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# Behaviour of Ferrocement Panel under Impact Loading

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***Abstract:*** *Ferro cement is one of the structural materials, widely used because of its advantages of excellent behavior under flexural, and impact strength. Also it has excellent mechanical properties. A total of 6 types of panels were modeled for each grade of concrete i.e. M30, M40 and M50. The thickness of ferrocement panel considered is 20 mm and 30 mm. There are two type of fibres, Corrugated steel fibers and Hooked steel Fibers, and two types of meshes, Galvanized welded square mesh and Galvanized woven square mesh are used. High velocity impact and low velocity impact test is done on Ferro cement specimen. High velocity impact test is done by Ak-47 bullet and Parabellum bullet striking with a velocity of 300 m/s, 400 m/s, 500 m/s , 600 m/s and 700 m/s and low velocity impact test is done by dropping weight of 3.5kg from a height of 0.5m and 0.75m. All of this analysis is being performed on ANSYS Explicit Dynamics. Deformation, Equivalent Stress and Normal Stress of all the panels are evaluated and compared. It is concluded that when fibers are added in the mortar deformation due to impact loading is reduced and stress resistance of ferrocement panel is increased also when welded square mesh is used instead of woven mesh penetration depth reduces.*

***Keywords: Ferrocement,*** *ANSYS WB 16.0, Impact Strength, Corrugated Steel Fibres, Hooked Steel Fibres, Ak-47 bullet, Parabellum bullet.*

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## I. INTRODUCTION

"Ferrocement is a form of thin wall reinforced concrete made of hydraulic cement mortar strengthened with closely spaced layers of continuous and comparatively tiny size wire mesh". Mesh could be made of metallic or different appropriate materials. The matrix might contain discontinuous fibers. This definition ignores as vital form of reinforcement presently in use in ferrocement i.e. the mixture of steel rods and wire mesh.

India has been known as a developing economy that tends to provide rise to a loads of infrastructure developments particularly the building projects. RCC is most generally employed in everywhere all over world because of its high load carrying capability however the price of cement and steel is increasing day-by-day. So, we tend to need a substitute to concrete which provides the strength as that of RCC with low price. In ferrocement, hydraulic cement mortar with closely spaced tiny diameter wire meshes is employed. To enhance certain characteristics of ferrocement varied materials like admixtures, silicon dioxide fumes, fly ash and fibers are used. Generally, the thickness of ferrocement ranges from 20 up to 50 mm. Ferrocement is a wire mesh reinforcement inseminated with mortar to provide components of tiny thickness, high sturdiness and resilience and, once properly formed, high strength and rigidity. To bypass these issues and directly confirm the response of ferrocement in unconventional applications, numerical simulations exploiting the Finite Element Method (FEM) have yielded necessary ends up in recent years. To provide realistic outcomes that accurately replicate real-world situations, the constitutive model of ferrocement should be improved to reproduce even the foremost elementary phenomena. Developments in FEM like enhancements in material constitutive models and enormous increases in computer calculation speed have led to the likelihood of reproducing advanced real-world scenarios with sensible accuracy. Ferro cement elements are typically a lot of ductile when put next to standard reinforced concrete element thanks to the actual fact that, reinforcement is uniformly distributed over the complete section of the element. The increasing density of road traffic means for structures on and on the edges of the traffic routes the chance of impact of vehicles should be thought-about. In the chemical factories leaky gas mains, defective appliances resulted in of significant internal explosions in recent years. For embankments, bridge piers, dock walls, barrages impact loading by floating objects should be thought of. Explosions caused, for instance, by accidents occurring in the chemical plants or oil refineries can result in heavy impact loading on adjacent buildings by flying objects. Increasing air traffic conjointly involves additional attention to the accidental collision with the structures. Impact load effects on the structural parts by falling and swinging objects throughout construction also needs to be considered. As the cover to Ferro cement is less it generally suffers from spilling of tensile layer and also the outer matrix cover at high reinforcement ratio which usually results in premature. Therefore, the composite design is controlled by serviceability rather than strength of the material. Also, many researchers found out that due to the addition of discontinuous short synthetic fibers in the cementitious matrix shows significant improvement in ductility and shear capacity of the matrix which in turn also shows some increase in tensile strength.

### 1.1 OBJECTIVES OF THE RESEARCH

1. Effect of panel thickness on deformation, equivalent stress and normal stress of panel under low velocity and high velocity impact loading.
2. Effect of types of mesh on deformation, equivalent stress and normal stress of panel under low velocity and high velocity impact loading.
3. Effect of types of grade of mortar on deformation, equivalent stress and normal stress of panel under low velocity and high velocity impact loading.
4. Effect of types of fibers deformation, equivalent stress and normal stress of panel under low velocity and high velocity impact loading.

### 1.2 PARAMETERS OF THE STUDY

a) Types of meshes used are, Galvanized welded square mesh and galvanized woven square mesh.
b) Grade of mortar used are M30, M40 and M50
c) Thickness of panels taken are 20mm and 30mm
d) For low velocity impact loading a drop weight of 3.5 kg is used, the drop weight is dropped from a height of 0.5m and 0.75m.
e) For high velocity impact loading two types of bullets, Avtomat Kalashnikov (Ak-47) bullet and 9x19mm Parabellum bullet are used with velocity of 300m/s, 400m/s, 500m/s, 600m/s and 700m/s.
f) Two types of fibers are also used, corrugated steel fibers and hooked steel fibers.

