NEW TRENDS IN THE TECHNOLOGICAL DEVELOPMENT OF TAIWAN'S CONSTRUCTION INDUSTRY

Samuel Yen-Liang Yin
Honorary president, International Academy of Engineering (IAE),
Founder, Tang Prize,
Group CEO, Ruentex Group

Abstract: Nowadays, labor market in Taiwan has a structural change due to population aging and low fertility rate, which result in a severe labor shortage in conventional construction industry. Owing to the shortage of labor, construction progresses are usually behind schedule in governmental or private construction works. This is the main problem faced by construction industry in Taiwan. In this way, construction automation and precast concrete construction technology are regarded as alternative solutions to labor shortage. The author has introduced precast technologies from Europe and Japan into Taiwan 20 years ago. Till the present, the precast technologies are well developed to fit in the local conditions, as well as create a lot of innovative technologies and patents. As the innovative technologies focus on automation, labor-saving, and acceleration, the labor shortage can be properly overcome in construction industry. Among the technologies, two representative technologies, multi-spiral shear reinforcement and precast waffle slabs, are illustrated in this paper with their technical contents and implemental effectiveness.

1. Background

The precast technologies have been introduced to Taiwan several decades ago. At that time, the technologies are based on foreign geographical and climatic conditions, which could not be applied to all Taiwan construction works. After making great effort to research and improve the technologies, they have been adjusted to fit in Taiwan's constructing conditions. Besides, hundreds of technologies have been obtained patent rights in Taiwan, including precast constructing method, rebar processing, vibration isolation and so on. These innovative technologies are widely used in Taiwan's residential buildings and high-tech factories, and have also been exported to Singapore and Mainland China.

Taiwan is an important town in the global semiconductor industry. In order to increase the global competitiveness, owners of high-tech industry have to expand factories continuously, so that they can keep the leading position around the world. Generally, owners take quality, cost and construction period into account when building factories. Under the same conditions, owners tend to spend more cost to shorten the construction period, which is influenced a lot by labor shortage. However, the precast construction methods allow the labor resources of the industry to be leveled, and most construction works can be performed smoothly.

In addition, as global house prices keep increasing, young generation suffers a great pressure from buying houses. In order to guarantee of residency, the government starts to build numerous council houses. With high expectation by the people, the government must speed up to build the houses as soon as possible. Consequently, labor shortage causes the delay of construction works since the government cannot burden worker's salaries within the present budget. As labor shortage becomes a critical problem, the government works hard on finding solutions.

Multi-spiral shear reinforcement and precast waffle slab are important invention patents owned by the author, which are also the technical indicators of construction automation and precast methods. Both technologies have been widely used in construction works. The successful applied experiences of the technologies in Taiwan are shared in the following paragraphs for the businesses to review.

2. Multi-spiral shear reinforcement

The innovative concept of applying the multi-spiral shear reinforcement (5-spirals) in rectangular columns was developed in 2003 by Dr. Y. L. Yin[1], president of Ruentex Group, thus also called "Yin's spirals." This technology has obtained invention patents in seven countries. Up to the present, it has been widely used in precast engineering and is regarded as an important indicator for construction automation. Instead of traditionally designing circular hoops for circular columns and rectilinear stirrups for rectangular columns, the multi-spiral reinforcement adopts interlocking circular spirals with difference size to fit the cross-section of rectangular columns (Figure 1). Unlike the confinement effectiveness of rectilinear stirrups are decreasing with spalling of concrete cover, the circular spirals could provide stable lateral confined force until fracture of the spiral steel and consequently reduce the amount of transverse reinforcement by up to 50%.

