

“Analysis of Steel Fibre Reinforced Concrete wall-column connection using headed bars Subjected to Blast Loading”

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ABSTRACT

The increasing occurrence of terrorist incidents and accidental explosions in recent years has emphasized the need to incorporate blast-resistant considerations in structural engineering design. Although blast loads are infrequent, they are highly dynamic and may lead to severe damage or collapse of conventional reinforced concrete structures if not properly addressed. This study examines the structural performance of precast steel fibre reinforced concrete (SFRC) wall-column connections using headed bars as the primary connection system under blast loading. Four types of connection configurations are considered: (1) conventional dowel bar connections, (2) headed bar connections, (3) dowel bar connections with steel fibres, and (4) headed bar connections with steel fibres. The use of steel fibres is intended to improve ductility, energy absorption capacity, and crack resistance under extreme loading conditions. Numerical modelling and simulation are carried out in ANSYS Workbench using nonlinear dynamic analysis to evaluate parameters such as displacement, stress distribution, and failure modes under different charge weights and standoff distances. The results are expected to show that SFRC with headed bar connections performs better under blast loading compared to conventional systems due to improved anchorage, lower stress concentration, and enhanced post-cracking behavior. The findings aim to contribute to the development of effective blast-resistant connection systems for precast structural elements, thereby enhancing safety and resilience in modern construction practice.

Keywords: Blast loading, Steelfibre reinforced concrete, Headed bar connection, Wall-column joint, Dynamic analysis.

INTRODUCTION

Blast explosions occurring either inside or in the vicinity of a structure may result from pressure-based devices, vehicle bombs, or quarry blasting operations. Such events can cause severe structural damage, both externally and internally, depending on the intensity and location of the explosion. The consequences may include collapse of walls, shattering of windows, and failure of essential life-safety systems. Structures such as buildings, bridges, pipelines, industrial plants, and dams are considered lifeline infrastructure, playing a significant role in a country's economy. Therefore, they must be adequately protected against dynamic and wind loads.

These structures are often vulnerable to bomb attacks and may become potential targets of terrorist activities. Due to the nonlinear behavior of construction materials, analyzing the dynamic structural response under blast loading becomes complex. Explosive events generate intense dynamic forces that are significantly higher than the conventional design loads considered during structural analysis. Hence, effective blast-resistant design requires a comprehensive understanding of blast phenomena and their structural implications. Terrorist threats and related activities have become an increasing global concern. As a result, blast protection has emerged as an important consideration in structural engineering practice. In recent years, the inclusion of blast loads along with other dynamic loads such as earthquake and wind loads has become increasingly necessary, particularly in metropolitan areas where such risks are more pronounced. Terrorist attacks often target locations where potential human casualties and economic losses are substantial. Structural buildings are considered attractive targets due to their accessibility and the significant impact their damage can have on human life and economic activities.

1.1 Steel Fiber Reinforced Concrete:

Fiber reinforced concrete (FRC) is a composite material consisting of Portland cement, aggregates, and discrete fibres. Conventional plain concrete is brittle in nature and possesses low tensile strength and limited strain capacity. The randomly distributed fibres within the matrix act to bridge and control the development of cracks in the composite material.

Steel fibre reinforced concrete (SFRC) is a type of composite in which steel fibres are incorporated as an additional component and uniformly dispersed in small volume fractions within plain concrete. Typically, the fibre content ranges from 0.3% to 2.5% by volume..

1.2 Headed Bars

Headed bars are reinforcing bars fitted with a steel anchorage plate, referred to as a head, attached at one end by welding at a relatively shallow embedment depth. The presence of the head increases the bearing area and enhances the anchorage performance of the reinforcement.

- Headed bars provide higher bond strength compared to conventional reinforcement.
- They ensure effective transfer of shear forces across connections.
- The use of headed bars eliminates the need for large hooks to achieve proper anchorage.
- Compared to traditional dowel bars, headed bars offer improved ductility and greater ultimate strength in walls and columns

MATERIALS AND METHODS

2.1 Explosion and Blast Phenomenon.

An explosion is a sudden release of stored energy that results in the rapid expansion of energy into the surrounding environment. A portion of this energy is transformed into thermal radiation (flash), while another portion is transmitted through the air in the form of blast pressure and shock waves that propagate outward in all directions.

