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Analysis of Automated Advance Construction Methods over Conventional Construction Methods

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Abstract—*India is an emerging market with an expanding construction market and huge potential for large scale residential and commercial development (because of population and economical growth). The automated advance construction method playing a significant role in especially for new developing countries, due to shortage of work force (high-wage manpower). The demographic change in education system, the young workers in developed countries are not interested in this industry because of working conditions and their problems like health & safety issues and on-site hazards. All mentioned reasons to necessitate choosing the automated advance construction method to accomplish the demand of construction industry.*

Automated advance construction method (AACM) is the definition of most recent technology and the innovative engineering and management to accelerate the growth of construction industries. The AACM is the combination of robots, machines, ideas and skilled work force etc. AACM create the space and provides the new statures of productivity of construction industry with better life, quality and rapid construction. Some key parameters of AACM are decentralized energy generation, in-situ farming, in-situ resource utilization, life-work integration, rapid construction, Ubiquitous-city design and on site & off site logistics.

East Asia and Asia most of the Countries are adopted this technologies and applied in new construction like Japan, Korea Germany, Brazil, Mexico, China and even India. Japan had develop their own automated construction systems like Shimizu's SMART and ABCS & Big Canopy of Obayashi, robotic trolleys/cranes are used for transportation and positioning of building elements. The aim of the study to explain the new technology, modern construction methods and innovative idea was provide to next level construction and the changes in conventional construction method (CCM).

1. INTRODUCTION

The construction industry worldwide is predicted to have a total growth of 30% from 2010 to 2015, giving it an approximated total value of over $3,000 billion (US) by 2015. Large supplies of manpower are required to achieve this huge growth trend, the majority of which will be mobilized from international sources India is in a veritable boom, forecasting impressive yearly increases of 15.5% from 2013 to 2017. Despite its huge population explosion, these figures define the shortfall in human capital for qualified staff and the need for specialist construction workers within the market [1]. The Indian construction industry, an integral part the economy and a conduit for a substantial part of its development investment, is not only poised for growth on account of industrialization, urbanization, economic development and people's rising expectations for improved quality of living, it is also bracing for modernization that calls for improved productivity and higher competitive edge. Its main challenges are fast growth in response to increasing demand for goods and services; technological upgrading for speed, quality, cost reduction, and substitution of manual labour; modern management practices for greater profitability and a `modern', clean image; and technical skills, financial strength and organizational competence to meet domestic and international competition and capture a part of the international market. The construction industry, steeped in traditional technology and largely informal labour practices, is in a hurry to change both its image and content. The workers in construction industry are vulnerable to the inherent risk to their life and limbs. Construction activities are also characterized by poor training, temporary relationships between the employer and the employee, uncertain working hours, lack of basic amenities, inadequacy of welfare facilities, and casual approach of employers towards the problems of employees. All problems to force for moving the young blood to choosing the option of other industry for his career.

Automated advance construction method is best substitute of the conventional method to ignore their work force problems and upgrading the construction technology with speed (rapid construction), safety, quality, cost reduction and duration of projects. Design of structure is important for proper planning and execution of the project with latest technologies like that automated advance construction methods. Prefabrication method, monolithic fabrication method and cast-in-situ methods are important parameters of this AACM according to

the design of structure. The automation and modern techniques in construction is improving the life of workers, owners and neighbors already in Japan, Korea Germany, Brazil, Mexico, China and even India. The developing countries should follow this kind of industry, but with the appropriate measures to tropicalize the final products, according with characteristics such as weather conditions, natural resources, price, and social needs [2]. This paper aims to explain the journey of construction industry, conventional construction methods to modern and advance automated method with implementation of arising innovations in terms of technology to set new goals of construction industry

2. JOURNEY OF CONSTRUCTION INDUSTRY IN INDIA

Taj Mahal is the greatest example of conventional construction method in our Indian History. The construction began in 1632 and lasted until 1653 that's 22 years! It took 22 years to build and 22,000 workers to build it with using materials from all over India and Asia and over 1,000 elephants were used to transport building materials [3]. After consequently changes in the development the India has been reached in developed countries category. India is creating the emerging market with an expanding construction market and huge potential for large scale residential and commercial development (because of population and economic growth).

