Effect of 0.32 Caliber Bullets on Fiberglass at Various Firing Distances and Determination of Range of Firing from the Fracture Patterns on Fiberglass

Bhoopesh Kumar Sharma, Vinod Kumar Shukla, Amareshwar Rath, Sharon Ann Philip

Abstract: Ballistics is the study of the science of the motion and behavior of a projectile during its flight in any given medium. The flight path of a bullet in cases of firearms includes: traveling down the barrel, path through the air (or in a medium), and path through the target. The damage to the target by a hurling projectile depends upon various parameters like the type of the propellant charge used, type of the firearm, the distance of firing, etc. In some instances, it becomes difficult to estimate the range of firing when the projectile has been shot through the glass as an intermediate target. Present work is based upon the effect of 0.32 caliber bullets on fiberglass fired from different ranges and determination of range of firing from by studying the fracture pattern created on the fiberglass. The present study will be helpful for the investigator to estimate an approximate range of shooting when the firing is done through the fiberglass. It will also be utilized in the estimation of the point of entry and exit on the glass and the basis of the fracture produced will provide an idea of the type of firearm used can also be estimated.

Index Terms: Ballistics, 0.32 caliber bullet, fiberglass, projectile, range of firing

I. INTRODUCTION

Ballistics is the study of the science of the motion and behavior of a projectile during its flight in any given medium. The flight path of a bullet in cases of firearms includes: traveling down the barrel, path through the air (or in a medium), and path through the target [1]. Ballistics is categorized as internal or interior ballistics (within the firearm), External or exterior ballistics (from firearm muzzle to the target) and Terminal ballistics (within the target). The present study is focused on the terminal ballistics where the projectile (0.32 caliber bullet) hits the fiberglass at various distances, creating particular fracture patterns. Brittle materials have essential uses as protection against the bullet impact, e.g., glass windows in vehicles and concrete walls of buildings etc. Numerous studies of ballistic impact against glass targets revealed unusual fracture behavior.This is due to the brittle material being fracture sensitive to not only shear and tension but also to compression [2]. The fiberglass used in the present study was made up from extremely fine fibers of glass and is used as a strengthening agent for many polymer products; the resulting composite material, appropriately identified as fiber-reinforced polymer (FRP) [3].

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The high usage of fiber-reinforced polymers (FRP) raised a concern about their resistance towards the ballistic impact, the thing that provides ease of shaping FRP's properties - a multitude of structural components and links between them - causes natural dissipation of impact energy and often irreversible damage to the material itself [4]. The energy absorption and distribution on any surface depends upon various factors and hence resulting in different damages when a projectile hit the target [5]. The most important factor is the kinetic energy of the displaced part of the target. The other factors are the fiber tension, fiber destruction through tensile failure, delamination, and friction between impactor and target material [6-8]. Projectile impacts on the targets in ballistics can be classified on the basis of their velocities. The low velocity impacts (velocity below 10 m/s), medium velocity impact (10 to100 m/s), high velocity impacts (100 to 1000 m/s) and hypervelocity impacts (velocity above 1 km/s) [9-10]. The time of contact between the projectile and the target is too short for elastic waves to propagate through the material and sometimes even quicker than the time needed for the wave to reach the materials edge. Thus, the damage is confined to a relatively small area around the impact point [11]. However, the fracture pattern still can be used to differentiate the various ranges of firing as per the acquired and the remaining velocity of the projectile, if carefully studied.Numerous experiments have been performed to study the projectile impact on different material targets mainly based on the elasticity approach. Zhu et al. have investigated the force acting on conical projectile using laminate plate theory. They separated the impact event in three phases namely indentation, perforation and exit. Resisting forces in all three aspects are determined and applying Newton's laws velocity, and deceleration was determined [11]. Sun, et al. in their work proposed spring model to predict the residual velocity and ballistic limit of the projectile. Different criteria for damage initiation, progression, and plug formation are considered [12]. Goldsmith, et al. Calculated energy absorbed in global plate deflection, fiber breakage, delamination, configuration, and bending of petals, hole enlargement and friction between striker and sample [13]. Present work was aimed to study the effect of 0.32 caliber bullet on fiberglass so as to estimate the possible range of firing on the basis of fracture pattern produced and also to establish the characteristics features of point of entry and exit of bullet on the fiberglass.