For a material to be classified as explosive, it must possess certain characteristics. It should consist of a substance or mixture that remains stable under normal conditions but undergoes a rapid chemical reaction when subjected to external stimulation. This reaction produces gases which, at elevated temperatures generated during the explosion, occupy a much larger volume compared to the original material under normal pressure conditions. The reaction must also be exothermic, generating heat that increases the temperature and pressure of the resulting gases.

Common examples of explosions include controlled construction blasting used for rock excavation or demolition of structures and foundations, as well as accidental explosions caused by natural gas leaks or other chemical or explosive substances

2.2 Problem Statement

- Terrorist activities and related threats have become an increasing global concern. Ensuring the safety of citizens against such incidents requires effective prediction, prevention, and mitigation strategies. In the context of structural engineering, mitigation can be achieved by enhancing structural resistance and maintaining physical integrity under extreme loading conditions.
- The present study involves the analysis of a precast reinforced concrete (RC) wall–column system subjected to blast loading using ANSYS Workbench software. The considered system consists of a solid wall 2260 mm in height and 150 mm in thickness, connected to precast RC hollow columns of size 350 × 350 mm. The materials used are M30 grade concrete and Fe415 grade steel reinforcement.
- A comparative investigation is conducted on the precast RC wall–column system by adopting dowel bars and headed bars as connection mechanisms, both with and without the inclusion of steel fibres.