Recently few months ago the India used ultrafast technology of construction and achieved the new milestone in construction history. Synergy Thrislington create history and registered in "Limca Book of Records" with complete the 10-floor 'Istacon' sky scraper at Mohali within just 48 hours with the help of Four cranes and 24 engineers, 200 technicians, supervisors and labourers were pressed into service. "We successfully achieved what we dreamt. There was a perception this kind of building was not possible in India, but we proved it wrong," Said Synergy Thrislington CMD Harpal Singh. The technology, first of its kind in the country, is unique in many ways. All the components of the building were manufactured in the factory, pre-fitted with floors and other essentials, including provisions for water supply, wiring, sanitation and air conditioning ducts. This construction mechanism was approved by the Council of Scientific and Industrial Research (CSIR) Delhi and Structural Engineering Research Centre [4]. This technology as it unfolded today has vast potential to totally revolutionize the much-needed infrastructure technology in the country by rapidly speeding up construction of projects.

Fig. 1: The complete construction process photographs of the "10-floor 'Istacon' sky scraper at Mohali within just 48 hours". (Sources; download the picture form http://www.21stcentech.com

3. AACM TAKE OVER THE CCM

Indian construction industry status growing day by day with help of the latest techniques and new design concepts. Numerous companies are part of this growth and someone of these is L& T India, Gammon India etc. All these companies adopt every time advanced technologies to provide the quality projects in easy way with economical cost and lowest time duration. Automated Advanced construction methods are overcome the conventional construction methods and it is prove in project of "Delhi Metro Rail". It is a common project in last 10 to 15 years of duration. All new & latest technology was used in this project according the situation, condition and design. Delhi Metro Rail was a big Project. Now we are focused on little part i.e. Elevated Railway tracks (Flyovers) construction methods.

3.1. Beam Based Flyovers: This is common technology of flyovers and bridges. Different type of beams is placed or casted in between pier to pier span for providing the support and base platform of deck slab and other components of structure. In Metro the prefabricated beams are placed and the deck slabs planks are placed or casted on site in some place as per site project circumstances. The other components fascia and barrier are also prefabricated. The substructure part of this track was fully on site work. This type of elevated tracks was constructed at initial stage or phase-I & II of metro rail projects.

3.2. Segmental Flyover (Bridge): The substructure part of this type elevated track was fully cast in-situ. The superstructure part of this type of techniques was completed by prefabricated segments, fascia and side barriers. In pre-cast bridges, the concrete segment is constructed on the ground, and then transported and hoisted into place. As the new segment is suspended in place by the crane, workers install steel reinforcing that attaches the new segment to preceding segments. Each segment of the bridge designed to accept connections from both preceding and succeeding segments. These bridges are very economical for long spans (over 100 meters), especially when access to the construction site is restricted. They are also chosen for their aesthetic appeal. This type of bridges was constructed in Phase-II and now, presently the construction work is in progress at some places for the Phase-III.

Fig 2. Beam Based flyover (Sources; visit the site and click the photograph)

Fig3.Construction process of segmental bridge.(Sources; visit the site and click the photograph)

3.3. U-shaped full span segmental Bridge: The substructure part construction techniques same as general bridges. The superstructure part is fully pre-casted or prefabricated full span U-shaped segment as shown in fig. the technique was impressive for rapid construction of elevated track or flyover. Each segment of the bridge designed to cover the span of piers in single length. These bridges are very economical, short time duration project, aesthetical good and light weight structure. The technique used in presently running project of violet line extension of the Phase-III.

Fig 4. Under construction U-shaped full span segmental bridge. (Sources; visit the site and click the photograph)

4. VARIETIES OF AACM

Construction methods are continuously improved according to changes of technology and material and latest working processes with new management rules. Latest technologies have been given the new path for construction industry. Developed techniques and their supporting equipment's are strengthening the both segment of construction phase i.e. the Off-site construction and On-site construction. According to NHBC Foundation.