## II. LITERATURE REVIEW

The unique properties of ferrocement have been investigated extensively by many researchers. The following literature survey includes summery of research papers presented in popular journals on topics similar to current field of study. Abdulkader Ismail, A. Al-Hadithi *et.al*[7], the authors carried out this study to investigate the behavior of ferrocement slabs under impact loading. A total number of 48 Ferrocement panels where constructed to investigate its behavior under impact loading. Out of 48, 36 slabs was casted to test under low velocity impact loading and 12 slabs under high velocity impact loading. The slab of size 500x500x50mm was subjected to impact loading by repeated blows of mass 1300 gm. Falling under gravity from 3 heights of 2.4m, 1.2m and 0.83m at 56 days age. A 500x500x50mm slab were checked under high velocity impact loading, in which a bullet of 7.62 mm length was fired from a distance of 15m with a velocity of 720m/sec. The author concluded that to make the initial crack and failure, amount of blows required is increased with increase in amount of wire meshes and polymer content. For bullet impact test, it is concluded that with the increment in amount of wire mesh layers and polymer content, the area of spalling and area of scabbing decreased compared with reference mixes. Anitha M *et.al*[8], the authors carried out an experimental work to review the behavior of hybrid ferro-cement block subjected to impact. The square ferro-cement panels casted was of cross-section (500*500) mm. The thickness of the squared ferrocement panels is 25 mm and 35 mm. The ferrocement panels were tested for impact by using drop impact test. All the bottom four sides of the panel was fixed and repeated drop load test was carried out. The authors concluded that due to presence of number of layers of wire mesh, the panel requires more no. of blows for first crack as well as failure also the ductility of the ferrocement panel is increased with increase in no. of layers of wire mesh. Yousry B.I. Shaheena *et.al*[10], the authors designed and tested twenty four ferrocement panels with a dimension of (500 x 500 x 25mm). The specimens were loaded by 1.15 kg under its height 1.12m at the middle of plates. The ferrocement plates were divided into five groups reinforced with skeletal steel bars, metal meshes and metal meshes with steel bars. Results of reinforced Ferro cement plates emphasized that, increasing the amount of the steel mesh layers within the Ferro cement composites will increase energy of initial cracking, energy at up to failure, and energy absorption properties. Using steel bars with steel meshes achieved to higher energy absorption compared with those strengthened with steel bars solely. The authors concluded that with increasing the amount of the steel bars with welded and expanded steel mesh layers within the ferro cement composites delaying the incidence of the primary cracking as results of increasing the particular surface area of steel meshes that results in higher bond area. Mamdouh E. Mohamed *et.al*[13], the authors carried out an experimental work on the square concrete panels under impact loading. The thickness of panel considered by the author was 30 mm. Galvanized woven square wire mesh was accustomed reinforce the concrete panels for penetration check. The object used was of somewhat cylindrical shape with diameter of 23 mm and length of the object was 64 mm. The object was shot from a distance of 50 mm from the target. The authors concluded that, using Ferro-cement in concrete enhances the resistance to penetration in concrete by reducing the penetration depth. The authors also concluded that due to the use of wire mesh in concrete results in reducing the front and rear damage of the panel.

## III. ANALYTICAL WORK USING ANSYS

The ANSYS explicit dynamics suite permits to capture the physics of short-duration events for product that bear extremely nonlinear, transient dynamic forces. With ANSYS, user may gain insight into how a structure responds once subjected to severe loadings. Algorithms based on initial principles accurately predict complicated responses, like massive material deformations and failure, interactions between bodies. ANSYS is helpful when we need to study extremely complicated issues particularly ones with high strain rates and different complications that are troublesome to resolve with general-purpose implicit solution methods.

### 3.1 ANSYS EXPLICIT DYNAMICS ANALYSIS

An explicit dynamics analysis is used to determine the dynamic response of a structure due to stress wave propagation, impact or rapidly changing time-dependent loads. Momentum exchange between moving bodies and inertial effects are usually important aspects of the type of analysis being conducted. This type of analysis can also be used to model mechanical phenomena that are highly nonlinear. Nonlinearities may stem from the materials, (for example, hyper elasticity, plastic flows, failure) and from contact (for example, high speed collisions and impact). Events with time scales of less than 1 second (usually of order 1 millisecond) are efficiently simulated with this type of analysis.

The time step used in an explicit dynamics analysis is constrained to maintain stability and consistency via the CFL condition, that is, the time increment is proportional to the smallest element dimension in the model and inversely proportional to the sound speed in the materials used. Time increments are usually on the order of 1 microsecond and therefore thousands of time steps (computational cycles) are usually required to obtain the solution.

An explicit dynamics analysis typically includes many different types of nonlinearities including large deformations, large strains, plasticity, hyper elasticity, material failure etc.

ANSYS explicit dynamics tools facilitate to explore a very wide range of challenges:

- Short-duration, complex or changing-body interactions (contact)
- High speed impacts and drop test
- Severe loadings leading to giant material deformation
- Material failure
- Material fragmentation
- Penetration mechanics

### 3.2 TYPE OF ELEMENT

The definition of the proposed numerical model was made by using finite elements available in the ANSYS code default library. SOLID186 is a higher order 3-D 20-node solid element that exhibits quadratic displacement behavior. The element is defined by 20 nodes having three degrees of freedom per node: translations in the nodal x, y, and z directions. The element supports plasticity, hyper elasticity, creep, stress stiffening, large deflection, and large strain capabilities. It also has mixed formulation capability for simulating deformations of nearly incompressible elastoplastic materials, and fully incompressible hyper elastic materials.

This SOLID186 3-D 20-node homogenous/layered structural solid were adopted to discretize the concrete slab, which are also able to simulate cracking behavior of the concrete under tension (in three orthogonal directions) and crushing in compression, to evaluate the material non-linearity and also to enable the inclusion of reinforcement (reinforcement bars scattered in the concrete region). The element SHELL43 is defined by four nodes having six degrees of freedom at each node. The deformation shapes are linear in both in-plane directions. The element allows for plasticity, creep, stress stiffening, large deflections, and large strain capabilities. SHELL 43 elements, which allow for the consideration of non-linearity of the material and show linear deformation on the plane in which it is present. The modeling of the shear connectors was done by the BEAM 189 elements, which allow for the configuration of the cross section, enable consideration of the non-linearity of the material and include bending stresses as shown in fig 3.5. CONTA174 is used to represent contact and sliding between 3-D "target" surfaces (TARGE170) and a deformable surface, defined by this element. The element is applicable to 3-D structural and coupled field contact analyses. Contact pairs couple general axisymmetric elements with standard 3-D elements. A node-to-surface contact element represents contact between two surfaces by specifying one surface as a group of nodes.

### 3.3 MODELLING

In this study analytical work is done totally in ANSYS Explicit Dynamics. In which Ferro cement panel was modeled. The size of Ferro cement panel is 250 x 250mm. The thickness of the panel is taken as 20mm and 30mm. In 20mm and 30mm panel, number of wire meshes are two which are placed at a cover of 5mm from top and bottom.