There are three types of headed bars

- Plain headed bar
- Grooved headed bar and
- Ribbed headed bar

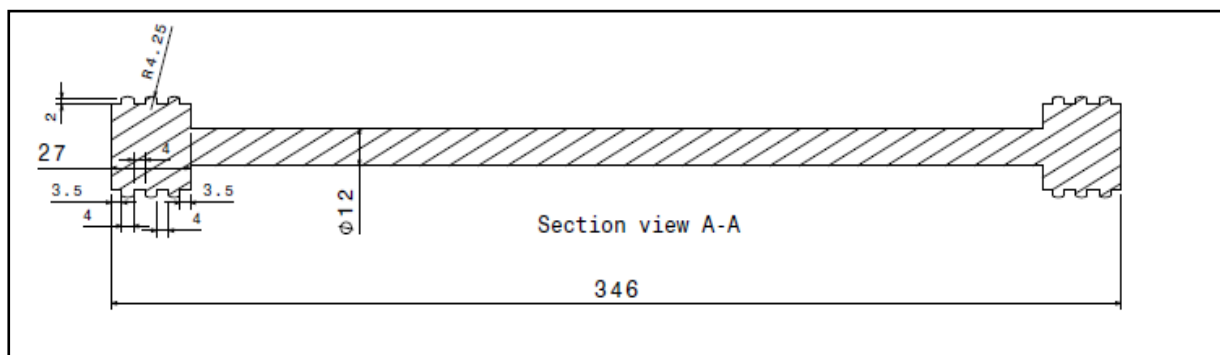


Figure 1 Detailing of headed bar

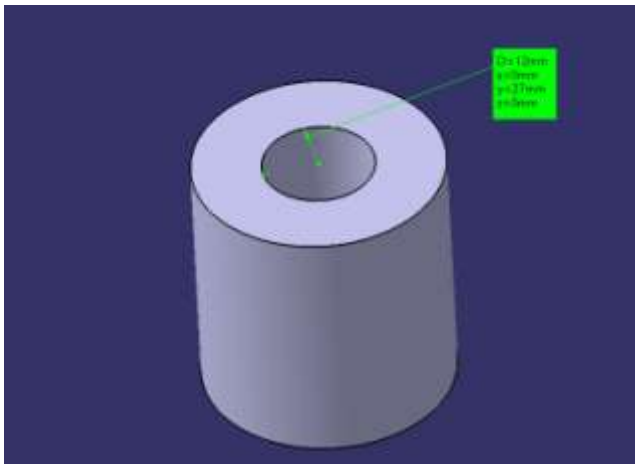


Figure 2 Plain headed bar

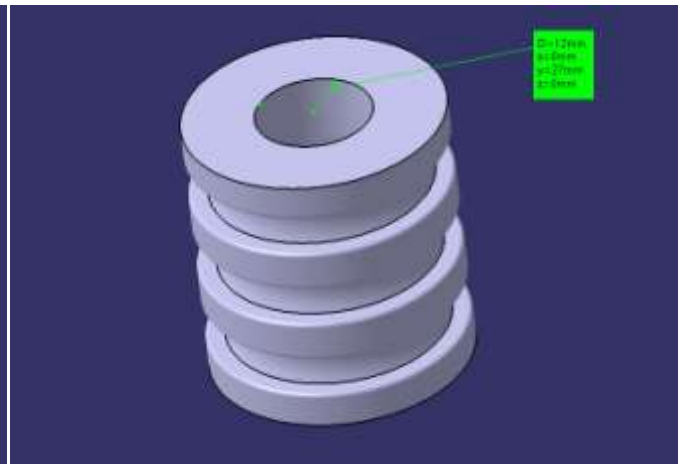


Figure 3 Grooved headed bar

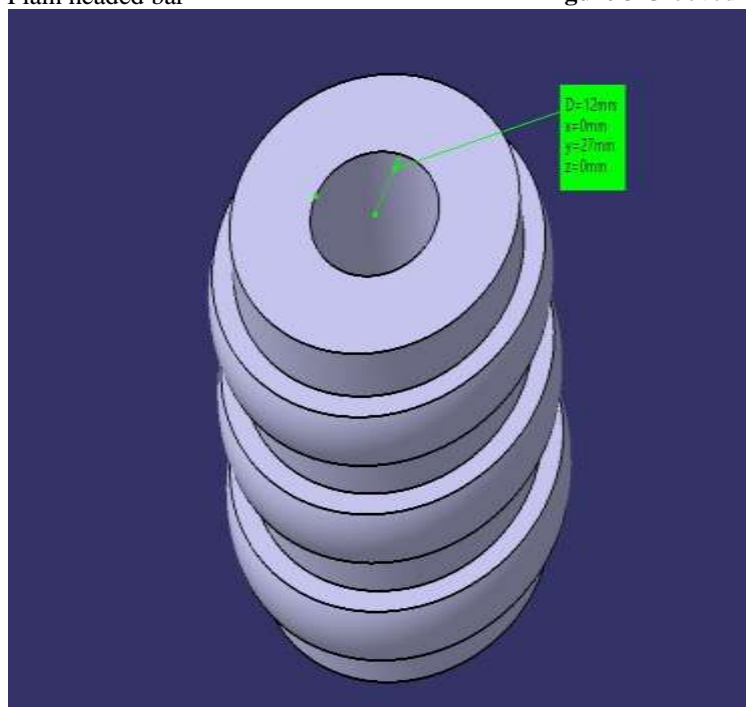


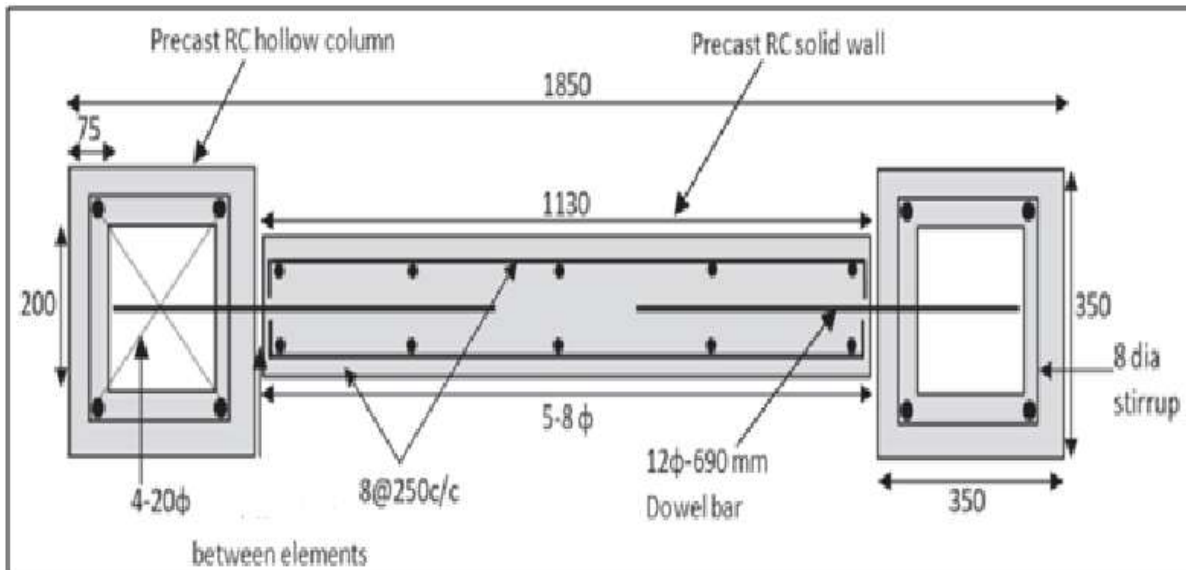
Figure 4 Ribbed headed bar

Table 1 Modeled specimens for numerical analysis

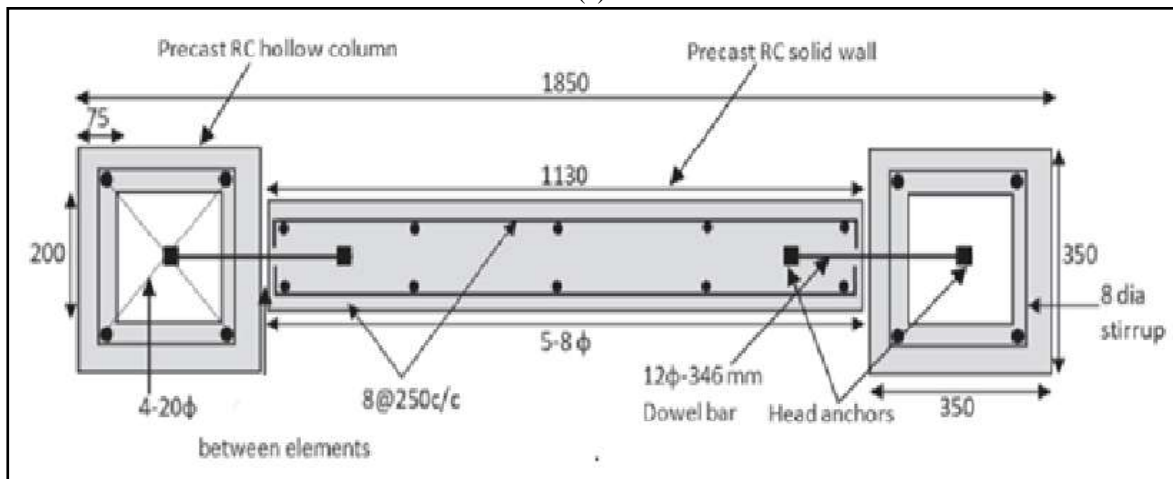
Specimen notation	Connection details	Embedment depth in wall (mm)	Embedment depth in column (mm)
DB	Dowel bar (without head)	433	257
PHB	Plain headed bar (27 mm dia. and 27 mm length)	173	173
GHB	Grooved headed bar (27 mm dia. and 27 mm length)	173	173
RHB	Ribbed headed bar (27 mm dia. and 27 mm length)	173	173

According to ACI 318-14, the net bearing area of a headed reinforcement bar should be at least four times the cross-sectional area of the bar. Accordingly, a head anchor with equal length and a diameter of 27 mm is adopted for the 12 mm diameter reinforcing bar.

Based on this configuration, the total embedment length (including embedment in both the wall and the column) is 346 mm for the headed bar connection and 866 mm for the dowel bar connection.



(a)



(b)

Figure 5 Precast RC wall and columns connected through (a) dowel bar system; and (b) headed bar system.

