Prefabrication and Automation in Concrete Building Construction

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Purpose One of the most urgent issues faced by human being nowadays is the gradually decreased space for living. Especially the growing number of people on one hand creates the demand for higher quality house, on the other hand the decline trend of workers drive up a sore need of highly advanced methodology in building technology. Concrete building as a main form of houses in some densely populated developing country such as china calls for a fundamental reformation for both the ideology and technology in this field. **Method** 1.The paper will sum up and analyze the most advanced automation technologies for both the production and information management of concrete prefabrication.2. Solutions will be provided to overcome the shortage of labor, because of the demographic change.3.To find ways of solving the house shortage issue especially in developing country by means of an advanced building technology. It is defined as the technology that increases production efficiency when compares to the traditional concrete house building technology.4.To find methodology of making the concrete house supply chain more efficient.5.Comparison will be made in the level of automation development for industries between automobile, consuming goods and house nowadays. Tendency of the building automation in house will analyze in article. 6. Introduce a prototype by means of using DLR LRW III robot in realizing on site building automation (Fig1 is the photo took by author in his DLR human friendly robot application in building bricks, type of robot in use: DLR LWR lightweight robot). **Results & Discussion** By enumerating and analyzing the most advanced automation technologies and creating a prototype, the author demonstrates the technologies in concrete house production and on site building. Currently, because of a high labor cost in developed country is existed ahead of developing country, many experiences of construction automation can be learnt by developing country which the issue of high cost labor is gradually appearing. However, the ideologies introduced could increase the productivity and quality of house building in the developing country in the future. In the context of demographic change, automation and information technologies will no doubt facilitate to drive up the whole standard of construction industry nowadays after the main technological hurdles are conquered.

***Keywords**: Precast concrete, Automation, BIM, Standardization, Human friendly robot,*

INTRODUCTION

The advantage of automation technology in using construction industry reflects in the making prefabrication in a short period of time. A standardized prefabricated product can be defined as a product with discrete solid parts. In this paper, analyses will make on the topics of off-site precast concrete production, standardization, the impaction on construction industry caused by demographic change, a human friendly robot application on precast concrete manufacture and onsite assembling. Moreover, precast concrete industry is not only entwined with the use of highly advanced equipment, but handing down from the essence of history and culture.

METHOD

Precast concrete technology past and present

Ancient romans are documented as the first user of precast technology. They considered concrete as a sustainable material to carry out their infrastructure plan. In last century, precast construction is quite popular in the republic of the former Soviet Union and Eastern European country. Afterwards, this style of building became welcoming by some Communist countries as well. By seeing the history of precast concrete, precast supplier plays a crucial role in prefabrication concrete building industry. Nowadays, besides a widely application in civil engineering, precast concrete is also a good solution for building high quality Residential construction. The demand of diversity of house hastens the development of advanced production system for precast concrete. Both the reasonable designing of factory layout and the robotized equipment supported a high productivity and the possibility of producing diverse elements. Concrete precast supplier plays a crucial role in prefabrication concrete building industry.

Fig.1. Evolution of precast concrete

Pallet Circle

"The skill is built into the tool" is one of the descriptions of mass production. The tool in assembly line plays a crucial role in precast production as well. A faster production is always containing state of the art ideologies in mind. This pallet circulation system can be regarded as the most advanced production system of precast concrete. All the automatic equipment concentrate on providing services for "Pallet" which is the standardized mould made for precast concrete. Most equipment in this circulation system can be defined as robotized manipulator which means that they are highly automated and can be operated in autonomy. Five tasks in the flow are corresponding to cleaning robot, formwork robot, bar feeding robot, concrete spreading machine and automatic storage machine respectively. Meanwhile, a lean manufacture site presents that a new building information management facilitates a high efficiency of production. So as to increase the turning over rate, BIM (Building information modeling) is a potential method to work hand in hand with highly automated equipment. Nowadays, the diversity of precast is constrained by the size and shape of the pallet itself. It seems less room for the application of BIM in off-site side. However, the tendency of diversity augmentation will doubtless lead a wider and more organic application of BIM. Vice versa, the process of manufacture will be optimized by using BIM as well. Factory as the incubator of precast is the start point of the whole precast building lifecycle. It should be a most important link of the building process.