The squared wire mesh which are model are such as, that the Centre to Centre spacing of the wire is 20mm in both direction. The outer wire of the mesh is placed at a cover of 15mm on both side. The diameter of the wire is taken as 1.6mm. A body interaction is defined while modelling, which is used to define that the wire mesh which is placed inside the Ferro cement panel is reinforcement of it. After defining it ANSYS considers wire mesh as reinforcement inside the panel and does analysis accordingly.

The bullet that is modelled are Avtomat Kalashnikov (Ak-47) and Parabellum. Ak-47 bullet is conical in shape in which it radius starts from literally 0 to 7.62mm in the end. The length of the Ak-47 bullet is 39mm. Parabellum bullet is cylindrical in shape its diameter is 9mm and the length of the bullet is 19mm.

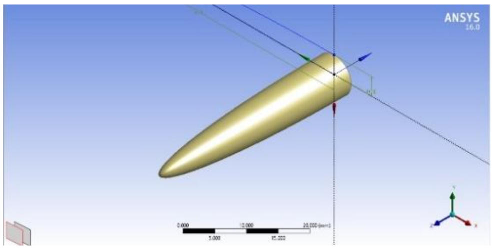

Fig 1: Isometric view of Ak-47 Bullet

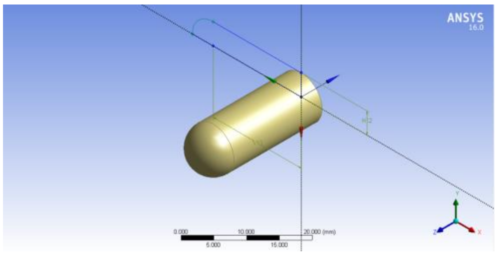

Fig 2: Isometric view of Parabellum Bullet

The drop is also modelled in software. The weight of the drop is 3.5kg. Total Height of the drop is 365mm, out of which 340mm is cylindrical in shape and rest of it is conical in shape. The conical part is located at the bottom side of the drop. Diameter at the bottom side of the conical is 10mm and diameter at the top side of the conical is 40mm. Diameter of the cylindrical shape is 40mm throughout and total length of it is 340mm.

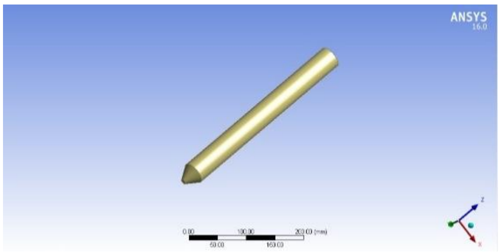

Fig 3: Isometric view of Drop

### 3.4 MATERIAL PROPERTIES

In ANSYS after making the model, it is necessary to assign type of material to the model one had made before starting analyzing it. So in this study two grade of concrete are used, M30, M40 and M50. They are casted with and without fibers. When fibers are added in the mortar, properties of the mortar gets change. The changes are in their elastic modulus, bulk modulus and shear modulus.

After adding corrugated fibers in Ferro cement it is calculated that the mortars young modulus get increased by 10% and by adding hooked fibers young modulus get increased by 15%. Young's modulus of mortar is taken as 138GPa without inclusion of fibers.

Two types of meshes are used in the Ferro cement panel in this study, Welded square mesh and Woven Square mesh. Yield strength of both the meshes is 450MPa. Young's modulus of welded square mesh is 200GPa and due to more elasticity in woven square mesh its elastic modulus or young's modulus is less than that of welded square mesh, it is 138GPa.

| Type of Mesh | Density | Modulus of Elasticity | Yield Strength |
|---|---|---|---|
| Welded Mesh | 7850 kg/m$^3$ | 200 GPa | 450 MPa |
| Woven Mesh | 7850 kg/m$^3$ | 138 GPa | 450 MPa |

As in this study we does not need to perform or calculate or want to know the distorted shape or stresses in the bullet it is considered as a rigid material. That is no analysis will be performed of it. Density of bullet is defined as 8930 kg/m$^3$. Similarly, drop is also defined as a rigid material with a density of 8054 kg/m$^3$.

Before running analysis firstly model that are made should be assigned with the material which are defined. Fixed support are assigned on the bottom edges of the panel. Certain velocity is assigned to the bullet and also required to assign the direction of velocity. Analysis time for high velocity impact is taken as 0.002 and for low velocity impact is taken as 0.01. Analysis meshing element size is taken as 10 mm.

## IV. RESULTS OF ANALYTICAL WORK
## V.

Various parameters are considered in this study according to which there is various number Ferro cement panels are formed, and on that panels two types of bullets strikes with velocity ranging from 300m/s to 700m/s. Similarly for drop weight, panels with variation in properties are made with drop dropping from a height of 0.5m and 0.75m.

Notations used for different types of ferrocement panels are as follows -:

1. WLD – Ferrocement panel using Welded Square Mesh only.
2. WLDCF – Ferrocement panels using Welded Square Mesh with Corrugated Fibres.
3. WLDHF – Ferrocement Panels Using Welded Square Mesh with Hooked Steel Fibres.
4. WLD – Ferrocement panel using Woven Square Mesh only.
5. WLDCF – Ferrocement panels using Woven Square Mesh with Corrugated Fibres.
6. WLDHF – Ferrocement Panels Using Woven Square Mesh with Hooked Steel Fibres.