2.3 Model details:

Dimensions

Size of foundation – 2.15 x 3.65 x 0.4 m

Size of column – 0.35 x 0.35 x 2.26 m

Size of wall – 3.11 x 1.15 x 0.15 m

Table 2 Modelling in ANSYS

Model 1	Plain headed bar	2 Bars
		3 Bars
		4 Bars
Model 2	Grooved headed bar	2 Bars
		3 Bars
		4 Bars
Model 3	Ribbed headed bar	2 Bars
		3 Bars
		4 Bars

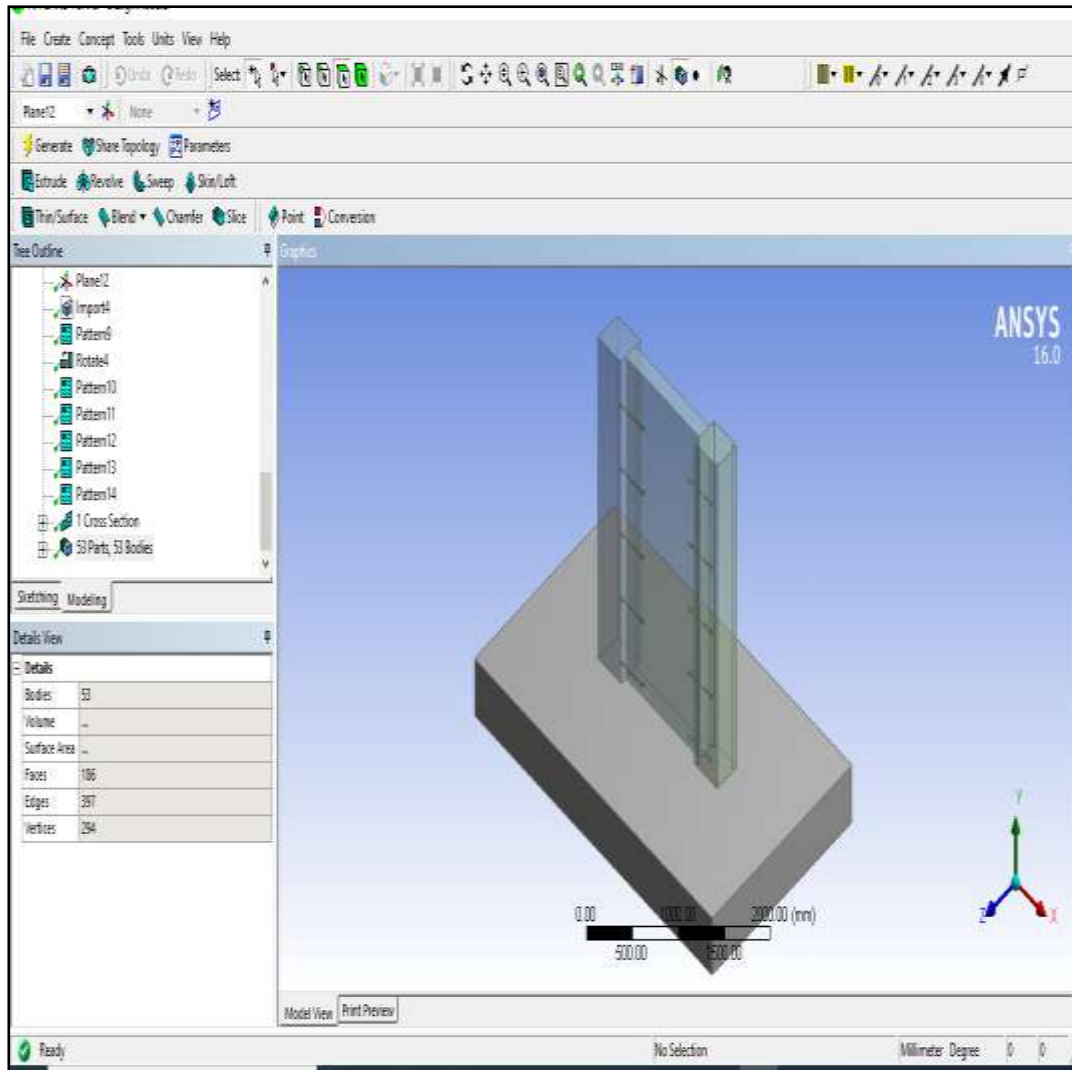


Figure 6 Model as u required sizes in Geometry option

RESULTS AND DISCUSSION

3.1 Total Deformation

Table 3- Common result table of Total Deformation in mm

Connection Bars	Total Deformation in mm			
	2 Bar	3 Bar	4 Bar	Steel Fibre 4 Bar
Dowel bar	38.06	32.623	28.545	22.203
Plane bar	30.448	26.099	22.836	18.873
Groove bar	27.785	23.644	20.911	17.282
Ribbed bar	28.063	23.881	21.12	17.455