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II. MATERIALS AND METHODS

In total, six pieces of fiber glasses (1 x 1 sq. Ft) were targeted from 0.32 caliber bullets (2 bullets each from three different firing ranges from a licensed revolver). The firing was done perpendicularly to the target with the help of a fixed frameset (figure 1-2) positioned at a height of 4.5 ft. from the ground level. The distances selected for the study are four, seven and 11 meters respectively (figure 3-5). The samples were collected by firing a licensed (license number cannot be disclosed due to security purposes) revolver of 0.32 caliber on fiberglass from various distances as mentioned at shooting range (Amity University Uttar Pradesh, Noida) with all the precautions and under the supervision of the experts.

Photographs of the target were taken after firing with all the possible angles using a 35mm DSLR camera and then enlarged in the system as required to study and analyze the fracture pattern. The enlarged photographs were then compared and evaluated to enumerate the impact of the projectile at various ranges.
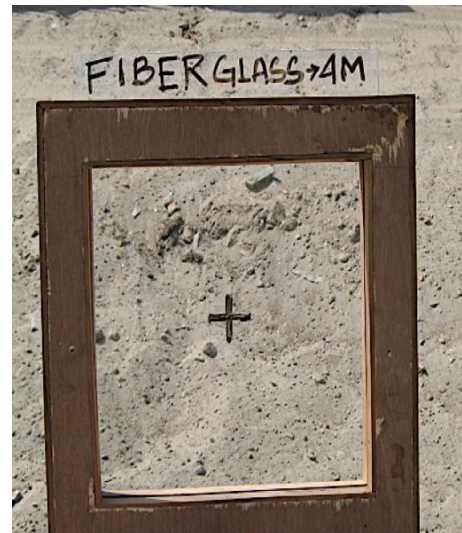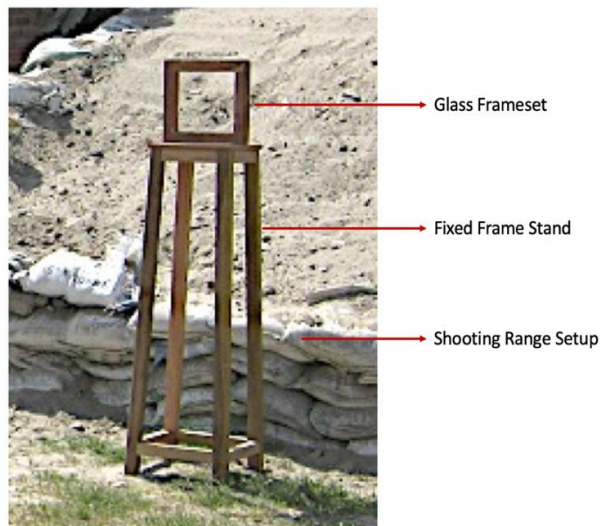

Figure 1-2- Demonstration of the setup for the shooting with a changeable glass frameset.
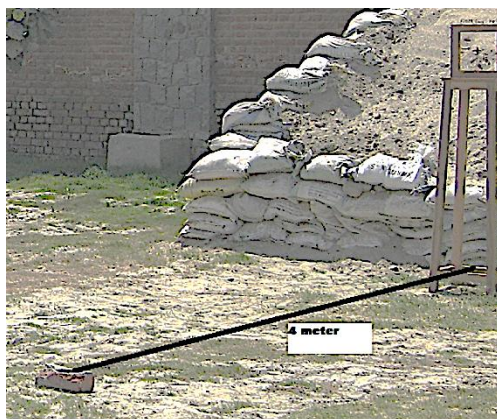

