Evaluation of Precast Concrete Slabs under High Velocity Impact Loading using Holmquist-Johnson-Cook Material Model

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***Abstract*— In this paper four different types of precast concrete slabs such as beam and block slab, hollowcore slab, hollowcore composite slab and solid prestressed composite slab along with solid precast slab are analysed using ABAQUS software. Holmquist-Johnson-Cook damage model is used to predict the impact behavior of these precast slabs. High velocity impact is given to these precast slabs with a steel ogive nosed projectile and the results are compared.**

Keywords:- ABAQUS, High-velocity impact , Holmquist-Johnson-Cook, Precast concrete slabs, Steel ogive nosed projectile

I. INTRODUCTION

Precast concrete slabs are strong and durable since high grade steel and high strength concrete is used. Since it is already factory made it can be stored in stock until they are needed for project. Precast concrete has an advantage over traditionally made slabs because it is poured in a controlled environment. Precast concrete slabs strengthens with age and reduce labor cost. When projects use precast concrete, there is an assurance that the quality of the material will be consistently high. This is due to the way in which the materials are crafted. Each precast concrete slab is created by pouring concrete into a mold under supervised conditions, guaranteeing excellent results with each creation. It is resistant to many elements such as fire, water damage and environmental rot or decay. In addition, the slabs are relatively unaffected by prolonged use or consistent wear. Precast slabs are by design, also much easier to maintain and care for than other materials might be. They are relatively non-porous materials, which need very little maintenance and upkeep to hold their original form and serve their purpose. There are five different types of precast slabs such as beam and block slab system, hollowcore slab system, hollowcore composite slab system, and solid prestressed composite slab system. (Reference 8)

II. TYPES OF PRECAST SLABS

A. Beam and Block Slab System

Beam and block slab system is the combination of prestressed inverted T beam and other piece being a simple block which can be any shape such as rectangle. The blocks are placed at regular intervals and the beams placed between them to form a connection between each block section. The shape of block depends on the slab size and since it is already factory made, different standard sizes are available for beam and block. Spans of up to 8m can be used. (Reference 9)

Fig. 1. Beam and Block Slab System

B. Hollowcore Slab System

Hollowcore slab also known as voided slab or hollowcore plank. Comprised of precast concrete with lengthwise voids. It has tubular voids extending the full length of slab. This makes the slab much lighter than a massive solid concrete floor slab of equal thickness or strength. (Reference 10)

Fig. 2. Hollowcore Slab System

C. Hollowcore Composite Slab System

A composite hollowcore slab combines precast hollowcore units with a structural concrete topping resulting in enhanced structural performance and lateral load distribution. The prestressed precast element acts compositely with an in-situ structural topping, combining the benefits of precast and in-situ construction. (Reference 11)

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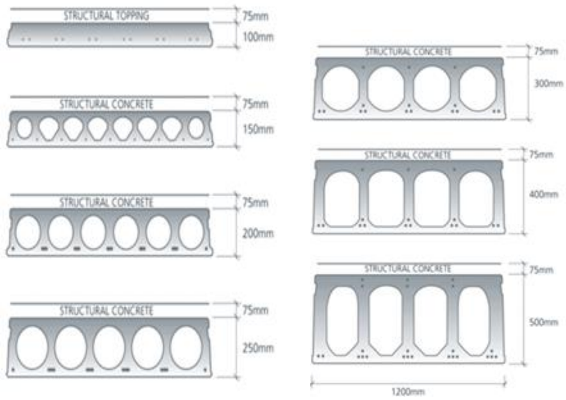

Fig. 3. Composite Sections

D. Solid Prestressed Composite Slab System

Precast slabs together with an in-situ topping can provide can provide a structural deck with full diaphragm action where required in multi storey structures. Solid precast units are prestressed using high tensile reinforcement. (Reference 12)

Fig. 4. Solid Prestressed Composite Slab System

III. OBJECTIVES

- To predict the impact behavior of different types of precast concrete slabs
- To find the effectiveness of using Holmquist-Johnson-Cook damage model
- Generation of following graphs of impact point due to impact
  - Plastic strain graph
  - Logarithmic strain graph
  - Displacement graph
  - Acceleration – Time graph
  - Load – Displacement graph
  - Plastic dissipation energy – Time graph

IV. MODELLING

Two way slab of size 1m x 1m is modeled in ABAQUS software. M25 grade concrete and Fe415 grade steel is used. Total slab depth taken for modelling is 100mm, 150mm and 200mm. 10mm diameter bars are given at 100mm spacing. A steel ogive nosed projectile having 200mm height and 50mm diameter are modelled for giving impact. There are total 5 models including solid precast slab and the impact is given at the center perpendicularly at the top of the slab. 1000m/s is given at the center of each slab.