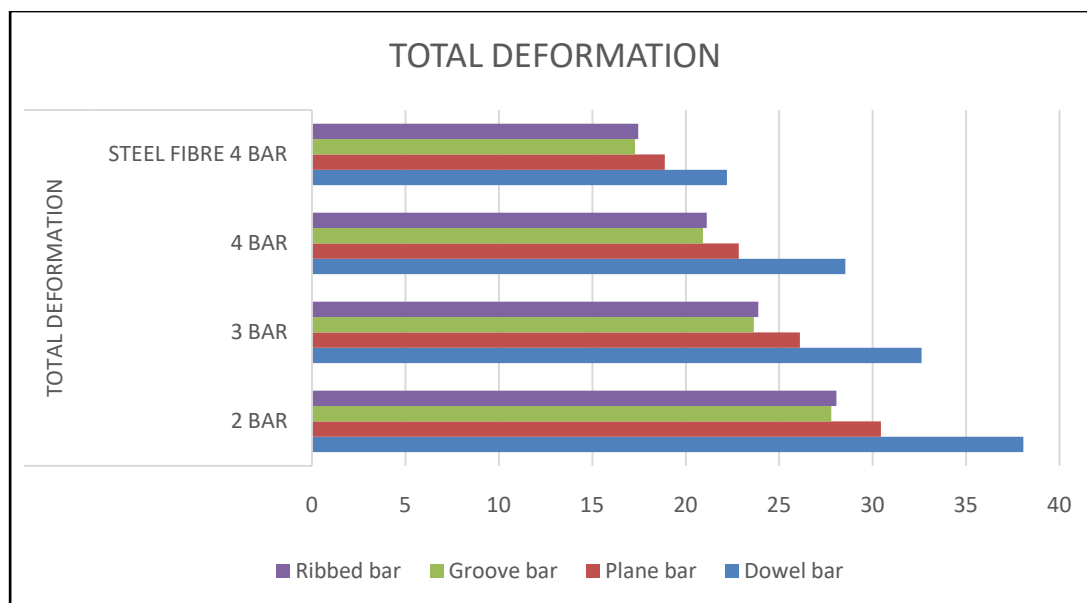


Figure 7. Common result of Total Deformation

From Table 3, it can be observed that the groove bar connection demonstrates the minimum total deformation under blast loading, followed by the ribbed bar connection, whereas the dowel bar connection exhibits the maximum deformation. Increasing the number of bars from two to four leads to a noticeable reduction in deformation for all connection types, indicating enhanced stiffness and improved load distribution capacity.

The addition of steel fibres further reduces total deformation by improving ductility and increasing energy absorption capability. Among all the studied configurations, the steel fibre reinforced groove bar connection records the lowest deformation, indicating superior performance in resisting blast-induced stresses and preserving structural integrity.

CONCLUSION

The present study investigated the blast performance of precast steel fibre reinforced concrete (SFRC) wall-column connections incorporating headed bars as the primary connection mechanism. Numerical analysis was performed using ANSYS Workbench to assess the deformation and stress response of different connection configurations subjected to varying blast loading conditions.

The results indicate that bar configuration, type of connection, and the presence of steel fibres have a significant impact on structural deformation and energy absorption capacity. Among the four connection types examined—dowel, plane, groove, and ribbed bars—the groove bar connection exhibited the minimum total deformation, followed by the ribbed bar connection, reflecting improved bond characteristics and energy dissipation capacity. The addition of steel fibres further reduced deformation and enhanced ductility in all connection systems, demonstrating their effectiveness in strengthening blast resistance in precast structures.

A comparison between analytical calculations and ANSYS simulation results showed good agreement, confirming the accuracy and reliability of the numerical model. The findings suggest that steel fibre reinforced groove and ribbed bar connections provide superior performance under blast loading by offering an effective combination of strength, ductility, and resilience.

The study highlights the significance of optimized connection detailing and material modification in improving the safety of precast concrete systems subjected to extreme dynamic loads such as explosions. The results provide a useful reference for the future design and development of blast-resistant structural connections.

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IS Codes

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