Figure 3- Demonstration of the setup for the shooting at the distance of 4 meters.
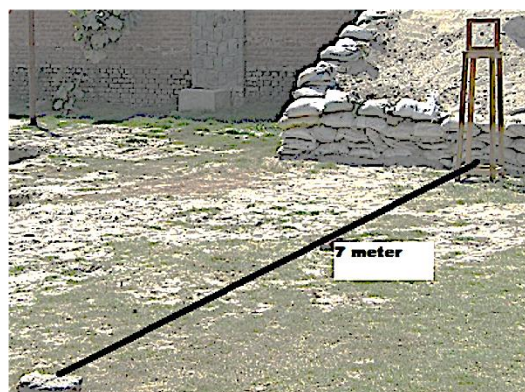
Figure 4- Demonstration of the setup for the shooting at the distance of 7 meters.
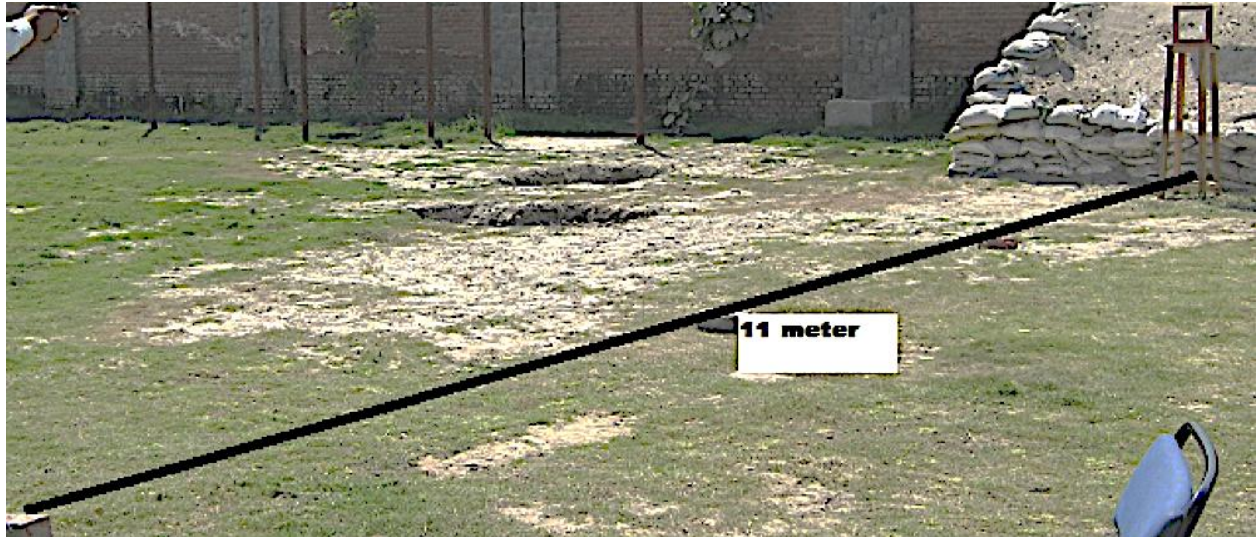
Figure 5- Demonstration of the setup for the shooting at the distance of 11 meters.

III. OBSERVATIONS AND RESULTS

The results analysis in the present study was based upon the study fiberglass fracture pattern that was created after firing with .32 caliber bullet from a revolver on from different selected ranges. The particular firearm was chosen keeping in mind its common usage in India. The target was photographed after each firing with the help of a sophisticated 35mm DSLR camera, enlarged and enhanced by using photoshop. For more appropriate analysis the fractured glass at the same distance was studied and compared first to see the consistency in the fracture pattern and then with the samples at varying distances to see the dissimilarities at different distances. The inferences brought out were as follows: -