4.1. Off-site construction system: all pre-fabricated and industry products which are prepared for construction the building and structure at site with installation of them. The key parameters of this system are:

- **Volumetric construction** : Three-dimensional units produced in a factory, fully fitted out before being transported to site and stacked onto prepared foundations to form the dwellings
- **Panelized construction systems**: Flat panel units built in a factory and transported to site for assembly into a three-dimensional structure or to fit within an existing structure
  There are many different types of panel, the main types are:
  I. Open panels
  II. Closed panels
  III. Concrete panels
  IV. Composite panels
  V. Structural insulated panels (SIPS)
  VI. Curtain walling
- **Hybrid construction**: Volumetric units integrated with panelized systems
- **Sub-assemblies and components**: Larger components that can be incorporated into either conventionally built or AACM dwellings. Sub-assemblies and components in this category are:
  I. Pre-fabricated foundations
  II. Floor cassettes
  III. Roof cassettes
  IV. Pre-assembled roof structure

V. Pre-fabricated dormers
VI. Wiring looms
VII. Pre-fabricated plumbing
VIII. Timber I beams
IX. Metal web joists

4.2. Site-based construction systems (On-site construction ystem)

Innovative methods of construction used on-site and the use of conventional components in an innovative way. A variety of systems are available which include:

- **Tunnel form in situ concrete**: concrete bays cast between 'L'-shaped steel shutters. The ends of the bays are in-filled with other materials (e.g. masonry, light gauge steel or timber frame panels) to create a habitable space. Insulating formwork: insulation in the form of hollow blocks or sheets used as permanent shuttering for concrete to create the external walls of a dwelling. Very airtight and thermally efficient dwellings are created using this system.
- **Aircrete**: aerated concrete products (thin joint block work or aircrete planks) used to form the major elements (i.e. walls, roof and floors) of a structure.

5. WHY AACM IS PREFERRED OVER CCM

Some of the main advantages of AACM are:

- **Standard Quality**: Improved quality control of components produced under factory controlled conditions.
- **Minimized Services dependencies**: Services (e.g. electrical, plumbing) can be pre-planned and either fully or partly pre-installed for final connection on site.
- **Rapid Construction**: Faster construction times on site.
- Limited Work Forced: Fewer workers required on site and for shorter periods.
- **Optimum Usage of Material**: Less wastage of materials.
- **Eco and Environmental friendly**: Collective importance is being placed on the environmental performance of buildings, not only in use but also during construction, and the environmental authorizations of the materials being used. One aspect of the construction process that is evaluated on conventional sites is the level of wasted material, either through damage or wastefulness. On conventional sites, materials are normally purchased in bulk and contractors are hired to fit them. There is little incentive for the contractor (who is usually on a fixed-price contract) to economies on the use of materials. There are other environmental benefits particularly for manufactured dwellings because much of the work is conducted in a factory; therefore the impact on the local community in terms of noise, dust and traffic movements associated with conventional construction sites is reduced [5].

6. NEW AND ADVANCED TECHNOLOGIES

An advanced technique has been already implemented in other countries like Japan, China, Europe and Germany etc. Japanese construction companies are founders and they are great leader for application and implementation of such advance techniques. Some of Japanese companies are used special designed robots for perform the task like façade installation, painting, concrete of compaction, distribution, leveling and finishing, interior finishing, steel welding and tile setting etc. [6].well established companies of Japan like that Kajima, Takenaka, Fujita, Tokyu Construction and Sekisui,Toyota homes are working in own specialized and designed system for quality, safety and rapid construction with minimum wastage and eco-friendly regulation. BIG CANOPY by Obayashi and AMURAD by Kajima are great examples of Automated advanced construction method and system.

6.1. BIG CANOPY by Obayashi

The system's most characteristic feature is the big canopy itself, which is an all-weather temporary roof structure that is supported on four corner posts and is broad enough to overhang on all four sides the entire building under construction. The canopy is raised as construction of the building moves up. When the building reaches its full height, the canopy is dismantled and its perimeter structure jacked down. The Big-Canopy system uses a combination of precast and in situ concrete with modular subassemblies. Precast components include columns, beams, slabs and interior wall elements. Additional prefabrication includes vertical and horizontal drainpipes, air-conditioning ducts, low current indoor cables and wooden interior partitions. The system consists of a gondola-type construction lift for vertical material delivery, automated overhead cranes for horizontal delivery and structural element orientation and positioning, and the climbing mechanism for the elevation of the factory when required.

