

Hollow Core Slabs in Construction Industry

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ABSTRACT: A hollow core slab is a precast prestressed concrete member with continuous voids provided to reduce weight and cost. They are primarily used as a floor deck system in residential and commercial buildings as well as in parking structures because they are economical, have good fire resistance and sound insulation properties, and are capable of spanning long distances with relatively small depths. Structurally, a hollow core slab provides the efficiency of a prestressed member for load capacity, span range, and deflection control. Hollow core slabs can make use of prestressing strands, which allow slabs with depths between 150 and 260 mm to span over 9 meters. When used in buildings, several hollow core slabs are placed next to each other to form a continuous floor system. The small gap that is left between each slab is usually filled with a non-shrink grout. To give the floor a smooth finished surface, a topping slab overlay, typically 5cm deep is poured on the top surface of the hollow core slabs. The design concepts, manufacture and the erection techniques of Hollow core slabs are discussed in detail

KEYWORDS: Hollow core slabs, Manufacture, Erection techniques, Precast Prestressed concrete.

I. INTRODUCTION

The present concrete industry is constantly searching for revolutionary products and building system that can satisfy the future challenges posed by modern society, ie shortage of; and costly labour force, structural efficiency, fire resistance, sound proofing, rate of speed of construction, execution quality and also most importantly, sustainability. However, one of the most remarkable and successful developments in this context is the precast prestressed hollow core slab. The precast prestressed hollow core slab provides a solution to the current and future market demand for the building industry.

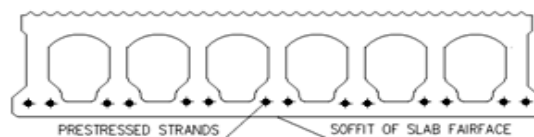


Fig.1.1 Hollow core slab

A hollow core slab[1] is a precast, pre-stressed concrete member with continuous voids which extend throughout the length of the slab, provided to reduce weight and, therefore, cost and as a side benefit, to use for concealed electrical or mechanical runs. Primarily used as floor or roof deck systems, hollow core slabs also have application as wall panels, spandrel, members and bridge deck units. Span length of hollow core slab reach up to (18m) without columns or any supporting. Precast prestressed hollow core slabs can be used for a wide range of applications requiring floor or roof systems. This system can be ideally used in residential, commercial, car parks or repetitive construction projects. Precast prestressed hollow core slabs provide maximum structural efficiency with the utilization of high strength concrete, yet at the same time requiring low material consumption.

II TECHNICAL DETAILS

A. Materials for Hollow Core Slabs

The concrete mix components (cement, aggregate and water) are used in producing hollow core slabs. A low slump mix having water cement ratio about 0.3 is used. The maximum aggregate size is 12 mm. Aggregates should be inert and properly graded. Aggregates containing organic or such deleterious substances like sulphates or salts should be rejected. Porous and expansive aggregates should not be used. Light weight aggregates are occasionally used to reduce the weight of the sections and to achieve a significant reduction in required equivalent thickness. Strands used in hollow core slabs are 7 wired low relaxation strands of diameters 5mm, 9.3mm and 12.7mm. The philosophy of strand use varies from using many strand sizes to optimize cost for a given project to using only one or two strand sizes for simplicity of inventory and production. Keyway grouts are normally a cement and sand mortar in proportions of 1:3. The mix should be as wet as it ensure easy filling.

B. Machines and Equipments

The machines and equipments used for the production of HCS are:-

Casting Machine Extruder

The machine is capable to cast slabs of different thickness started from 15 to 40 cm. The width is Standard (120 cm) and the length is to be cut according to the span required. Compressive strength of the concrete is up to 90 Mpa. The core is hollow along the slab with void percentage ratio up to 50%.

Prestressing Device

Prestressing devices are of two types. Either all of the strands of one bed are tensioned simultaneously, or else tensioning can be done using a single wire stressing jack. A single wire stressing jack consists of a motor pump and stressing jack. It is a single wire hydraulic pre-stressing pump. This method is reliable, secure and safe. Also it is very fast, precise and accurate. Pre-stressing capacity is up to 400 bars.