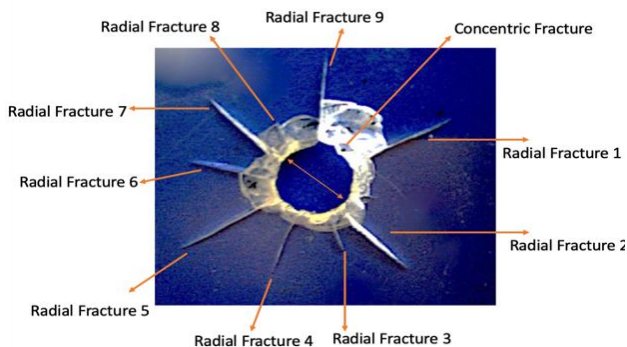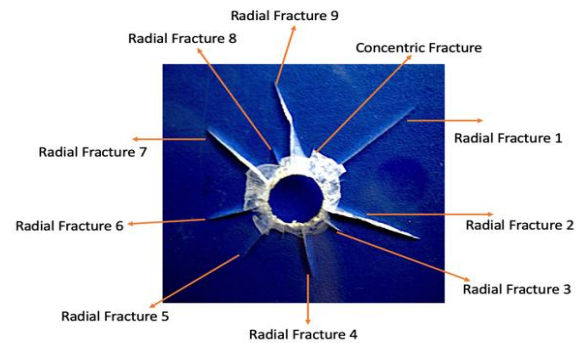3a. Glass fracture pattern comparison at the distance of 4 meters

Figure 6a

Figure 6b

Figure 6a and 6b displays the fracture pattern created by the .32 caliber bullet at a distance of 4 meters.

Table 1: Showing the details entry and exit hole and the fracture pattern at 4 meters range of (figure 6a and 6b)

Sample number/Figure number	Diameter of Entry Hole (in inches)	Fracture Pattern Type	Total diameter extension of fracture (in inches)	Number of Radial Fractures	Exit Hole Diameter (in inches)
Sample 1 (Figure 6a)	$0.35 \approx$	Radial Fracture	$1.29 \approx$	9	$0.69 \approx$
Sample 2 (Figure 6b)	$0.34 \approx$	Radial Fracture	$1.26 \approx$	9	$0.60 \approx$

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From the table 1, it can be inferred that there are many similarities between two glass samples fired from the same range i.e. the close range of 4 meter. The diameters of entry hole (0.35 and 0.34 inches), the exit hole (0.69 and 0.60 inches) and the dimension of the fracture pattern (1.29 and 1.26 inches) are almost similar whereas the numbers of radial fractures are exactly similar in both the sample i.e. 9. The cruciferate everted margins are seen in both the sample in the exit side. The everted margins also show the penetrative effect of the bullet through the fiber glass.

3b. Glass fracture pattern comparison at the distance of 7 meters

Figure 7a

Figure 7b

Figure 7a and 7b displays the fracture pattern created by the .32 caliber bullet at a distance of 7 meters
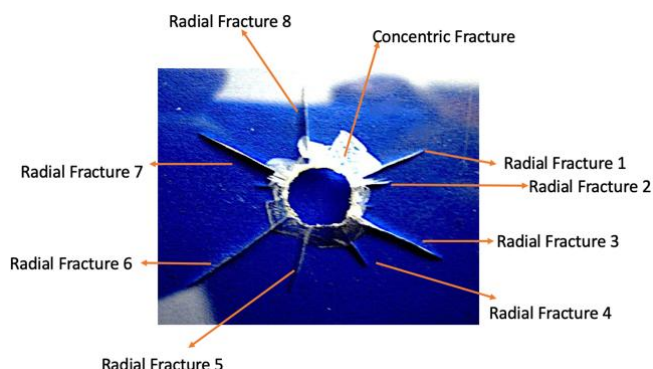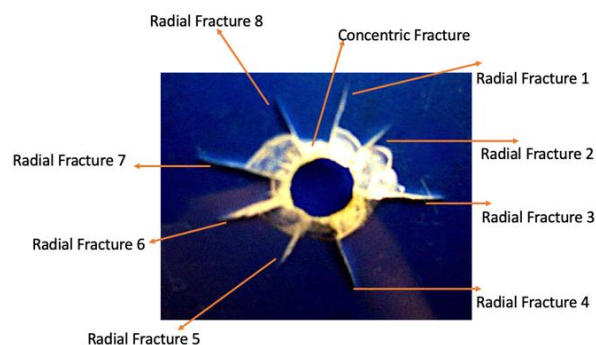
Table 2: Showing the details entry and exit hole and the fracture pattern at 7 meters range of (figure 7a and 7b)