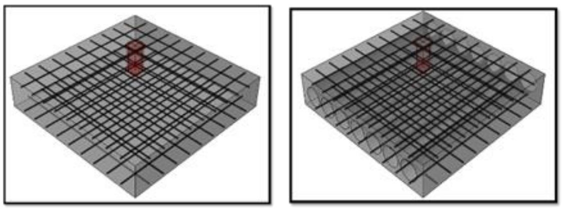

Fig. 5.Model of Solid Precast Slab and Hollowcore Precast Slab

The hollowcore diameter for hollowcore precast slab for 200mm, 150mm and 100mm thickness are 100mm, 75mm and 50mm.

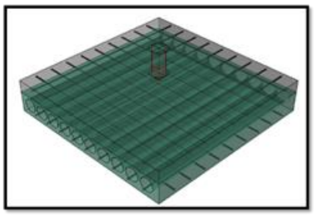

Fig .6 .Model of Hollowcore Composite Precast Slab

TABLE. 1. DIMENSIONS OF HOLLOWCORE COMPOSITE SLAB FOR DIFFERENT SLAB THICKNESS

	200mm	**150mm**	**100mm**
Hollowcore diameter(mm)	80	60	40
Precast slab thickness(mm)	125	100	75
Concrete topping thickness(mm)	75	50	25

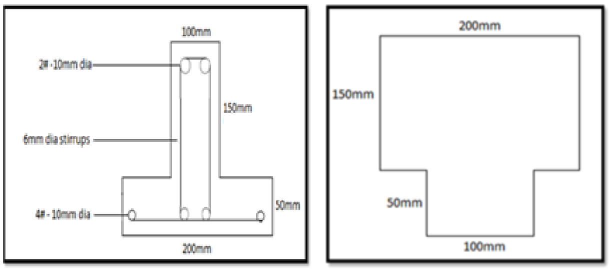

Fig. 7 .Dimension of Beam (Left) and Block (Right)