Standard Concrete Saw

It has a fully hydraulically operated saw blade and travelling control. The cutting capacity is up to 40 cm depth Easy and quick handling.

Bed Cleaner Machine

It has a fully hydraulically operated control, powerful vacuum system for dry bed cleaning, easy and quick handling.

Computerized Mix Plant

The mix plant is controlled and operated by a computer system. It is supplied with water content sensor to control the mix.

C. Structural toppings

Structural toppings can be applied to concrete of a specified thickness. This topping must be continuous from support to support and can distribute loads, add strength, and improve the floor system's fire rating.. The topping thickness most commonly used has been 65 mm. The thickness should be at least 50 mm. The hollow core slab and the topping will act as a composite slab and the moment capacity of the hollow core slabs can be enhanced. Typical topping reinforcement is A142 mesh over the body of the floor, and starters from the perimeter supports and all supports where the floor does not continue both sides of the support, and normally, but not always, saddle bars over all internal supports.

D. Diaphragm action

The diaphragm action of hollow core slab is realized through a good joint design to transfer of horizontal forces to the main structure system. The peripheral reinforcement plays a determinate role not only to cope with the tensile forces of the

diaphragm action but also to prevent the relative horizontal displacement of the hollow core units, so that the longitudinal joints can take up shear forces.

E. Openings

Small holes may be formed at the centre of the longitudinal voids. Holes are normally made in the fresh concrete during the production process. The edges of the opening are rough.

F. Duct work

The spaces within hollow core slabs may be utilized for distribution ducts for heating, air conditions or exhaust systems. Field installed devices generally offer the best economy and ensure placement in the exact locations where the connection devices will be required.

G. Typical connection details

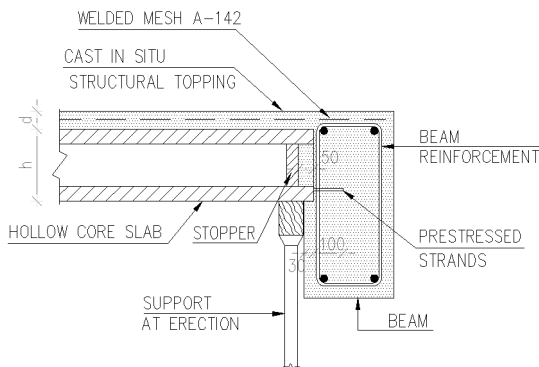


Fig.2.1 Typical fixing detail at drop beams

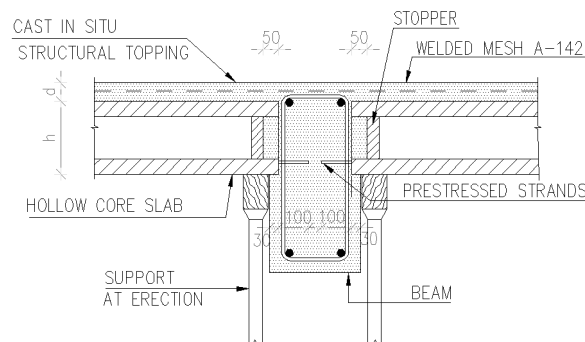


Fig.2.2 Typical fixing detail at drop beams when both side is Hollow core slab

III. PRINCIPLES AND DESIGN PROCESS OF HOLLOW CORE SLABS

A. Principles of Product forming Systems

Two basic manufacturing methods currently in use for the production of hollow core slabs are:-

Extrusion

In extrusion system a very low slump concrete is forced through the machine. The cores are formed with augers or tubes with the concrete being compacted around the cores. Extrusion is known for the high compaction capabilities and excellent structural capacity of the hollow core slab[1]. One of the advantages in the modern extrusion is the silent and automatic operation. The key to an optimum compaction on dry cast is the frequency of vibration since the absence of water makes it more difficult for the concrete particles to flow. Some of the Extruders manufactured today do not use the high frequency vibrators, instead they operate based on pressing extrusion screws, which usually requires more water to achieve the same level of compaction than the Hollow Core Extruders based on high frequency of vibration.