Sample number/Figure number	Diameter of Entry Hole (in inches)	Fracture Pattern Type	Total diameter extension of fracture (in inches)	Number of Radial Fractures	Exit Hole Diameter (in inches)
Sample 3 (Figure 7a)	0.34 ≈	Radial Fracture	1.46 ≈	**8**	0.75 ≈
Sample 4 (Figure 7b)	0.32 ≈	Radial Fracture	1.40 ≈	**8**	0.70 ≈

From the table2, it is clear that there are many similarities between both the glass samples fired from the same range i.e. the near range of 7 meter. The diameters of entry hole are 0.34 and 0.32 inches respectively, the exit hole diameter is 0.75 and 0.70 respectively and the extension of radial fracture is 1.46 and 1.40 inches respectively. The numbers of radial fractures are 8 in both the samples. The radial fractures found here in near range are uniform in nature i.e. there are almost same distance between two successive radial fracture from the entry hole.

3c. Glass fracture pattern comparison at the distance of 11 meters

Figure 8a

Figure 8b

Figure 8a and 8b displays the fracture pattern created by the .32 caliber bullet at a distance of 11 meters.
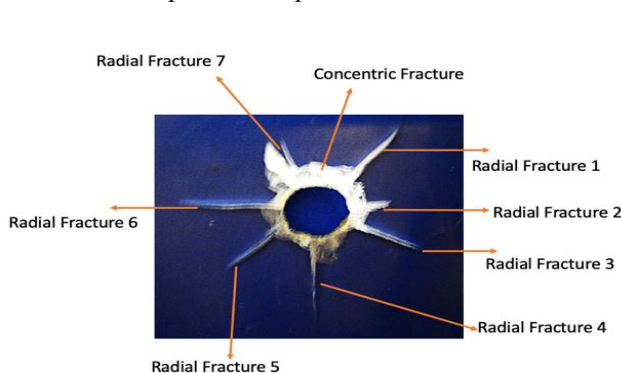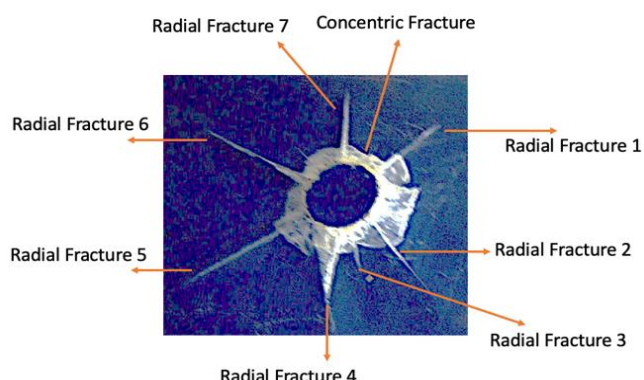
Table 3: Showing the details entry and exit hole and the fracture pattern at 11 meters range of (figure 8a and 8b)

Sample number/Figure number	Diameter of Entry Hole (in inches)	Fracture Pattern Type	Total diameter extension of fracture (in inches)	Number of Radial Fractures	Exit Hole Diameter (in inches)
Sample 5 (Figure 8a)	0.36 ≈	Radial Fracture	1.42 ≈	7	0.67 ≈
Sample 6 (Figure 8b)	0.32 ≈	Radial Fracture	1.38 ≈	7	0.60 ≈

From the table3, it is clear that there are many similarities between both the glass samples fired from the same range i.e. the near range of 7 meter. The diameters of entry hole are 0.36 and 0.32 inches respectively, the exit hole diameter is 0.67 and 0.60 respectively and the extension of radial

fracture is 1.42 and 1.38 inches respectively. The numbers of radial fractures are 7 in both the samples.