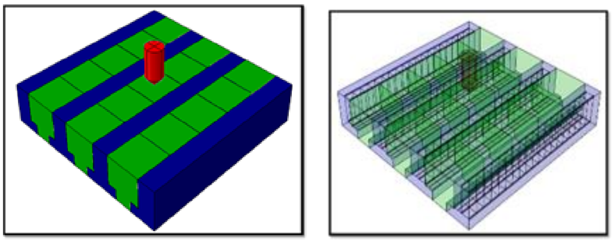

Fig. 8 .Model of Beam and Block Slab System

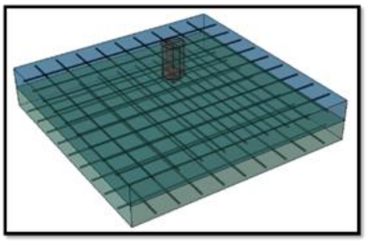

Fig. 9 .Model Of Solid Prestressed Composite Slab

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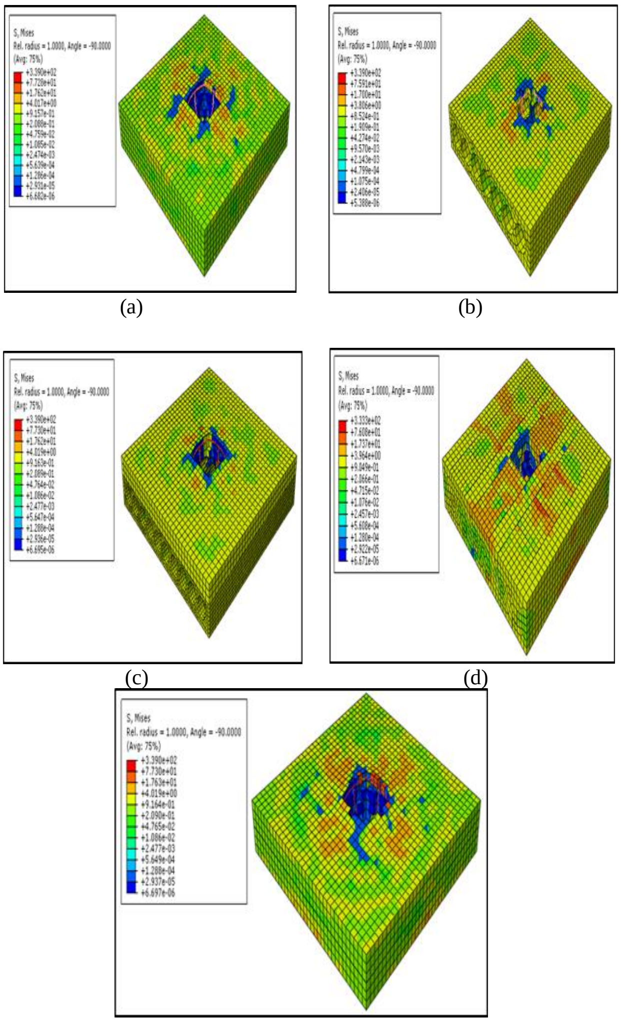
TABLE 2 DIMENSIONS OF SOLID PRESTRESSED COMPOSITE SLAB

	200mm	150mm	100mm
Precast slab thickness(mm)	100	75	50
Concrete topping thickness(mm)	100	75	50

V. ANALYSIS AND RESULTS

Each precast slab having thickness 200mm, 150mm and 100mm are analysed by giving an impact velocity of 1000m/s. Impact is given at the center on top of the slab. Impact angle between projectile and top of slab is 90° that is impact is given perpendicularly at the top the slab.

A. Stress



(a) (b) (c) (d) (e)

Fig. 10. Von- Mises stress of (a)Solid Precast Slab (b)Hollowcore Slab (c)Hollowcore Composite Slab (d)Beam And Block Slab (e)Prestressed Composite Slab

Above figures show stress distribution and damage pattern of solid precast slabs and different types of precast slabs under an impact velocity of 1000m/s for 200mm slab thickness. Von-Mises stress is a value used to determine if a given material will yield or fracture. In this present study, stress distribution is more for beam and block slab system and lower for hollowcore slab system. So, more damage will be for beam and block slab system.

By varying the slab thickness by 150mm and 100mm under the same impact velocity 1000m/s, stress distribution is more for beam and block slab system and lower for hollow core slab system. Here also more damage is obtained for beam and block slab system. So, by varying slab thickness there is no change in stress distribution and damage pattern under same impact velocity.

B. Plastic strain

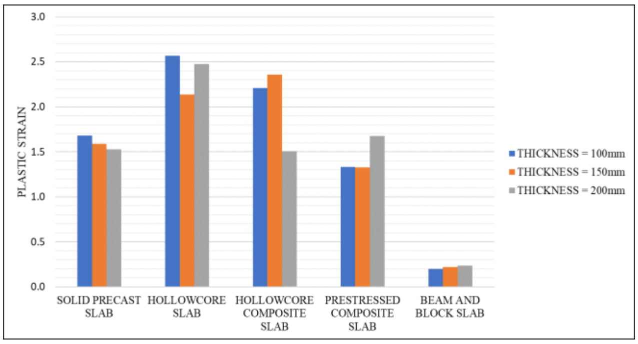


Fig. 11 .Graph showing Plastic Strain for different types of Precast Slabs

Above graph shows plastic strain of different types of precast slabs under impact velocity of 1000m/s for different slab thickness 100mm, 150mm and 200mm. In this present study, it is obtained that beam and block slab yields firstly and hollowcore slab yields lastly. The pattern of plastic strain is different for different slab types irrespective of thickness.

