

# Technical and economic analysis of hollow (thin wall corrugated pipe) beamless floor in underground garage

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**Abstract:** as a new type of construction technology, hollow floor without beam has been widely used in constructions. This paper studied economic efficiency of selecting hollow (thin-walled corrugated pipe) beamless floor structure system, common beam slab structure system and beamless floor structure for the roof of underground garage. Through the comparative analysis, the following conclusions are obtained: If thin wall corrugated pipe hollow beamless floor technology is used in the construction of underground garage roof, the use of construction materials and the direct cost of the project can will be greatly reduced.

## 1. Introduction

With the concentration of urban population and the increase of car ownership, it is imperative to develop and utilize the underground space as the underground garage. There are many factors that determine the construction cost of the underground garage, such as the number of floors of the underground garage, the layout form of the column network, the construction method and so on. Choosing the appropriate structure type is very helpful to reduce the construction cost of underground garage. The roof structure of underground garage usually includes Main and secondary beam floor, beam free floor, etc. This paper analyzes the economic indexes of a new type of hollow slab without beam (using thin-wall corrugated pipe) and traditional floor under the condition of proper column grid arrangement, hoping that the conclusions can be helpful for the selection of roof structure of underground garage.

## 2. Introduction to the technology of thin wall corrugated pipe hollow beamless floor

The cast-in-place concrete beamless hollow floor is composed of solid flat beam, hollow slab belt and side beam. The structure of hollow slab belt is composed of top plate, bottom plate and middle rib beam. In order to produce regular cavities, it is necessary to embed the inner membrane before pouring concrete. The inner membrane can be regular such as hollow cylinder core and cube hollow box. There are some problems in the inner hollow cylinder core, such as the poor internal fixation of the board, the insufficient grip between the outer wall of the core and the cast-in-place concrete, and so on.

Thin wall corrugated pipe is a new type of inner membrane produced by special production equipment with thin steel strip. The outer surface of the inner membrane of the thin wall corrugated pipe has obvious concave convex double waves. The joint of the steel pipe is treated as a tight embossing type, which makes it firm without tripping. It has the characteristics of light weight ( $< 4\text{kg} / \text{M}$ ), uniform material, many pipe diameter models (150 mm ~ 450 mm), convenient construction, vibration without breaking the wall, pouring without floating, etc. After pouring, it has a strong grip with the concrete and can form a complete integration with the concrete. If there is crack in concrete, corrugated pipe provides compressive strength when



pouring concrete. The rib will be stretched and flattened while other parts of concrete. Corrugated pipe are still in the state of engagement, which limits the repair of concrete cracks in local areas. At the same time, the integrity of the cavity is convenient for later repair, and a new solution is put forward for various problems of the hollow floor.

### 3. Technical and economic analysis of thin wall corrugated pipe hollow beamless floor

Combined with the actual engineering case, the paper compares the thin wall corrugated pipe hollow beamless floor with other common floor structure schemes, and obtains the economic performance of the thin wall corrugated pipe hollow beamless floor.

#### 3.1 Technical and economic comparison between thin wall corrugated pipe hollow beamless floor and traditional main and secondary beam floor

The roof of an underground garage has a structural area of 5618m<sup>2</sup>, a single layer, a covering thickness of 1.5m, a column net of 8.0m × 8.0m, a concrete strength grade of C35, and three grade steel bars. Traditional beam floor structure scheme: slab thickness of 200mm, main beam of 450 × 900mm, secondary beam of 350 × 750mm; thin wall corrugated pipe hollow beamless floor scheme: slab thickness of 400mm, concealed beam width of 800mm, thin-wall corrugated pipe core-mold diameter of 230mm. The economic indexes of the thin-walled corrugated pipe hollow beamless floor and the traditional primary and secondary beam floor are obtained through the calculation of engineering quantity and quota (Table 1).