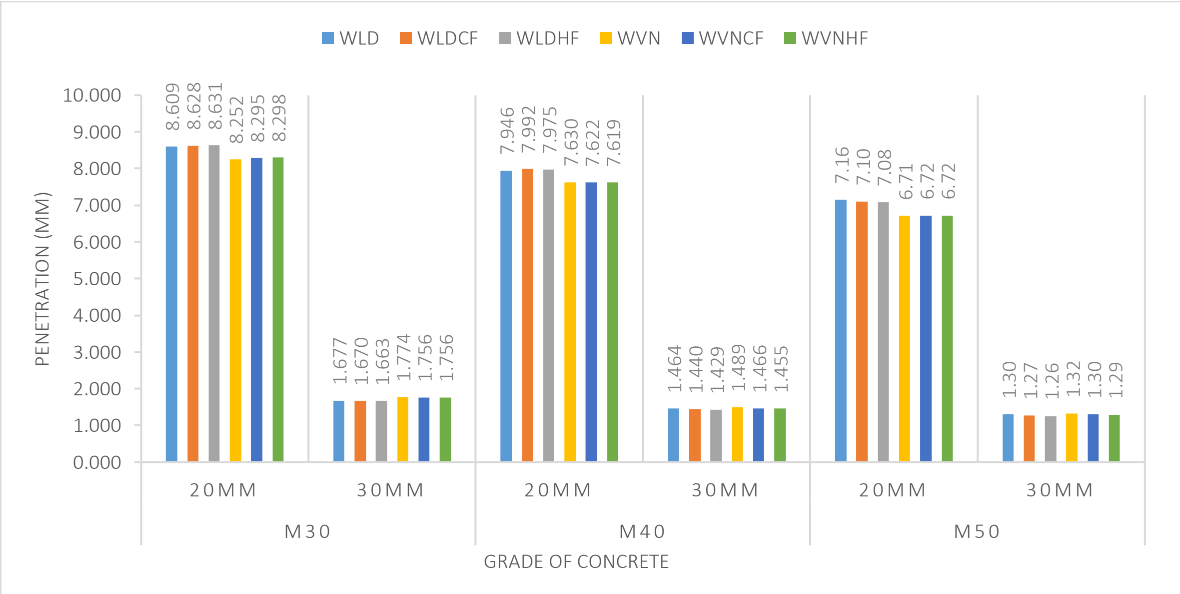


Fig 4: Penetration Vs Grade of Concrete For Drop Height 0.75 m.

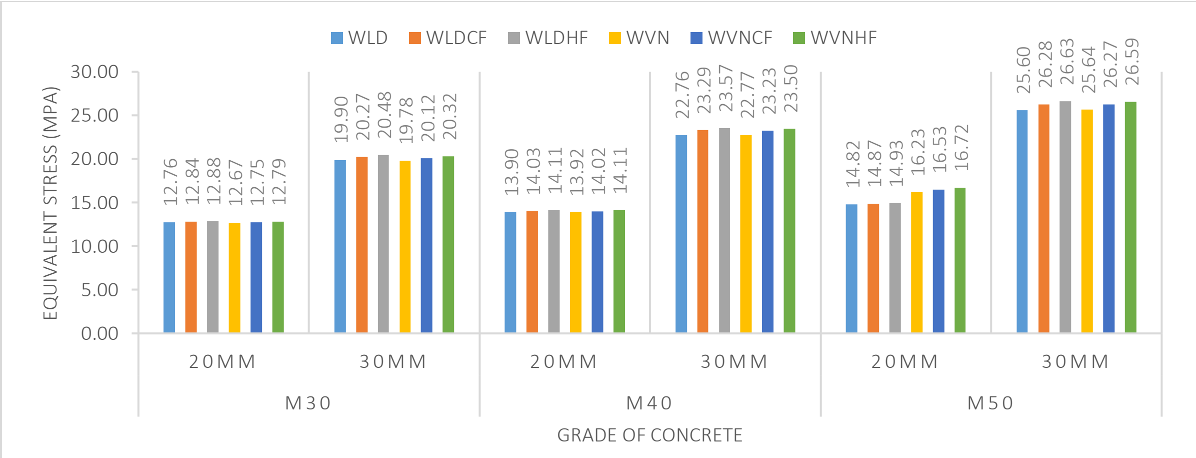


Fig 5: Equivalent Stress Vs Grade of Concrete For Drop Height 0.75 m.

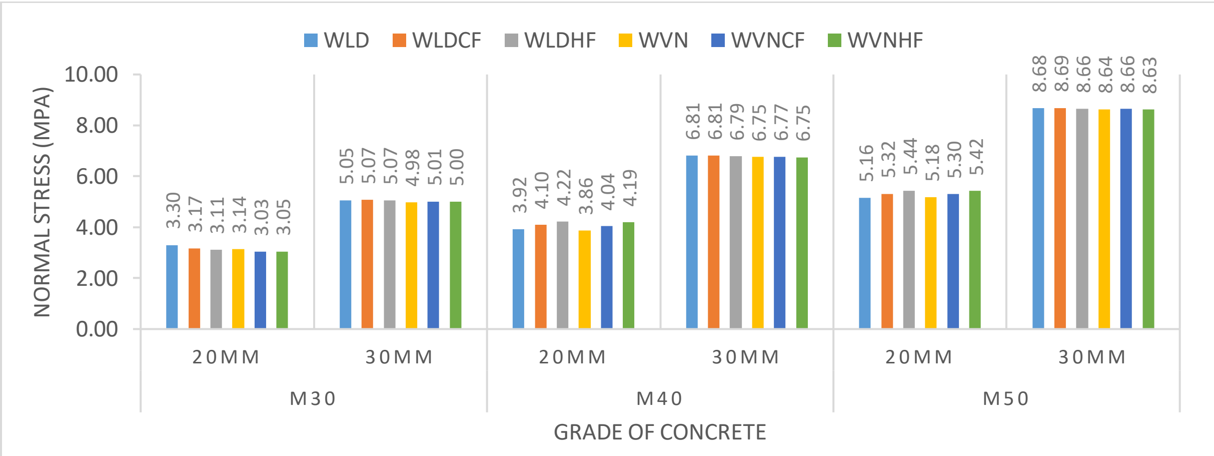


Fig 6: Normal Stress Vs Grade of Concrete For Drop Height 0.75 m.