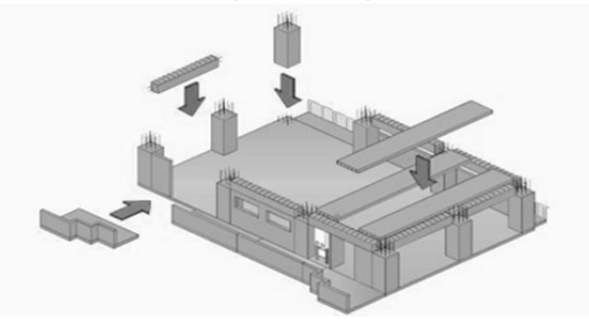

Fig 6. Precast modular construction technique of the BIG CANOPY automated construction system by Obayashi. (Sources; Reference [6])

Fig 7. Overview of the BIG CANOPY automated construction factory. (Sources: www.obayashi.co.jp)

6.2. AMURAD by Kajima

This is also a Japanese automated construction system, but contrary to the previously described system, the on-site factory is located on the bottom of the building. The last floor is constructed first and then pushed up one level, making room for the second last floor to be built. Meanwhile the plumbing works, interior fittings and the cladding of the façade begin on the last floor (that now is second). The process is repeated as many times as necessary until the whole building is completed.

This system uses the three following mechanical subsystems: A system for pushing up the whole building (Z-UP), transportation- and assembly system for concrete precast elements (Z-HAND), and a material transportation system for the second level of the factory (Z-CARRY).

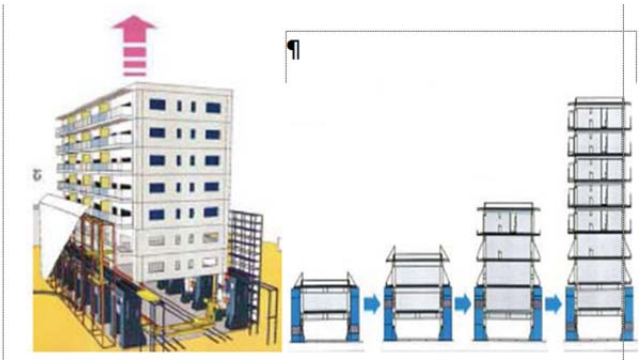

Fig. 8. Kajima AMURAD technique construction process (Sources; the pictures pick from the reference [7])

The main inconvenient with this system is that the height of the final building is limited to the maximum weight lifting capacity of the hydraulic jacks that perform the elevation. On the other side, logistics and material delivery are very easily handled due to the non-movable factory on the base of the building.

Kajima also developed a deconstruction system using the same principle of ground factory, it was named DARUMA. With it a recycling rate of 93% was achieved, which is outstandingly better than the 55% of the conventional demolition methods.

6.3. FSRPC by Fujita

Fujita Steel Reinforced Precast Concrete Method (FSRPC). This is also a Japanese automated construction system. The arrangement of precast concrete or site casted concrete column with prefabricated steel beams. The joint of column and beam treated with some additional member i.e. Band plate, Rib Plate, Hoop bars and vertical stiffeners to resistance of moment and forces at normal and seismic condition. The main characteristics of this method as compare to others, long span is possible for 10 to 18 m and higher rigidity is attained, habitability also improve and the construction term cut upto 25 % and reduced overall cost 10 to 20% according to design & other parameters

Fig. 9 Kajima DARUMA technique of demolition of tall buildings (Sources; the pictures are pick from the reference [8])

Fig. 10 Overview of the FSRPC by Fujita (Sources; picture pick from reference [9])

6.4. Rapid Construction by China

China has also enter in this category with the concept of rapid construction and established a record for construction of 30 storey hotel building for Ark Hotel in just 15 days under the Builders of the Board Group Corporation. During, the 15 days has been created not just a building with prefabricated panels in-build services piping systems and completely ready for operation and Breakfast-the workers, communications and even furniture in all rooms. Ark Hotel skyscraper height of 30 floors has an area of 17 thousand square metres. By using the most advanced energy saving technologies, the building will consume about 5 times less resources than the other similar facilities it. And this indicator will meet high-tech cleaning system, controlled by a computer. Despite the apparent unreliability quickly erected structures of a skyscraper, he relies on the amplitude of the earthquake to withstand upto 9 on the Richter scale [10].

Fig.12 Overview of the rapid constructed 30 storey hotel building construction process (Sources; A Chinese Miracle 30-storey hotel in 15 days…http://thefabweb.com/16814/a-chinese-miracle-30-storey-hotel-in-15-days)

6.5. Smart Materials are introduced by different company of material. Now focused on Hanson Building Products [11] Off-site manufacturing utilizing technically advanced prefabrication processes for better build quality and efficiency.The products have been designed and developed to maximize the benefits of off-site manufacturing processes in the controlled environments of purpose built factories, whilst minimizing the need for on-site involvement that is subject to the unpredictability of both the weather and the availability of skilled labour. Some impressive products are:

Wonder-wall: Wonder wall cladding system combines all the advantages of modern prefabrication with all the appeal of traditional appearance. It can be installed faster than traditionally built masonry to a higher level of quality and is suitable for use as a durable, decorative and thermal insulating finish to external vertical walls.