C. Logarithmic strain

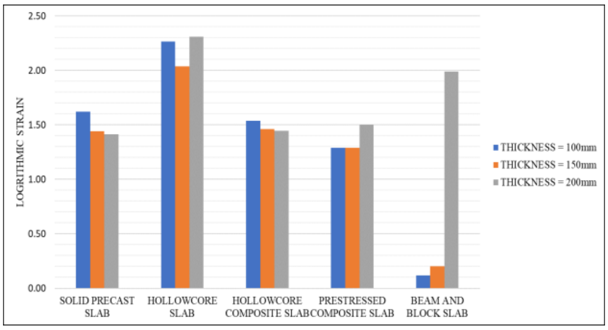


Fig .12 .Graph showing Logarithmic Strain for different types of Precast Slabs

Above graph shows logarithmic strain graph of different types of precast slab under impact velocity of 1000m/s for different slab thickness 100mm, 150mm and 200mm. In this present study, here also shows that like plastic strain, the pattern of logarithmic strain is different for different slab types irrespective of thickness. Logarithmic strain is maximum for hollowcore slab.

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D. Maximum displacement (mm)

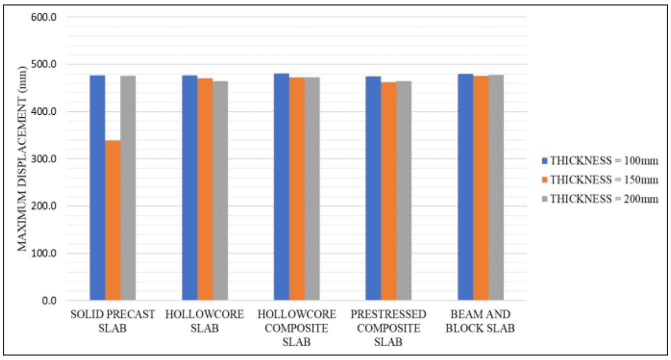
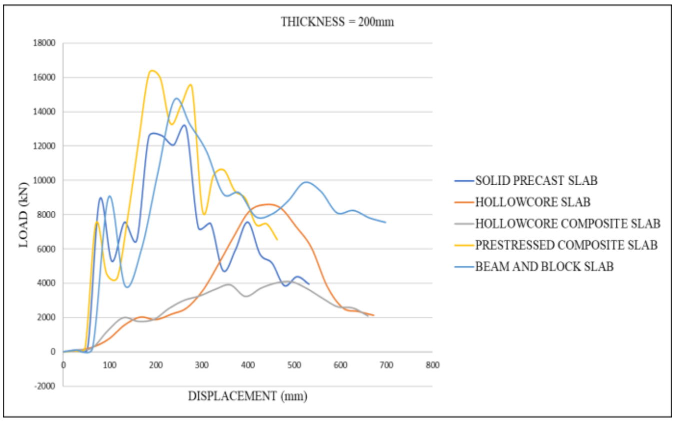


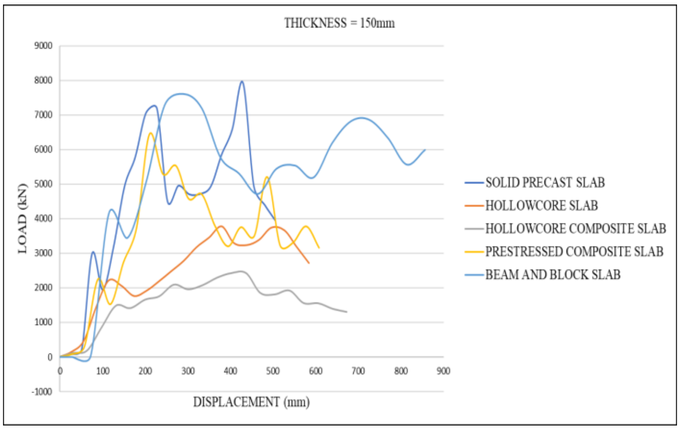
Fig. 13. Graph showing maximum displacement for different types of Precast Slabs

Above graph shows maximum displacement (mm) of different types of precast slabs under impact velocity of 1000m/s for different slab thickness 100mm, 150mm and 200mm. In this present study it is obtained that displacement is least for solid precast slab with 150mm thickness. If depth and percentage of reinforcement is optimum, displacement will be less. Displacement is irrespective of type of slab.