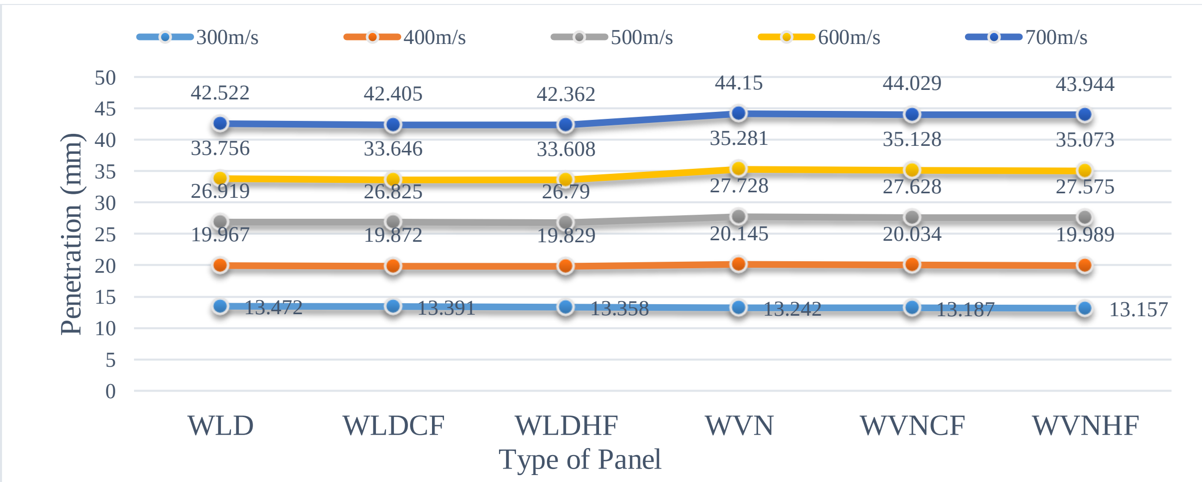


Fig 7: Penetration when Ak-47 bullet fired on 20mm panel of M30 grade mortar

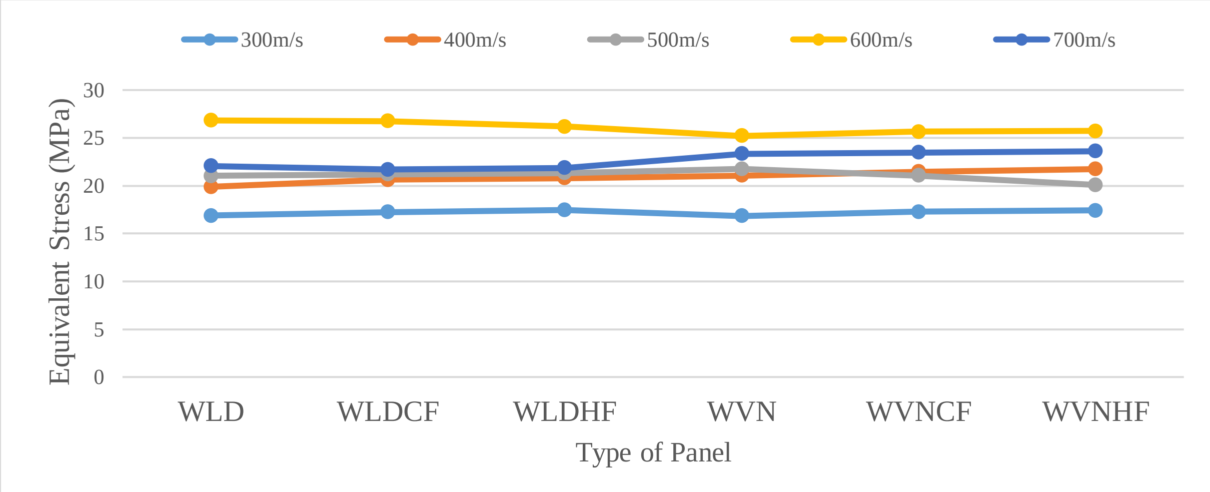


Fig 8: Equivalent Stress when Ak-47 bullet fired on 20mm panel of M30 grade mortar