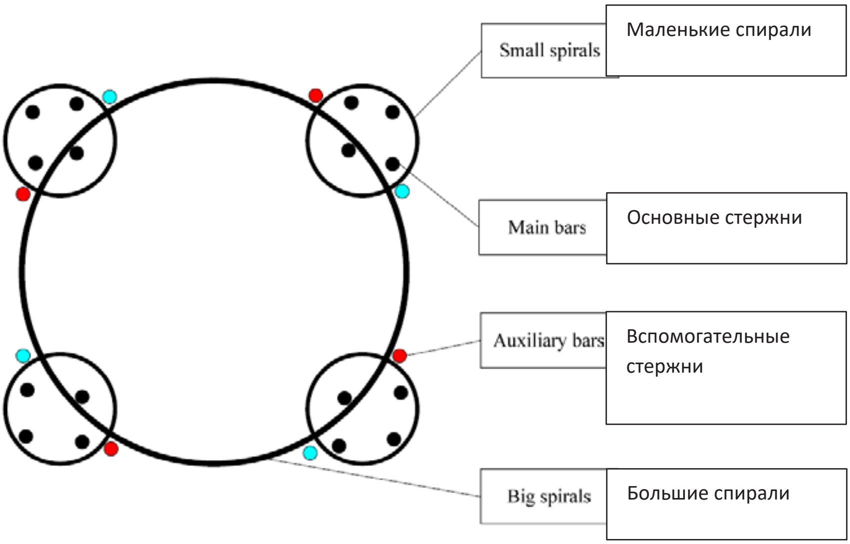


Figure 1. *Reinforcement cage with Multi-spiral stirrups*

The multi-spiral concrete columns which were well confined by continuous spirals exhibit excellent behaviors including axial compressive strength, axial ductility and seismic performance. After a series of full-scale seismic experimental studies[2, 3, 4], it were proven that the lateral drift ratio of multi-spiral columns can reach 8%, greatly increasing ability to withstand lateral deformation by up to 60%.

Assembly of the multi-spiral

Some auxiliary frames are necessary for assembling the multi-spirals. There are 3 major objectives for designing the frames, namely “spacing control”, “straightness control” and “support”. The spacing control mainly provides for the pitch of spirals according to the design value and the basic mold is referred as “CD frame” that can be wood, steel pipe, iron bar or concrete stick depending on the manufacturing environment and convenience. Basically, the maximum pitch between common spirals is 75mm and the mold design is based on the requirement in the structural design drawing. The CD frame must be secured on the mold or support to ensure accurate control of spiral pitch. The straightness control of the spirals is significant since it can improve the efficiency of the main bars passing behind, as well as preventing “tangling” between the main bars and the spirals. In addition, the quality of the reinforcement cage can also be enhanced. The support is mainly a consideration of saving labor’s effort, since the CD frame of small spirals must be supported via frames in the front and the back to save the operator’s power. Figure 2 shows the procedure for assembling the multi-spiral cages.

(a) Position of the spirals.

(b) Adjustment of the spirals

(c) Assembly of the spirals.

(d) Use templates at both ends of the cages to position the main bars.

Figure 2. *Assembling sequence of Multi-Spiral stirrups*

3. Precast waffle slabs for hi-tech plants

Some of the hi-tech plants require the use of slabs with thickness between 30~115cm to minimize the ambient vibration during the chip manufacturing process. Ambient vibration could have great influence on the "chip yield". In addition, the slabs need to have openings to allow for the circulation of the air. This type of slab is called "waffle slab."[5] Waffle slabs consist of equally spaced two-way stiffening ribs and numerous primary holes for air circulation or other mechanical needs are one of the bottlenecks for constructing a hi-tech factory. Instead of the cast-in-situ waffle slab construction, an entire full/partial precast waffle slab system was developed by Ruentex Group, including prefabrication method for reinforced cage, precast mold system, construction methods by overhead crane or by a rail vehicle running under the constructing level.

Production of reinforcement cage

The following steps detail the procedure for assembling the reinforcement cages for precast waffle slabs in the factories (Figure 3).