Slip form

This system uses a higher slump concrete. Sides are formed either with stationary, fixed forms or with forms attached to the machine with the sides being slip formed. This is a relatively simple principle where concrete is flowing on to the product in two to three phases (layers) each phase is compacted typically by vibrators. The Slip form system is used mainly for shallower hollow core cross sections and various other cross sections like inverted T-beams. However, there are slip formers, which can form 700mm hollow core sections. The production speed for each of the system varies depending on raw materials, depth of products and machine types being used. The speed ranges between 1 to 3 meters/min. Hollow core

slabs can be manufactured in different thicknesses such as 150mm, 200mm, 240mm, 265mm, 280mm, 300mm, 320mm, 350mm, 400mm etc as required.

B. Design process of Hollow Core Slabs

The design process for a hollow-core floor system should typically involve the following specifications:

- a. General structural arrangement including the assumed self weight of the floor and any significant floor penetrations.
- b. All other permanent actions including partition loads and potentially removable loads.
- c. All design imposed actions on the floor including uniformly distributed live loads and point loads.
- d. Intended floor support arrangements including any special requirements for plastic hinge regions.
- e. Earthquake induced support displacements and rotations.
- f. Vertical seismic loads (accelerations).
- g. Floor diaphragm requirements.
- h. Extent of any expected beam elongations resulting from inelastic behaviour in the support beams.
- i. Tolerance requirements.
- j. Any other requirements, such as minimum concrete strengths, propping restrictions fire rating, durability, specifically required details, etc.

The design of hollow core slabs is governed by the American concrete Institute (318-95) Building Code Requirements for structural concrete. As with prestressed concrete members in general, hollow core slabs are checked for prestress transfer stresses, handling stresses, service load stresses, deflections and design (ultimate) strength in shear and bending.

C. Camber and Deflection

Camber [2] is the upward deflection of a prestressed member and results from the prestressing force being eccentric from the centre of gravity of the cross-section. Since both prestressing force and eccentricity are established by the required design load and span length, camber is a result of the design rather than a design parameter. Deflections are also affected by the amount of prestressing only because prestressing establishes the load at which a member will crack.

Net camber can be calculated as:

$$\text{Camber} = \frac{Pe\ell^2}{8EI} - \frac{5w\ell^4}{384EI}$$

where,

P = Effective force in prestressing steel after all losses (KN)

e = Distance from neutral axis to centroid of prestressed reinforcement (m)

ℓ = Span length (m)

w = Uniformly distributed load (KN/m)

I = Cross-sectional moment of inertia (mm⁴)

E = Modulus of elasticity of concrete (N/mm²)

Precast/Prestressed Concrete Institute (PCI) deals with Hollow core slab as simply supported beam:-

Therefore,

$$\text{Max deflection} = \frac{5w\ell^4}{384EI} = 0.01302 \frac{w\ell^4}{EI}$$

$$\text{Max moment} = \frac{w\ell^2}{8} = 0.125w\ell^2, \quad \text{Max shear} = \frac{w\ell}{2} = 0.5w\ell$$

IV. MANUFACTURE, TRANSPORTATION AND ERECTION PROCEDURE

A. Manufacture/Production cycle

1. Cleaning and oiling of the bed
2. Strand pulling and tensioning of strands

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3. Lifting the extruder on the bed
4. Concrete mixing and transportation
5. Concrete dosing to extruder
6. Extruding
7. Making openings
8. Covering and curing of slab
9. Cutting of slab
10. Drilling of drainage holes
11. Transportation to storage
12. Handling of slabs in storage
13. Transportation to site.

B. Transportation of Hollow Core Slabs to site

Transportation of precast elements should be planned according to the general erection sequence to minimize unnecessary site storage and handling. Where possible it is desirable to transport the precast elements in a manner which they can be lifted directly for erection or storage without much change in orientation and sequence.

C. Storage and erection of Hollow Core Slabs

The storage area provided in the yard and job site should be adequate to permit easy access and handling of the precast elements. Appropriate stacking method should be used to store the precast concrete elements to prevent any undue stresses and damages. Horizontal precast concrete elements can be stacked and supported separately using strips of woods or battens across the full width of the designated bearing points. Precast walls and facade panels are usually stored in vertical position supporting their own weight using racks with stabilizing wall.