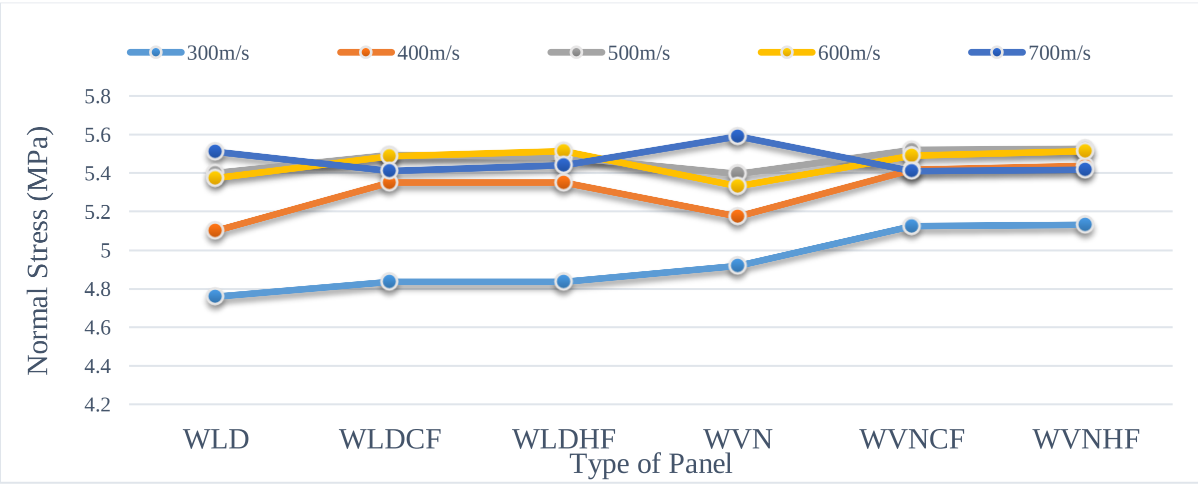


Fig 9: Normal Stress when Ak-47 bullet fired on 20mm panel of M30 grade mortar

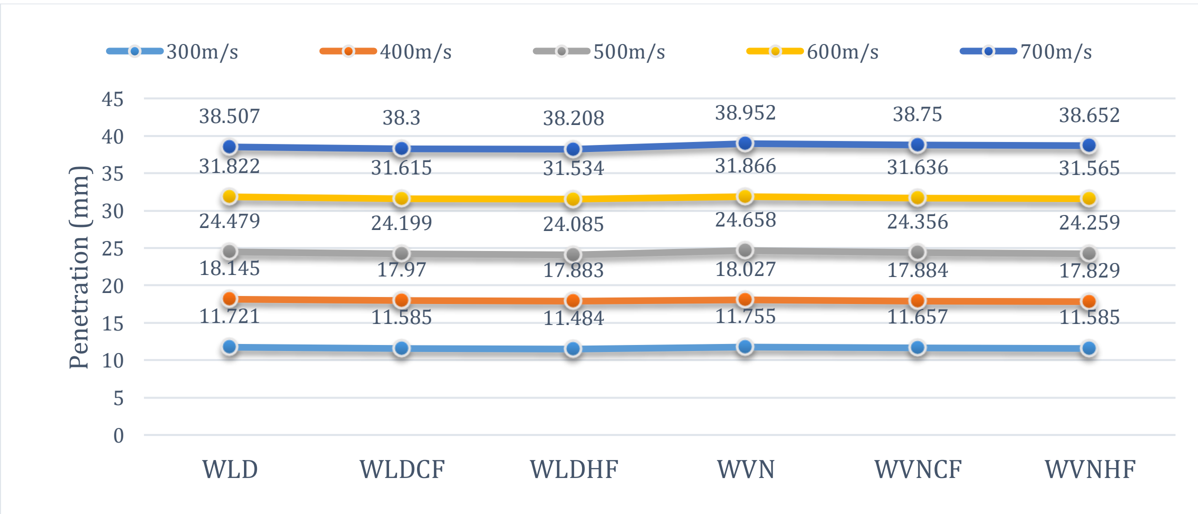


Fig 10: Penetration when Parabellum bullet fired on 20mm panel of M30 grade mortar

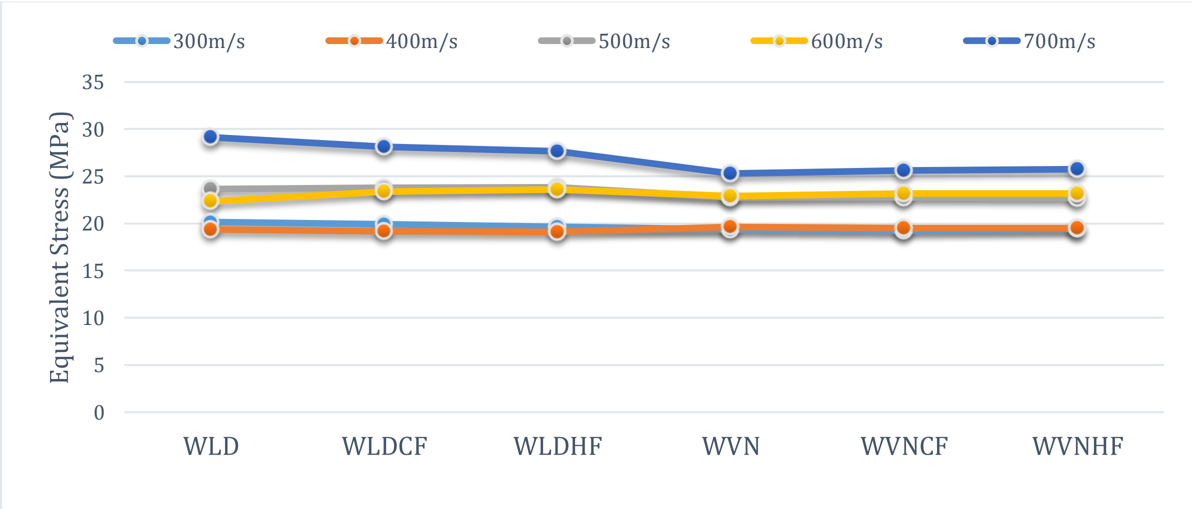


Fig 11: Equivalent Stress when Parabellum bullet fired on 20mm panel of M30 grade mortar

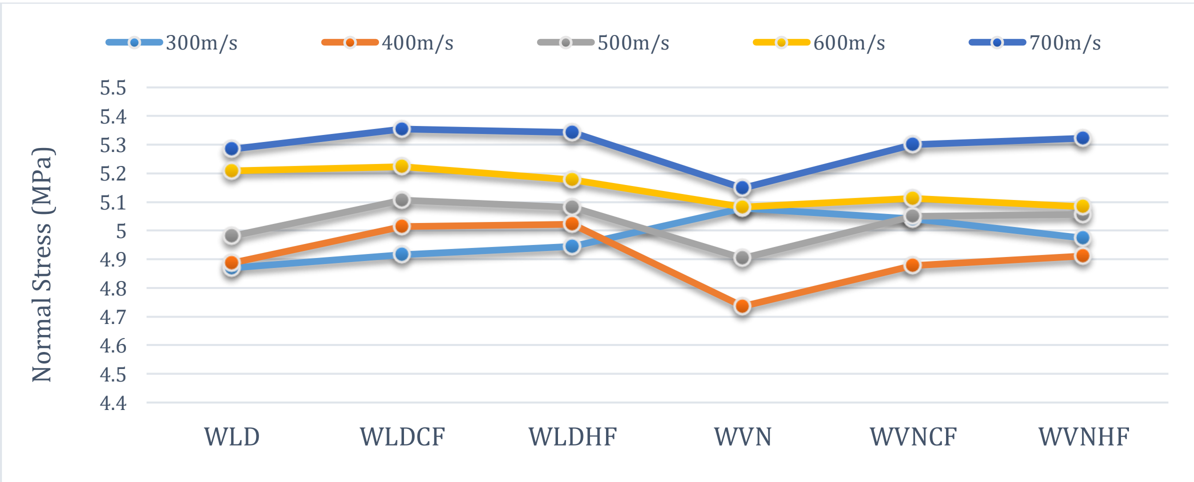


Fig 12: Normal Stress when Parabellum bullet fired on 20mm panel of M30 grade mortar