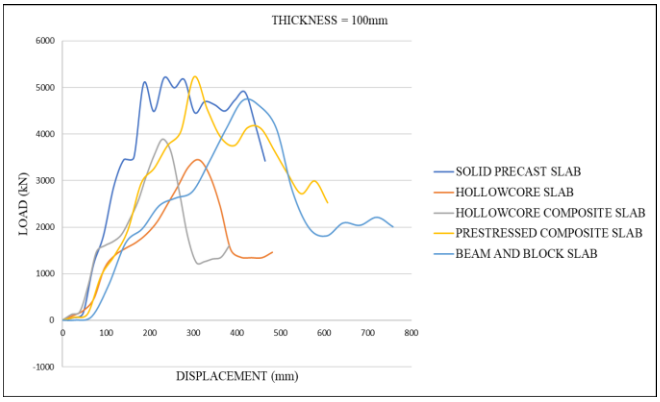
E. Load – Displacement curves



(a)



(b)

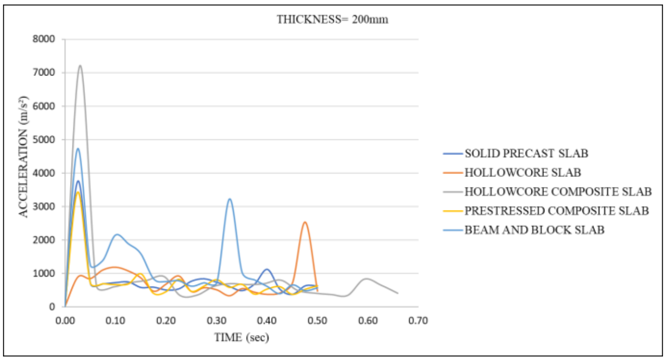


(c)

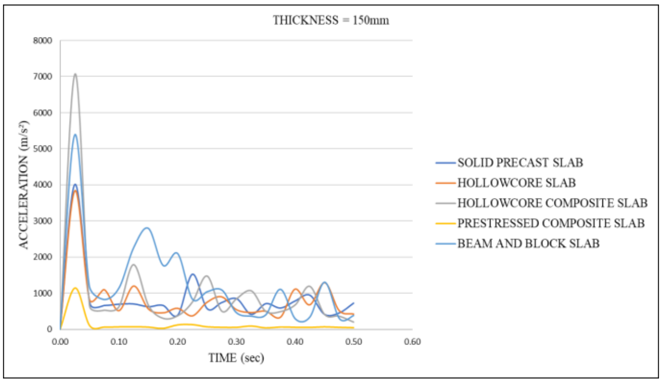
Fig. 14 .Load – Displacement curves of different slab thickness (a) 200mm (b) 150mm (c) 100mm

Above graph indicates load – displacement curves of different types of precast slabs under an impact velocity of 1000m/s for different slab thickness 200mm, 150mm and 100mm. At 200mm and 150mm slab thickness hollowcore composite slab displaces more at very less loads. It indicates its ductility. So, ductility is more for hollowcore composite slab compared to other precast slabs. At 200mm slab thickness prestressed composite slab displaces less at very high loads. At 150mm slab thickness solid precast slab displaces at higher loads. At 100mm slab thickness solid precast slab and prestressed composite slab displaces at higher loads. It indicated its stiffness. Hollowcore and hollowcore composite slab fails first for 100mm slab thickness.

F. Acceleration- Time curves



(a)



(b)

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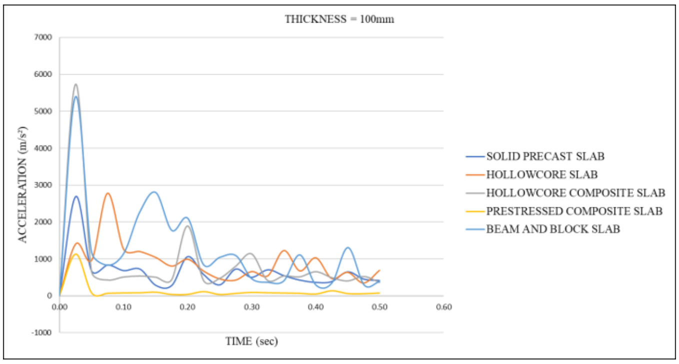
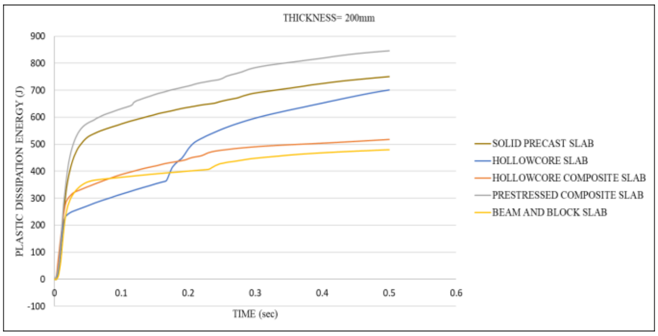