An installation plan shall be prepared well in advance and agree on the order of the delivery of the slabs. Select a lifting device that is suitable for the site conditions and the weight of the hollow core slabs. Compare each slab with the plan. Inspect the slab levels in the level drawings, the supports for the installation phase, the lifting necks, the number of strands, the location of deep-plugs and the slippage of the strand. Mark the location of the slabs and set installation shims or a neoprene bearing strip in place. Inspect the length of the bearing surface, level and location of the installation shims at the web of the slab. Assemble the temporary supports for the work phase according to the plan, prior to the installation of the slabs. The hollow core slabs are installed by using a spreader beam and lifting clamps. A slab that is shorter than three meters can be lifted with long lifting chains without a spreader beam. The angle between the legs of the lifting chains must be less than 60 degrees. Level out differences in the slab camber according to the plan, by using supports, adjuster bolts or installation shims. Reinforce the joints and install an electrical conduit according to the plan. Carry out the joint grouting and seal it. Carry out protection and curing according to the conditions. Inspect and open drainage holes after joint grouting. The following are the Advantages & Disadvantages[1]

Advantages

- Factory cast in controlled conditions
- High strength compared to conventional reinforced concrete
- Durable - crack free
- High load capacity
- Long spans
- Minimum formwork/props
- Immediate and solid work deck after grouting
- All weather construction
- Delivered for immediate erection on site
- Excellent fire resistance with ratings up to 3 hours

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- Prefinished ceilings
- Superior sound and thermal insulation factor
- Efficient lightweight cross-sections
- Extremely cost-effective
- Can apply floor coverings with minimal preparation
- Low maintenance-resists moisture and humidity
- Reduced on-site labour
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Disadvantages

- Does not incorporate well into a timber framed house.
- Only small openings can be made (10 inches or less) in the hollow core slabs at erection sites. All other openings must be shown on the approved shop drawings and cut at the factory.
- Limited building design flexibility.

Alternate Applications

Ware house walls

Some hollow core slab systems can also provide slabs to be used as walls. The hollow core wall panels are prestressed with two layers of strands for accommodating handling, structural loadings and bowing considerations. A variety of architectural finishes are available with hollow core wall panels.

Security Walls

Hollow core slabs can be used as security wall panels. Speed of erection and strength are two of the major advantages to take into consideration for this type of walls.

Retaining Walls

When used as retaining walls, the panels are generally two storeys high (6-7m) and 250mm deep.

Unlike floor slabs, which are cast with prestressed steel cables at the bottom to form a positive camber, wall panels must be straight as possible and are therefore cast with cables at both the top and bottom of the slab, and then evenly stressed. Wall panels are delivered on site with ready-made holes to facilitate lifting into position.

V. CONCLUSION

Designing for sustainable development not only involves using recyclable building materials and reducing energy consumption while building, but it also implies better use of available building materials, production systems with less environmental burden, products with higher performances, design systems in line with new demands for flexibility and adaptability to future needs. Hollow core slabs enable a very efficient industrialized production. By ensuring that the slabs are produced under a strict quality assurance program and that these are safely transported, erected on site and that proper detailing is ensured, a semi-monolithic structure is achieved with improved performance of the structural system with respect to fire resistance, safety against progressive collapse and transfer of horizontal loads. Hollow core slabs are used for a variety of applications in low and high-rise commercial residential and industrial buildings. It provides an answer to most of the present market demands and challenges for the building industry: structural efficiency, low material consumption, highly automated and environment friendly production process, high concrete strength, slender floor thickness, and possibilities for reuse and recycling at the end of the life cycle.

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REFERENCES

1. Stephen C. Hollow core manufacture and factory design. *The Indian Concrete Journal* 2013; 20--25.
2. Pintea A. Shear capacity of Prestressed – Prefabricated Hollow core slabs without shear reinforcement *Journal of applied Engineering Sciences* 2012; 2(1): 83-88.
3. Fallon E. The Design of Hollow core Slabs. *Computing in Civil and Building Engineering* 2000; 465--471
4. Yang L. Design of prestressed hollow core slabs with reference to web shear failure. *Journal of Structural Engineering* 199; 120(9): 2675-2696
5. Donald R, Roger J. PCI Manual for the design of Hollow core slab. 1998; Second edition, UK.