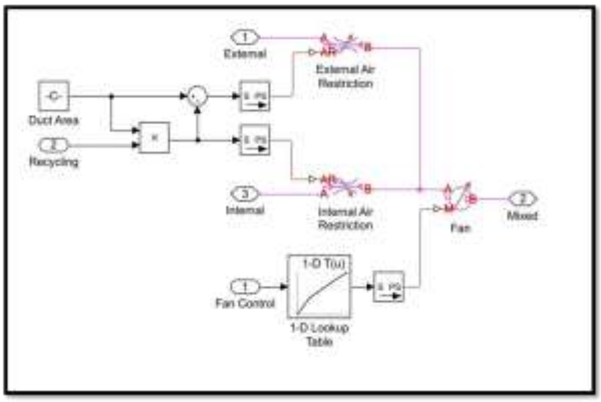

Fig.13- Ventilation Control subsystem

Simulation results of Blast Resistant Building Structure

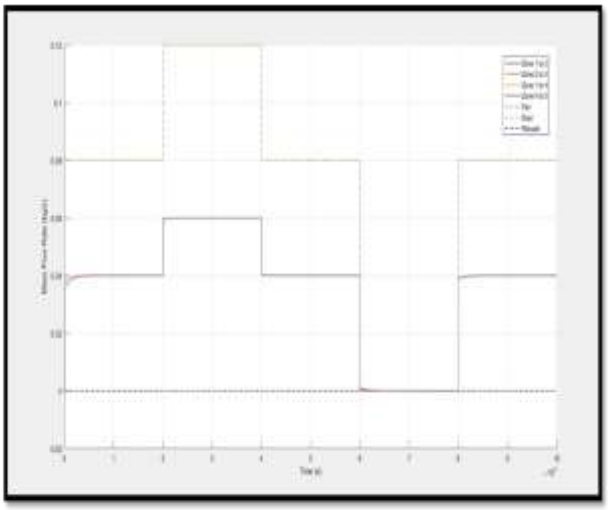

Fig.14- Building Mass flow controlling subsystem

Fig.15- Blast effect Temperature control output

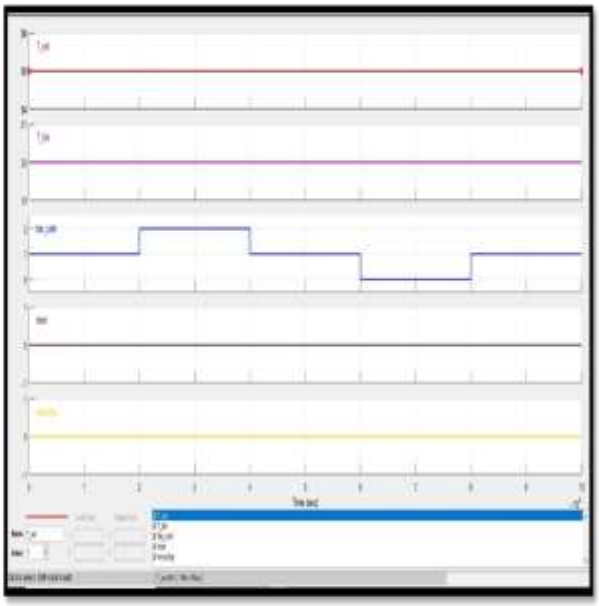

Fig.16- All block temperature output parameters

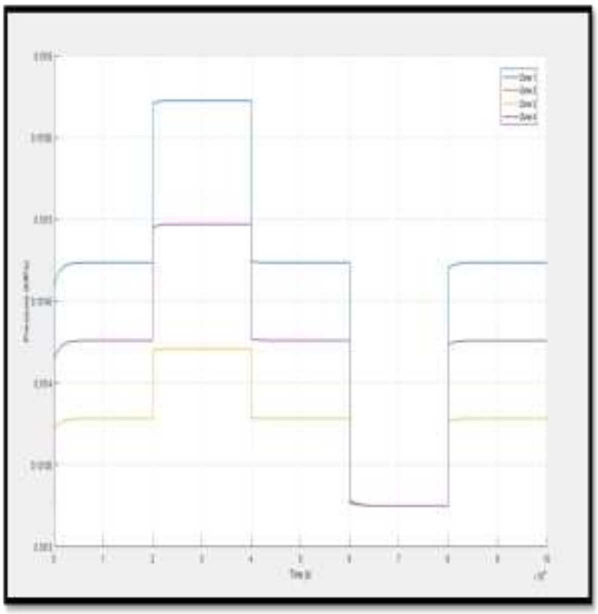

Fig.17- Pressure output parameters of the building structures

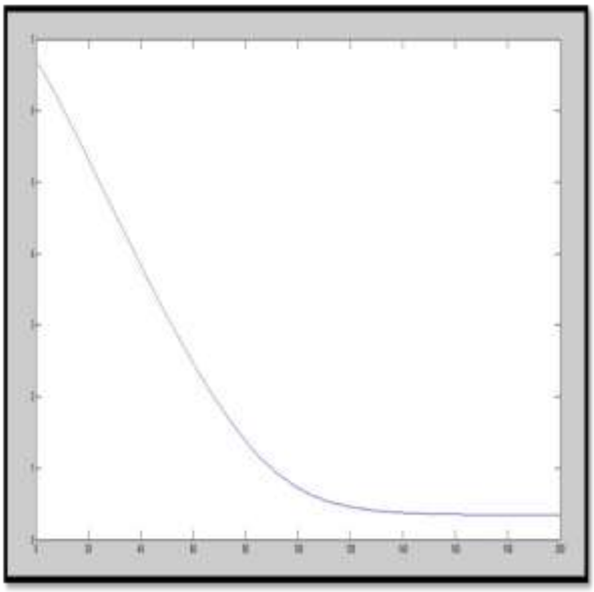

Fig.18- Speed variation control for blast effect variation

V. CONCLUSION

The aim in blast resistant building design is to prevent the overall collapse of the building and fatal damages. While it cannot be entirely predicted the severity of the explosion and its loads, as many situations as possible will find the technical and construction strategies that it requires. In the design process it is vital to determine the potential danger and the extent of this danger. Most importantly human safety should be provided. In addition, design and technical considerations should be addressed and an optimal construction layout should be designed to ensure practical continuity after an explosion.

This research is inspired by buildings being built in a blast resistant fashion, pioneering in enforcing the requisite legislation to avoid human and structural casualties incurred by the explosion and other hazards and to establish general knowledge that explosions pose potential dangers in everyday life. Architectural and building architecture should be especially considered in this context.

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