(c)

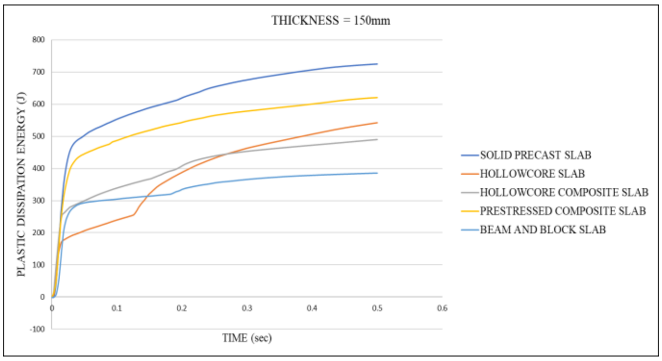
Fig. 15 .Acceleration – Time curves of different slab thickness (a) 200mm (b)150mm (c) 100mm

Above graph indicates acceleration- time curves of different types of precast slabs under an impact velocity of 1000m/s for different slab thickness 200mm, 150mm and 100mm. At 200mm slab thickness, hollowcore slab accelerates very less due to the rigidity of interconnected I-sections. At 200mm, 150mm and 100mm slab thickness hollowcore composite slab accelerates more initially then it slows down. At 150mm and 100mm slab thickness, prestressed composite slab has least acceleration.

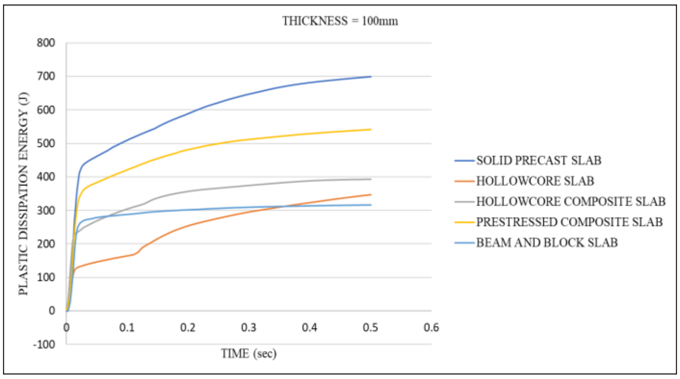
G. Plastic – Dissipation energy curve



(a)



(b)



(c)

Fig. 16 .Plastic dissipation energy- Time curves for different slab thickness (a)200mm (b) 150mm (c)100mm

Above graph indicates Plastic dissipation energy – Time curves of different types of precast slabs under an impact velocity of 1000m/s for different slab thickness 200mm, 150mm and 100mm. at 200mm thickness, plastic dissipation energy is highest for prestressed composite slab and lowest for hollowcore slab initially then increases. At 150mm and 100mm slab thickness, plastic dissipation energy is highest for solid precast slab and lowest for hollowcore slab initially then increased. So, plastic dissipation energy is lowest for hollowcore slab initially and then it increases in three different thickness.

VI. CONCLUSION

Hollow core Slab is more rigid and have more stability when an impact load is given. When Hollow cores are provided in the slab, the slab behaves as a bundle of interconnected I- beams. The shape of I beams makes them excellent for unidirectional bending parallel to the web. The horizontal flanges of the I-beam resist the bending movement, while the web resists the shear stress.

Beam and Block slabs are less stable, but it is used in today's construction because it is easy to mold, easy to handle by crane, faster in construction and shuttering is not required. Since beam and block slab system is the combination of inverted T- beam and simple block, strength of block compared to inverted T-beam is less. So, it is less stable compared to other precast slabs.

The pattern of plastic strain and logarithmic strain is different for different slab irrespective of thickness

Maximum deflection in slab is irrespective of type of slab. If depth of slab and percentage of reinforcement is optimum, deflection will be less.

Hollow core composite slab displaces more at very less loads. It indicates its ductility. Prestressed composite slab displaces less at very high loads. It indicates its stiffness.

Plastic dissipation energy is highest for prestressed composite slab. It indicates its stiffness. Plastic dissipation energy is lowest for hollow core slab initially then increases.

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