Fig.2. Producing loop of precast concrete

Pallet circulation system

Despite the less steps of producing a final product when compares to produce an Auto, the variety of precast concrete products makes the design of flow and factory layout the critical factor that effects on the efficiency. The experiences such as the moving and continuous assembly line, learnt from auto industry, consist and complete interchangeability of parts, the designing simplicity of factory layout makes the manufacture innovation on precast concrete assembly line possible. Pallet circulation system requires a highly efficient supply chain as well, because of the different kinds of material and processing time demanded by the final products. Moreover, tasks in pallet circulation system are mostly finished by automated machine and robot. Human errors are largely avoided.

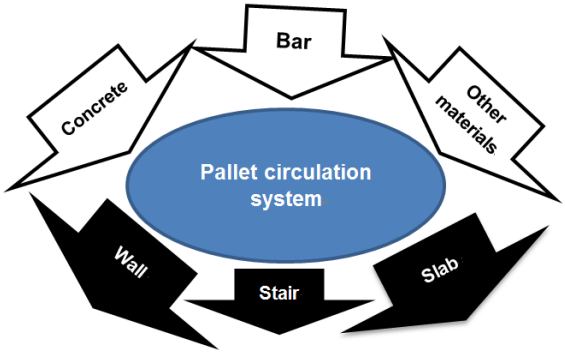

Fig.3. Core role of pallet circulation system

Lean production principle raised by Toyota is another thing can be learnt by precast concrete industry. Two pillar concepts, JIT (Just in time) and smart automation can fully apply on pallet circulation system which brings the zero waste, the highest quality and the efficiency.

A new prototype of accessory placing robot and onsite building robot

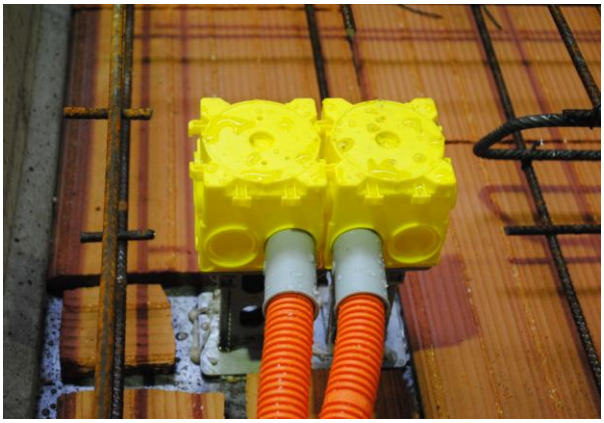

Fig.4. Accessories placed on pallet

Besides the formwork shuttering, accessories such as socket, pipe which are light weighted are installed manually, the workers pre-knew the types of accessories from job card. This process is the bottleneck of the whole flow. Man made mistakes are easy to happen in the step. Inaccuracy will bring about connection failure between the precast elements in the later stage. A human friendly robot called LRW III robot invented by DLR (German Aerospace center) can play the role to assist the worker to finish this task quickly, or finish this step itself. Safety is con-

sidered as a top priority in precast concrete producing site, the human friendly robot is designed under this principle. The flexible joint will not cause a violent contact when it has a collision with human who are working around. And this collision detection effects when the gripped accessories reach the final goal position as well. In prototype, the robot works with vision system, to select the accessories from warehouse, and then find the right way to grip them. By a 7 degree of freedom manipulator, end effector can reach the goal position easily. The module design of this robot (module joint, module link) makes the user easy to build their robot with special aims. For instance, in the case of precast concrete, more joints and longer links are needed for reaching a wider workspace. The blocks in below picture represent accessories, bricks or other material, tools with various shapes. Robot is able to recognize them by the assistant of vision system and find the goal position on pallet or final precast concrete without failure.

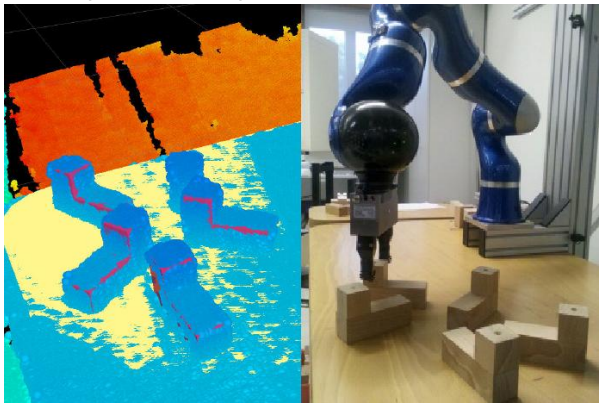

Fig.5. Prototype of DLR LRWIII human friendly robot in the application of building technology
Left side: The point cloud graphic simulated by vision system.
Right side: End effector grips one of the blocks

When flexible joint robot works on site, it is endowed with more ability to help the precast builder to finish the tasks, such as welding connection, inspecting gap, handling heavy stuffs and so on. Nowadays, this type of robot will firstly apply in car industry to help worker for screwing. It can not only operate as a stationary one like in Fig, but a movable model when sitting on a mobile chassis. To be sure, the prospective application on construction industry will have a larger potential in off site, on site as well.