Table 4: Shows the comparison of the impact of 0.32 caliber bullet on fiber glass at the distances of 4, 7 and 11 meters respectively

Observations> Ranges	Diameter of the entry hole (in inches)	Diameter of the exit hole (in inches)	Maximum Dimension (extension) of the fracture Pattern (in inches)	No. of radial fractures	Inferences
Close Range 4 meter (sample 1)	0.35 ≈	0.69 ≈	1.29 ≈	9	Less cruciferate fracture, least extended dimensions of the radial fracture with a greater number of fractures
Close Range 4 meter (sample 2)	0.34 ≈	0.60 ≈	1.26 ≈	9	
Near Range 7 meter (sample 3)	0.34 ≈	0.75 ≈	1.46 ≈	8	More cruciferate fracture with greater extension of the radial fracture with further decrease in number of radial fractures
Near Range 7 meter (sample 4)	0.32 ≈	0.70 ≈	1.40 ≈	8	

Distant Range 11 meter (sample 5)	0.36 ≈	0.67 ≈	1.42 ≈	7	More cruciferate fracture with greater extension of the radial fracture with further reduction in the number of radial fractures
Distant Range 11 meter (sample 6)	0.32 ≈	0.60 ≈	1.38 ≈	7	

Comparison of glass samples fired from different ranges:
The radial fractures found here in near range are uniform in nature i.e. there are almost same distance between two successive radial fracture from the entry hole.

IV. DISCUSSION

It is clear from the experiment that range of firing has a significant impact on the fracture pattern created on the fiberglass. Firstly, the noticeable point is that the fracture pattern will be a combination of concentric and radial fracture due to the elasticity of the fiber glass which did not get shattered. Where, dense concentric fracture is surrounded by typical radial fracture with an extension to certain dimension depending upon the range of firing. The other factors that may affect the fracture pattern is the thickness of the glass, velocity of the projectile, shape of the projectile and presence of another intermediate target. However, current study was done with the aid of 0.32 caliber bullet with a revolver as a constant variable, whereas only the ranges of the firing has been changed. Also, in the experiment all the projectiles hit the target (fiberglass) in a straight gyratory motion. In case of any intermediate target the ricocheted or reflected bullet might have tumbled down creating varying fracture patterns, that need to be studied separately. Conversely, from the above experiment many inferences can be drawn. At close range of four meters the damage is less as seen with the extension of the radial fracture diameter, whereas, in case of distant shot i.e. 11 meters the damage (radial fracture extension) was increased significantly from 1.29 inches to 1.42 inches approximately. The reason for this is the total amount of energy utilized in causing the damage to the target [14]. As at close distance the bullet possesses very high energy and velocity and hence, passes quickly through the glass creating less damage, whereas in case of distant shot, due to slightly lesser velocity the bullet for fractions of seconds took more time to pass through the target creating bigger impact [15]. There are slight differences in the bullets impact even in the same ranges of firing which may be due to the fact that the firing was done manually without using any computerized firing aid or a fixed firing stand mechanism that has resulted in the slight variations due to handling of the firearm. However, careful examination of entry hole gives a clear idea about

the caliber of the bullet as in ranges from 0.32 inches to 0.36 inches maximum. The slight increase in the entry hole is due to the elastic nature of the glass and the manual firing, but overall results can be considered well to determine the approximate caliber and which can also be used as a reference if alleged firearm is also present during test firing in cases of shooting incidents. Considering the number of radial fractures, it is clear from the findings that with the increasing range of firing the number of radial fractures keeps on decreasing due to the decrease or loss in the amount of kinetic energy at increasing distances.

V. CONCLUSION

The use of firearms by criminals is a major danger by the investigators and law enforcement. Occasionally, the firing is done through the glass of a window or vehicle. In such cases, it is challenging for the investigator to approximate the possible range of firing as most of the GSR (Gun Shot Residue) particle (if any) remains on the glass as an intermediate target in case of close-range shots, rather than reaching to the primary target. Therefore, it becomes hugely significant in such cases to study the fracture pattern on the glass along with the presence of GSR to estimate the possible range of firing. The present study on the fiberglass may assist the ballistic expert and investigators in the assessment of the possible range of firing in circumstances where fiberglass has been involved as an intermediate target. Also, by considering the bullet impact pattern and the dimension of the entry hole, the possible caliber of the bullet can also be established along with the type of firearm. The future scope of study by the use of different firearms and different kinds of glasses will provide more significant information that can be used further in the estimation of the range of firing and type of firearm, which will help the forensic community and law enforcement during such shooting incident reconstruction.

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