Table 1. index of hollow floor and Main and secondary beam floor

Roof of underground garage			Floor area (m <sup>2</sup> )	5618
	Main and secondary beam floor		Thin wall corrugated pipe hollow beamless floor	
Beam-slab rebar	Index kg/m <sup>2</sup>	63.13	Index kg/m <sup>2</sup>	54.14
	Quantities kg	354641	Quantities kg	304164
Beam-slab concrete	Index m <sup>3</sup> /m <sup>2</sup>	0.34	Index m <sup>3</sup> /m <sup>2</sup>	0.29
	Quantities m <sup>3</sup>	1909.44	Quantities m <sup>3</sup>	1628.64
Beam-slab scaffolding formwork	Index m <sup>2</sup> /m <sup>2</sup>	1.699	Index m <sup>2</sup> /m <sup>2</sup>	1
	Quantities m <sup>2</sup>	9547.20	Quantities m <sup>2</sup>	5618
Ceiling decoration	Index m <sup>2</sup> /m <sup>2</sup>	1.7	Index m <sup>2</sup> /m <sup>2</sup>	1
	Quantities m <sup>2</sup>	9550.6	Quantities m <sup>2</sup>	5618
Core formwork	Index m <sup>3</sup> /m <sup>2</sup>	—	Index m <sup>3</sup> /m <sup>2</sup>	0.11
	Quantities m <sup>3</sup>	—	Quantities m <sup>3</sup>	618.56
Artificial labor day	Working days (working days)	6891	Working days (working days)	5719
Total& comparison	Cost (CNY)	3876715.03	Cost (CNY)	3386084.40
	Unit cost (CNY/m <sup>2</sup> )	690.05	Unit cost (CNY/m <sup>2</sup> )	602.72
	The cost of hollow beamless floor is higher than that of primary and secondary beam floor			12.65%
Artificial labor day	The number of man days of hollow floor without beam is less than Main and secondary beam floor			17%

Construction progress	The progress of hollow floor without beam is faster than Main and secondary beam floor	17%
Reduced storey height	Storey height reduced by about 50cm for every layer. Considering the reduction of floor height, the comprehensive cost can be saved by CNY18 / m <sup>2</sup> for each 10 cm of storey height reduction	3.6%

Note: the unit price of materials is based on the market information price of Nanchang City in February 2019, and the consumption is based on the consumption quota of 2017 version of Jiangxi Province.

Through the comparison and budget cost analysis between the thin-wall corrugated pipe hollow beamless floor and the main and secondary beam floor, the advantages of the thin-wall corrugated pipe hollow beamless floor technology in the comprehensive economic benefits are obvious. For the underground garage with the thin-wall corrugated pipe hollow beamless floor, the comprehensive cost of the project is more than 15% lower than that with the main and secondary beam floor structure.

(1) The consumption of steel and concrete is greatly reduced. The steel content of hollow floor without beam is 54.14kg/m<sup>2</sup>, which is 14.24% lower than the main and secondary beam floor, and the consumption of concrete is 0.29m<sup>3</sup>/m<sup>2</sup>, which is 14.71% lower than the main and secondary beam floor. The use of thin-walled bellows hollow beamless floor saves a lot of building materials.

(2) The storey height is reduced. The thickness of the hollow floor slab is 400mm, and the height of the highest beam of the main and secondary beam floor is 900mm. The height of the lowest beam is 750mm. The storey height of the hollow floor slab can be reduced by 500mm compared with the main and secondary beam floor under the requirement of clearance. Thus, the excavation depth of the foundation pit is reduced, the earthwork volume is reduced, and the support cost of the foundation pit can also be reduced.

(3) The bottom of the thin-wall corrugated pipe hollow beamless floor is flat without side formwork, which reduces the amount of formwork work, makes it easier to install and dismantle the formwork, reduces the labor cost of sawing the formwork and the loss of the formwork, saves the plastering of the ceiling, facilitates the binding of the floor reinforcement, reduces the construction intensity of the workers, greatly improves the labor efficiency and reduces the construction cost. At the same time, it also facilitates the installation of various pipelines and pipeline equipment, saves the cost of pipeline installation and reduces the cost.

(4) Compared with the main and secondary beam floor, the number of man days of thin-wall corrugated pipe hollow beamless floor is reduced by 17%, which greatly reduces the labor volume, accelerates the construction speed and reduces the construction period, which is very helpful to alleviate the labor shortage.

Combined with the above comprehensive benefits, the scheme of thin-walled corrugated pipe hollow beamless floor has obvious advantages in use function and cost compared with the scheme of ordinary concrete main and secondary beams.