Fig. 13 Glued Brick Work, Lock clad and wonder wall[11]

6.5.1. Lock Clad: Terracotta cladding system with high quality clay sigma tiles. The system comprises of sigma clay tiles, sigma aluminum support rails and clips. The primary support structure and the sigma rails can be fully installed before tiling commences. Installation is fast and simple and can be effected in any direction and sequence. Lock Clad sigma is designed to be fixed to most substrates – including masonry, concrete, steel and timber frame systems and lightweight walling panels.

6.5.2.Glued Brick Work: Developed several years ago in Europe, The technique relies on joints which are formed using an adhesive or glue mortar, that have a high percentage of cement, very fine inert additives and specially formulated polymers. The adhesive is applied by using specially developed hand-held pumped nozzles that usually dispense two parallel beads of material along the horizontal bed joints and on perpends prior to the bricks being laid.

6.5.3. Concrete Block panels: prefabricated thin joint dense concrete block panels for easy and fast working on site. The panels offer the mechanical advantages of strength, sound insulation and fire resistance, even as minimizing wastage. They are suitable for use on ground and first-floor levels and because of their weight and high load bearing capacity, are equally suited to multi- storey construction.

Fig. 13 Concrete Block panels, Hollow Core and Twin Wall [11]

6.5.4. Hollow Core: It is for suspended floors with clear spans upto 13 metres, particularly where a clear spanning durable deck is required. With clear, unsupported spans of up to 13 metres, they can be used on masonry, steel or concrete structures, offering benefits of fast erection and the provision of an immediate working platform.

6.5.5. Twin Wall: Using prefabricated panels comprising two slabs connected by means of casting lattice girders to form a single unit into which concrete is poured on site. Twin Wall is a fully flexible walling system that combines the speed and quality of precast concrete with the structural and waterproof integrity of a continuously poured in situ concrete structure.

7. APPROACHING/INNOVATIVE TECHNOLOGIES.

7.1. Automated Pavement or Machined Paving: The automated machine developed by ONRUST BESTRATINGEN. Tiger Stone innovative machine to build streets/roads on time and on budget. The technique was perfect for small rural areas where no roads at all. It builds six meters wide streets/roads. The end result is that stones are immediately locked up tight between the curb. It is simple to operate and delivers a daily production of up to 300 square meters [12]

Fig. 15 Automated paving machine (source; www.google.co.in/machinale bestratigen)

Fig. 16 Vacuum clamping machine placed the kerbstones as per alignment (source; http://www.vacuumbestrating.nl/)

7.2. Vacuum Clamping Machine: Machine used for tile fixing on the footpaths and road side cycle track. The tiles and kerbstone are lift by vacuum force and placed as per design, alignment and the tile pattern. The finishing quality was unbelievable.

The major advantages for above both type automated machines are:

- The quality of the work is at a high level
- The production rate is increased
- Improve working conditions for the executive staff

So many companies are worked for the ground and road construction in Northern provinces of the Netherlands. Especially in recent years, there are big changes underway in the field of mechanical road. More and more work will be performed mechanically. According to the working conditions one company Unrest Bestratingen here is of course gone, and is fully focused on mechanical road. At present, the companies have found the right method, however, the development continues and Unrest Pavements keeps a close eye on this and will have to adapt in the future if necessary [13].

8. CONCLUSION

Construction industry is entwined with advanced and automated technology when it should gear to a growth of construction. Ever accelerated updating of precast concrete materials and equipment's are provide the wider range of product and option of construction. Of course the precast and prefabricated materials are not latest but it will be modified as per demand & latest techniques and its wider range change the construction method and shift to another level at advanced automated construction method. Meanwhile, the advanced & innovative technologies are change the thinking or concepts of young engineer and motivate to all to create new and different fields in Civil Engineering. To conclude, the conventional construction methods are hide behind the advanced automated construction methods according to the demand of rapid construction, quality products, minimize the wastage of material, economical cost and the situation of shortage of work force. Indian construction companies also work with advanced automated construction methods and definitely in future, the graph will be increased.

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