1. Fabrication of reinforcement and hoops
2. Assembly and placement of reinforcement along X-axis
3. Assembly and placement of reinforcement along Y-axis
4. Tying reinforcement cage
5. Assembly completed

(a) Assembly of reinforcement of waffle slabs for one direction

(b) Assembly of reinforcement of waffle slabs for another direction

(c) Assembly completed

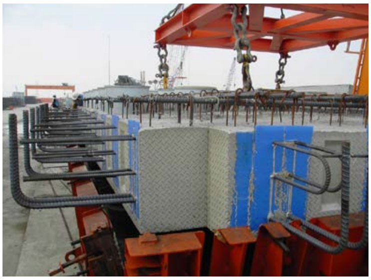
Figure 3. *Assembling procedure of reinforcement cages for precast waffle slabs*

Production of the precast waffle slabs

Steel formworks are advantaged for accuracy control of precast waffle slabs. Relevant dimensions of the formworks and accessories must be checked for compliance with the contract, and followed by positioning and leveling the bottom bed. The allowable tolerance of flatness for the mold bottom is 0.5mm. After finishing the inspection of the formwork, the reinforcement cage is moved and located within the mold (Figure 4). The reinforcement cage is tied up before placing the concrete. Steam curing can be used for accelerating the strength development of concrete. Generally the completed slabs are able to be moved to the storage yard after 8-hour curing.

(a) Location of the reinforcement cage

(b) Steam curing of the waffle slabs



(c) Removal of the waffle slabs

(d) Storage of the waffle slabs

Figure 4. *Production of the precast waffle slabs*

Semi-precast waffle slabs

1. Installation of overhead cranes and job site facilities.
2. Survey of the column positions to ensure that they are located within the design tolerances.
3. Fabrication of the bottom rebars and the shear reinforcement for girders.
4. Hoist and alignment of the precast waffle slabs.
5. Placement of concrete. For semi-precast slabs, the precast elements are monolithic with the cast-in-place girders and upper slab. For full precast slabs, the slabs are joined with the cast-in-place girders.

Example steps for constructing the half and full precast waffle slabs are as follows (Figure 5).

(a) Fabrication of reinforcement for girders.

(b) Hoist the precast waffle slabs by overhead cranes

(c) Position the semi-precast slabs

(d) Position the full precast slabs

Figure 5. *Example steps for constructing the precast waffle slabs*

The benefit evaluation of the precast waffle slab is organized and summarized in the below table.

	Fully precast waffle slab	Semi-precast waffle slab	Traditional cast-in-place construction
Construction time (speed)	3 spans / 2 days	1 span / day	0.5 span / day
Security cost	20%	20%	100% (massive debris)
Manpower requirement	17 workers/day	30 workers/day	105 workers/day
Reinforcement consumption	Lowest	Low	High
Unit rate	9(slabs/day)×30(m^2/slab) /17 workers	6(slabs/day) ×30(m^2/slab)/30 workers	3(slabs/day)*30(m^2/slab)/105 workers

4. Conclusions

this paper introduces two innovative technologies with the feature of labor-saving. By commonly applying these technologies to construction works in Taiwan, not only labor shortage can be released, but also the industry structure is changed. The construction industry in Taiwan enters a new generation with automation, labor-saving, and acceleration.

References

1. Ping-Hsiung Wang, "A study on new type of rectangular concrete column confinement", Master thesis instructed by Professor Cheng-Kuo Chang, Department of Civil Engineering, National Taiwan University, June 2004.
2. Yan-Liang Yin, "Multi-Spiral stirrups" with Taiwan patent no. M241456
3. Yan-Liang Yin, Cheng-Chiang Wong, Jui-Chen Wang, Ching-Yu Liang and Chun-Ming Huang (April 2006), "Test and development for application of 5-spirals on rectangular SRC columns", Chinese Society of Structural Engineering (CSSE), Journal of structural engineering.
4. Cheng-Kuo Chang, Jui-Chen Wang and Ping-Hsiung Wang, "A study of test on confining behavior from one-bar hoop and wire mesh hoop", Research report from Taiwan Construction Research Institute, 2003.
5. Yin, S. Y. L., Lai, S. H., Kuo, C. C., Wang, J. C. (2004). "New generation of construction method for hi-tech plants." Conference on cross-strait collaboration in civil engineering.