### 3.2 Technical and economic comparison of thin wall corrugated pipe hollow beamless floor and flat slab

The roof of an underground garage has a structural area of 16533m<sup>2</sup>, a single layer, a covering thickness of 1.2m, a column net of 8.4m × 8.4m, a concrete strength grade of C35, and three grade steel bars. The scheme with the flat slab: the slab thickness is 300 mm, the column cap is 3300 × 3300 mm, and the thickness is 800 mm; thin wall corrugated pipe hollow beamless floor scheme: the slab thickness is 450 mm, the concealed beam width is 700 mm, and the core-mold diameter of the thin-wall corrugated pipe is 250 mm. The economic indexes of thin-walled corrugated pipe hollow beamless floor and beamless floor are obtained by calculation of quantities and quota (Table 2).

Table 2. index of hollow floor without beam and floor without beam

Roof of underground garage			Floorarea (m2)	16533
	Flat slab floor		Thin wall corrugated pipe hollow beamless floor	
Beam-slab rebar	Index kg/m2	55.78	Index kg/m2	54.65
	Quantitieskg	922211	Quantities kg	903529
Beam-slab concrete	Index m3/m2	0.355	Index m3/m2	0.292
	Quantities m3	5869.22	Quantities m3	4835.9
Beam-slab scaffolding formwork	Index m2/m2	1.09	Index m2/m2	1
	Quantities m2	18021	Quantities m2	16533
Ceiling decoration	Index m2/m2	1.09	Index m2/m2	1
	Quantities m2	18021	Quantities m2	16533
Core formwork	Index m/m2	—	Index m3/m2	0.1575
	Quantities m2	—	Quantities m3	2604
Artificial labor day	Working days (working days)	14885	Working days (working days)	17791
Total& comparison	Cost (CNY)	9786129.21	Cost (CNY)	10413240.85
	Unit cost (CNY/m <sup>2</sup> )	591.91	Unit cost (CNY/m <sup>2</sup> )	629.85
	The cost of hollow beamless floor is higher than that of flat slab floor			6.41%
Artificial labor day	The number of man days of thin wall corrugated pipe hollow floor is more than that of flat slab floor			19.52%
Construction progress	The progress of thin wall corrugated pipe hollow floor without beam is slower than that of flat slab floor			19%
Reduced storey height	Storey height reduced by about 35cm for every layer. Considering the reduction of floor height, the comprehensive cost can be saved by CNY18 / m2 for each 10 cm of storey height reduction			2.5%

Note: the unit price of materials is based on the market information price of Nanchang City in February 2019, and the consumption is based on the consumption quota of 2017 version of Jiangxi Province.

According to the data analysis in the table, the following conclusions are drawn:

(1) There is not much difference between the steel content of thin wall corrugated pipe hollow beamless floor and that of flat slab. The concrete content is 0.292m<sup>3</sup>/m<sup>2</sup>, which is 17.75% lower than that of flat slab, which saves some building materials.

(2) The slab thickness of hollow beamless floor is 450mm, and the slab thickness of column cap and column cap of beamless floor is 800mm. Under the requirement of clearance, the storey height of hollow beamless floor can be 350mm lower than that of flat slab. Thus, the excavation depth of the foundation pit is reduced, the earthwork volume is reduced, and the support cost of the foundation pit is reduced.

(3) No matter the thin wall corrugated pipe hollow beamless floor or the flat slab, the bottom is flat, which is convenient for formwork installation and various pipeline equipment installation.

(4) The core-mold is needed to be installed in the thin-walled corrugated pipe hollow beamless

floor, so the number of working days of thin-walled corrugated pipe hollow beamless floor increased by 19.52% compared with that of the flat slab.

From the perspective of floor cost, the thin-walled corrugated hollow beamless floor has no advantage over the flat slab, and the cost is slightly higher than the flat slab. However, the height of the underground garage using the hollow floor without beam is 35 mm lower than that of flat slab, and the self weight is lighter than that of the flat slab, and the comprehensive cost can be reduced by 2.5%.

#### **4. Conclusions and suggestions**

Using the thin-wall corrugated pipe hollow beamless floor as the roof structure of the underground garage can reduce the height of the structure, increase the clear height, reduce the earth excavation and the cost of slope support, and save the building materials. It has certain economic and functional advantages. In particular, it has obvious advantages over the main and secondary beam floor. It can be vigorously promoted and applied.

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