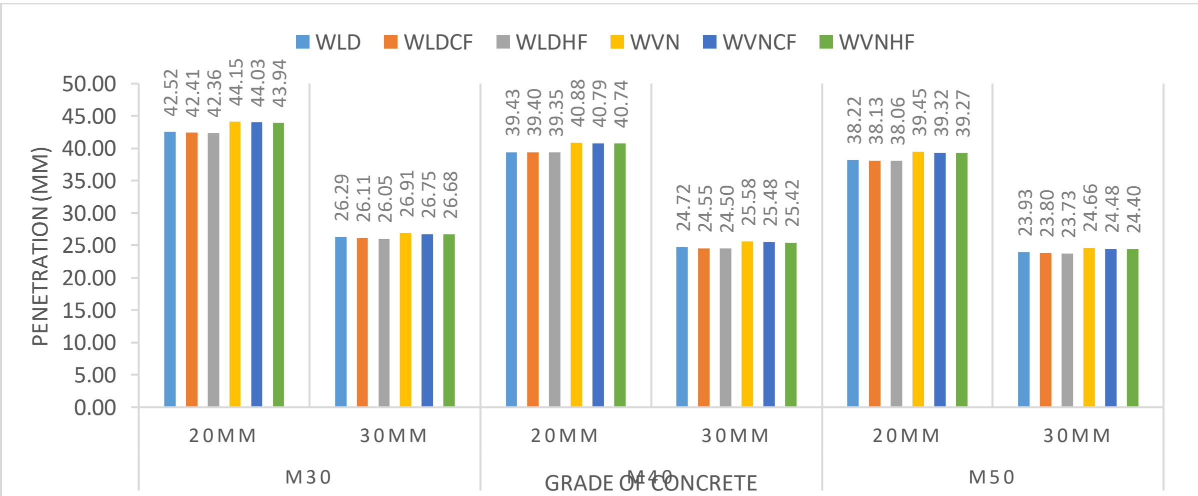


Fig 13: Deformation when Ak-47 bullet strikes with a velocity of 700m/s

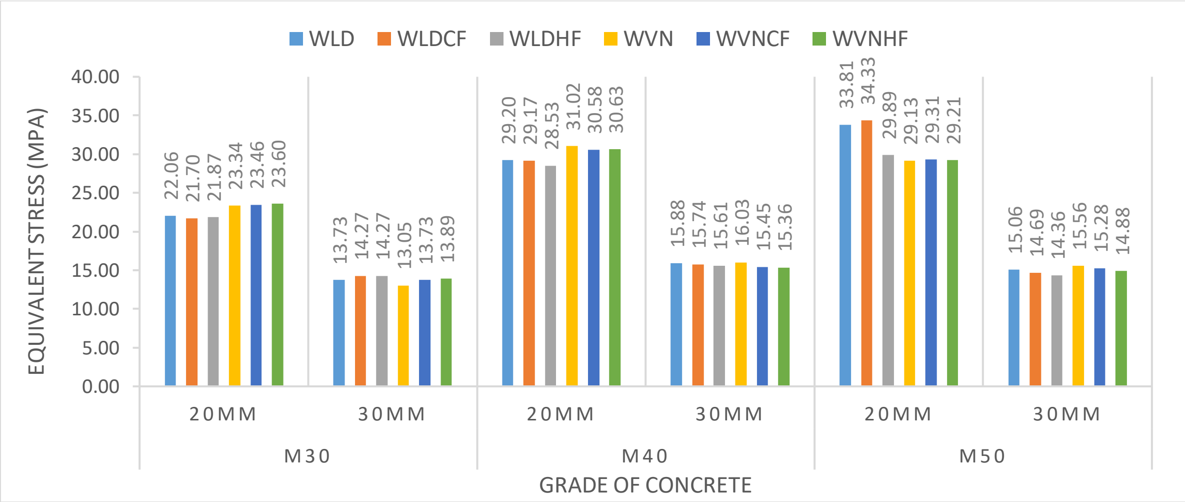


Fig 14: Equivalent Stress when Ak-47 bullet strikes with a velocity of 700m/s

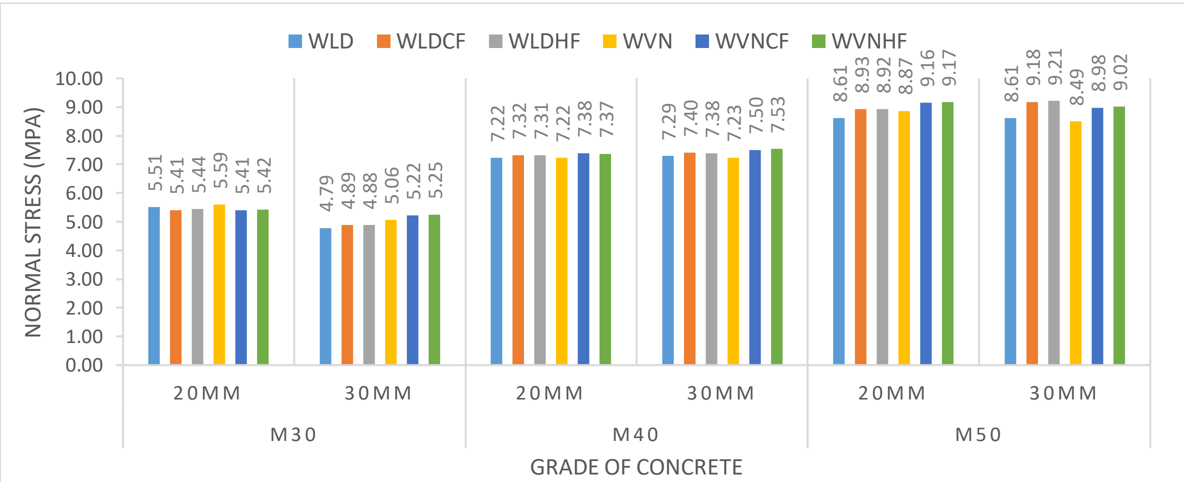


Fig 15: Normal Stress when Ak-47 bullet strikes with a velocity of 700m/s

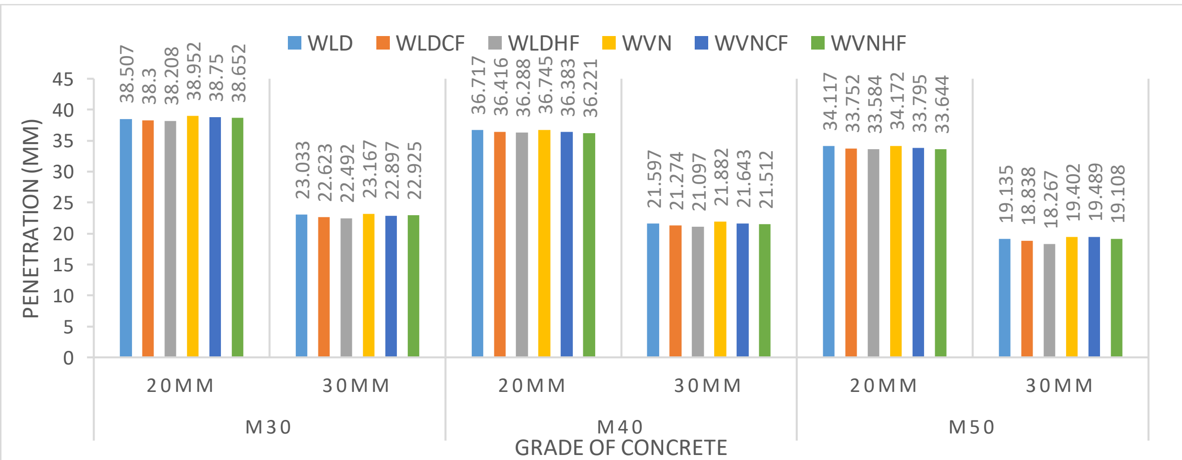


Fig 16: Deformation when Parabellum bullet strikes with a velocity of 700m/s

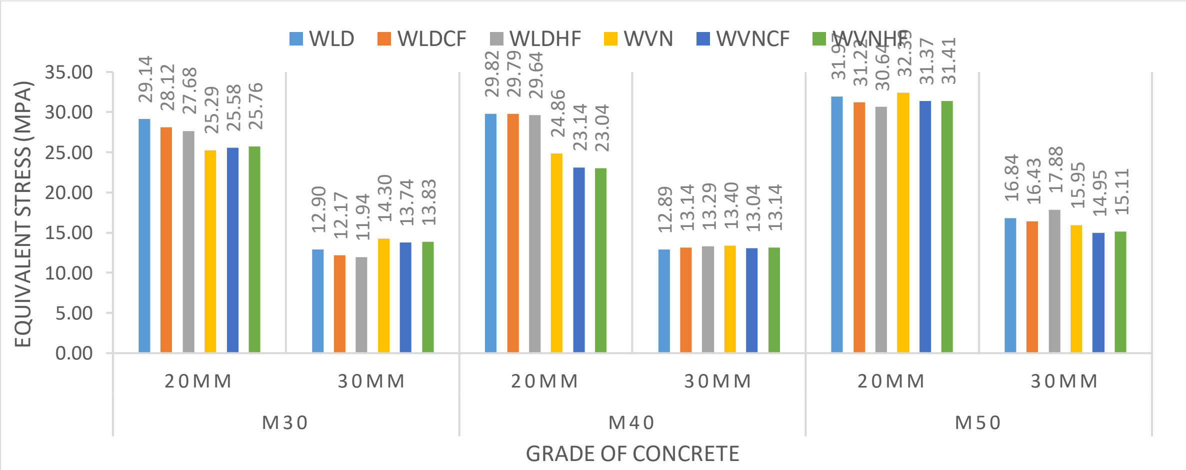


Fig 17: Equivalent Stress when Parabellum bullet strikes with a velocity of 700m/s

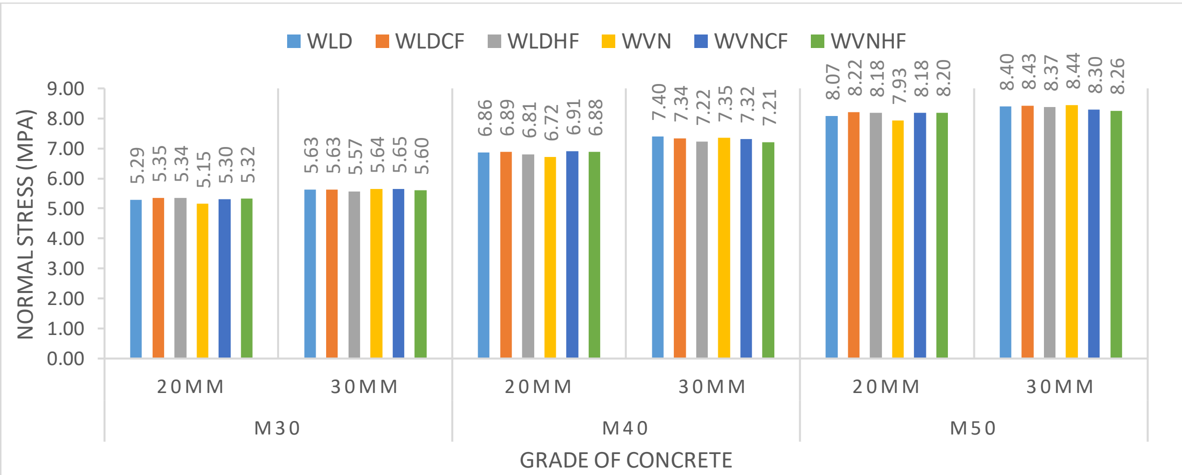


Fig 18: Normal Stress when Parabellum bullet strikes with a velocity of 700m/s

## VI. CONCLUSIONS

Based on FEM analysis following conclusions are made:

1. Drop weight impact loading shows that, the penetration depth, normal stress and equivalent stress increases when height of drop changes from 0.5 m to 0.75 m.

2. In high velocity impact loading with Ak-47 bullet penetration depth, normal stress and equivalent stress increases with increase in velocity of bullet. All of the above parameter decrease when thickness and grade of mortar increases and also when fibres are added.

3. In high velocity impact loading with Parabellum bullet penetration depth, normal stress and equivalent stress increases with increase in velocity of bullet. All of the above parameter decrease when thickness and grade of mortar increases and also when fibres are added.

4. From this experiment we can say that hooked fibers are more suitable than corrugated fiber and addition of hooked fibers increases the flexural strength and energy absorption capacity more as compared to corrugated fibers

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