Labor shortage raised by demographic change in developing country

Demographic change is a global issue. The shrinking proportion of young people leads to a labor shortage which is more apparent in construction industry. In this paper, take the situation in China for instance to research on. Construction industry in China has long since been regarded as a labor intensive industry. However, because of one child policy and the end of baby boom generation, in according to the statistic data from United nation's world population prospects, after 2016, the amount of working population will have a downside. In the year of 2050, the workers who are with the physical condition for the constructing job will go down to an even less level. (Fig.6)

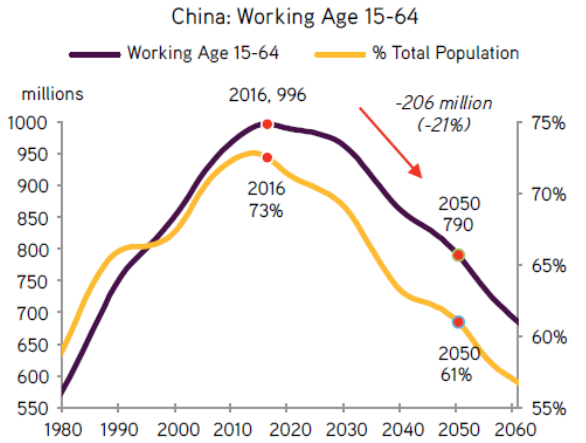

Fig.6. Data as at May11, 2011 Source: United Nations World Population Prospects for the people within working age in China

Nowadays, construction workers who are familiar with traditional manual building technology in China are uneasy to find the successor to inherit the skill. There are two reasons for this. On one hand, manual working on concrete construction building is in the tendency of dying out. On the other hand, there are very few of younger who are able to bear the suffering of traditional concrete building site. Based on macro reason from statistics and status analysis, precast and automatic, robotic machine being applied are two necessary way of solving both issues of improving the quality of concrete building and labor shortage in construction industry. After the cast-in-situ being gradually replaced by precast concrete in the big consuming nation of concrete building such as China, the pallet circulation system as a mature technology in developed country such as Germany will have great market potential. Advanced building technology means not only the automatic machine being used but a scientific mass production methodology. The re-planning of the resource distribution and re-scheduling of the process are assisted by software such as BIM. Besides the building information, manpower resources should be considered in schedule as well. Analysis for proportion of using manpower and machines will assist the decision maker to balance the rate of progress and cost control. Over time, a database built on empirical data will make suggestions on whole supply chain so as to optimize the whole lifecycle of concrete building. All in all, demographic change should be seen as a positive factor to push the industrial transformation from the long term point of view.

By the Standardization of construction process and precast elements to resolve the house shortage issue

The high price caused by malignant real estate speculation that gives rise to a man-made house shortage. Besides this improper reason, a natural fundamental human necessity is to have a roof over their heads. How to make this roof reliable and of a reasonable price is the dream of everyone. When it comes to concrete made house, standard deficiency is the question of questions needed to solve. It is interesting to note that the standard was quite developed during the ancient time of both the east and west. Both in ancient Rome and ancient China, the concept of modules (Latin: Modulus) is that use a unit to scale a building component. In Song dynasty of ancient China, Ying zao Fa shi (Treatise on architectural methods of state building standards) is a technical treatise on architecture and craftsmanship. In Qing dynasty, the engineer practices are summed as examples to refer the standardized engineering. The standard was made all around the delicate wood made house. Fig 7 is the evolution of the order structure in wood construction, mostly are for building the temples.

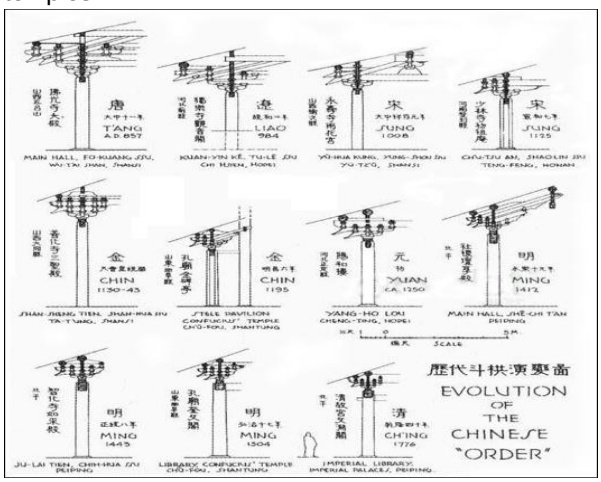

Fig.7. Evolution of the Chinese order, (http://www.ikuku.cn/38971/zhutaoyueduliangsicheng.html)

In Fig 8, Romans standardized the ancient Greek columns, which enriched and normalized architecture style.

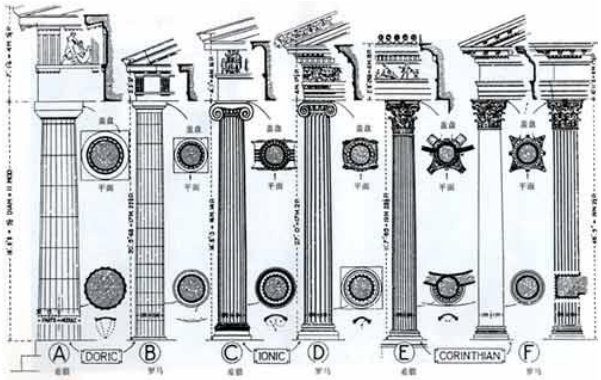

Fig.8. A standardized ancient Greek columns

(http://leizi-stons.blog.sohu.com/46659594.html)

When it comes to concrete precast researched nowadays, the architecture form takes place a great change. The demand of consumer urges more innovative reform on construction field. First issue of precast modularization is considered on the confliction against to the individuation. Take the car industry for instance, Alfred Sloan (General motors) thought to resolve the contradiction between the individuation required by consumers and the need for standardization. He introduced a series of “hang-on features” to provide wider choices for customers without changing the basic mechanical structure. Meanwhile, in architecture, Skeleton and infill system (SI) is a design concept that already executes in Japan residential building that result in a diversity of house without losing standard. In terms of precast concrete manufacture, the characters such as heavy weight, high stiffness make it uneasy to indiscriminately imitate SI. However, it is wise for the standard maker to set the standard flexible enough that in harmony with the house designer and precast concrete supplier. When combined and constrained by equipment, a heuristic loop between the housing developers and precast concrete suppliers will gradually expand the diversity of both the final house and precast elements based on a module standard. Therefore, more choices of equipment and manufacture methods are the vital part of the whole industry.

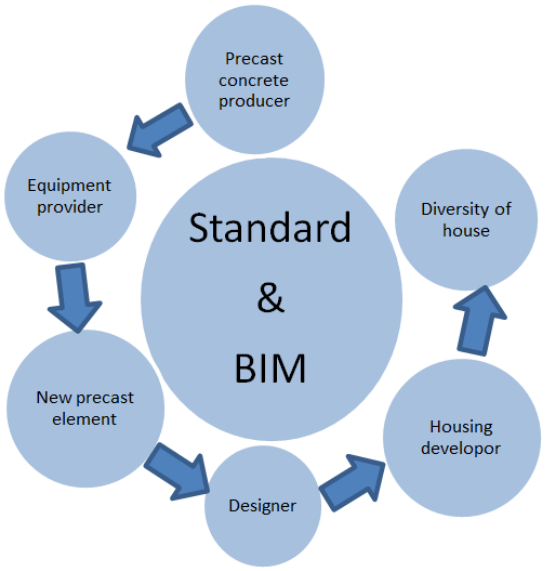

Fig.9. Enrich the diversity of house with the help of standards and BIM. The chain starts from precast concrete producer and ends in the diversity of house.

CONCLUSION

Construction industry is entwined with information and automation technology when it should gear to a sustainable development. Ever-accelerated updating of precast concrete equipment provides a wider choice of products for housing developer.

Meanwhile, this process poses major technological hurdles on supplier due to the standard deficiency. Prefabrication is not a new concept. Many experiences can learn from the history of architecture. However, a new shift in the concept of information exchange will make the builder and producer to coexist well and to supplement each other. To conclude, in the case of concrete building construction, prefabrication and automation will dominate his future.

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